BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 40

INTERIM REPORT ON THE STATE OF THE COASTAL WATERS OF THE BALTIC SEA

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
– HELSINKI COMMISSION –

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For bibliographic purposes this document should be cited as:
HELCOM, 199 1
Interim Report on the State of the Coastal Waters of the Baltic Sea,
Balt. Sea Environ. Proc. No. 40

ISSN 0357-2994

Helsinki – Government Printing Centre

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PREFACE

Within the framework of the Baltic Marine Environment Protection Commission -Helsinki Commission - the first compilation of the data of all coastal waters is under preparation in an ad hoc working group and it is expected to be finalized in 1992.

This interim report contains some general views on the state of the coastal waters of the Baltic Sea based on the national reports provided by each Baltic Sea State.

The interim report has been prepared by the ad hoc working group with Sweden acting as lead country and consisting of the following national contact persons:

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The convener and the members of the group are responsible for the text of this publication. In the Helsinki Commission Secretariat the editorial work has been coordinated by the Environment Secretary, a.i., Eeva-Liisa Poutanen and the assistant, Teija-Liisa Lehtinen.

1. INTRODUCTION

The Baltic Monitoring Programme (BMP) of the Helsinki Commission started its first stage in 1979. Since then the monitoring and assessment activities on the open sea areas as well as on the coastal waters have been the responsibility of the Baltic Sea States. The principle agreed in the Guidelines for the BMP was that national monitoring programmes in territorial waters should be established to supplement the joint monitoring programme in the open sea.

According to the decisions by the Commission, national coastal assessments should have been provided by each Baltic Sea State every fifth year starting in 1984. Due to a low activity in this matter the tenth meeting of the Commission (1989) adopted HELCOM Recommendation 10/2 concerning assessment of the effects of pollution on the coastal areas of the Baltic Sea, presuming that finalized documents will be available for the use of the Commission meeting in 1993.

Due to the importance of the coastal assessment the eleventh meeting of the Commission, however, urged the Contracting Parties to fulfil the task without delay and to submit their contributions to the coastal assessment earlier than the deadline.

An ad hoc working group was established by the first meeting of the Environment Committee of the Helsinki Commission (EC) in September 1990. All Contracting Parties were requested to submit their national reports not later than 15 April 1991 to the project coordinator Ulf Grimås. A very tight timetable was given to the ad hoc working group for the compilation of national reports, i.e. end of 1991. Most reports were delivered at the meeting of the Working Group in May 1991 and the last contribution arrived in July 1991.

The outlines given in the BMP Guidelines were advised to be used for the preparation of the national coastal assessments. However, the contributions delivered were very disparate, e.g. regarding subjects dealt with and discussed. One evident difference between the open sea assessment and the coastal assessment is the availability and quality of the coasts for recreation.

It should also be emphasized that the data and information delivered by the various countries is not emerging from harmonized monitoring programmes around the Baltic Sea but from different national and heterogeneous programmes. Therefore, this interim report is the first effort to compile the existing information on the status of the coastal waters of the Baltic Sea on the basis of the national reports provided, extracts of which have been annexed to this report. The more comprehensive coastal assessment will be finalized in 1992.

2. GENERAL FEATURES OF THE COASTAL AREAS OF THE BALTIC SEA

A wide variety of coastal systems are found in the Baltic. Rocky shores are dominating in the northern part, e.g. in the Gulf of Bothnia and southward along the Swedish coast. Archipelagoes are found, e.g. from the east of Stockholm in a belt over Åland and the large Archipelago Sea in Finland. Open, sandy and shallow shores are often found in the south-eastern part of the Baltic Proper and characteristic lagoons in some estuaries (“Haffens”). In the south-western part, fjords are found, of which some are shallow and semi-enclosed (“Boddens”) .

It is difficult to give a stringent and plain definition of a coastal zone. It constitutes a variable and complex system affected by the properties of both the land and the sea. Since transport mechanisms - physical, chemical, and biological - are one of the key functions, the morphometry of the coastline is of importance. In coastal areas with river estuaries, fjords, semi-enclosed bays or archipelagos, it is easier to define the border between land and sea compared to the wide open coasts. In these open areas we have accepted areas down to 25 m depth without being too orthodox.

The state of the open Baltic Sea environment is well documented in the assessments covering the period of 1980 to 1988. The description also covers some of the large coastal basins like the Gulf of Finland and Riga, the Gdansk Basin and the Belt Sea, which can be regarded as parts of a coastal zone.

The ecological functions of the main regions of the Baltic Sea area are affected by properties like salinity, temperature, water exchange, etc. There are horizontal gradients from the north/east to the south/west and vertical from the surface to the bottom. Most obvious is the salinity, which increases from about O-2 ‰ in the norther Bothnian Bay and in the easternmost Gulf of Finland to > 15 ‰ in the Kattegat. Of importance is also the mean temperature, which is low in the Bothnian Bay and increases successively through the Baltic Proper to the Kattegat. The combination of climate and salinity render some fundamental properties to the water masses, e.g. isolation by stratifications and ice-cover.

The consequences of the above-mentioned physical and chemical gradients can be described as an ecological gradient via the set of species, the biological and physiological processes in the ecosystem, the length of growing period, etc., which can be summarized as a concept of productivity.

Among large-scale mechanisms, the water transport system in the open sea basins might be mentioned. The main circulation is anti-clockwise in all main basins. This means, amongst others, that there is a southward transport of water along the western coast of the Baltic, an eastward net transport in the south and a northward along the eastern coasts. This pattern is reflected, e.g. by the salinity properties of the surface water.

The residence time of water in the various basins is also one important characteristic, being 3 years in the Bothnian Bay, 6 years in Bothnian Sea, about 25-30 years in the Baltic Proper and just a few months in the Kattegat. This has an effect on the conservation and potential recirculation of various elements within the main basins or between the open sea and the coasts.

Among other properties with a definite influence on the function of the basins can be mentioned the stratifications, e.g. between waters with different salinity. The halocline isolates the deeper, saline water areas and acts simultaneously as a "false bottom" where an increased microbiological activity contributes to a recirculation of various elements back to the upper water masses.

The sink of elements is of course also governed by the physico/chemical properties of the various elements. As examples, it can be mentioned that the theoretical retention time is 0.3 years for lead, about 6 years for cadmium and 17 years for arsenic in the free water mass of the Baltic Proper.

The coastal zone can act as a trap or filter for various elements or particles. In the open coastal areas the transfer of elements from land to sea is rather fast. A delay in the rate of transport and the uptake and sink of elements is more effective in the bays or the complex archipelagos, which can be regarded as natural sewage works or cleaning installations for the open sea. In many cases, however, this capacity is over-exploited and many coastal areas are nowadays functioning as sources rather than filters.

Waterborne pollutants enter the coastal zone and finally reach the open sea from local point sources like rivers or outlets from industries or municipalities. The reverse transport of pollutants from the sea to the coasts is, however, a fact. This is exemplified in the national reports, e.g. from Finland, by an increased transport of nutrients from the open Gulf of Finland into the local archipelagos. The fate of the waterborne elements released from local sources in the coastal zone will be demonstrated in the main report, e.g. in the Chapters on metals and organic compounds.

It is, however, well-known that the coastal current is broken by many hydrodynamic processes like upwelling, and coastal waters will be linked off and involved in the circulation of the main basins. This will contribute to a more pronounced geographical dispersion of polluting elements and the residence time of water in the basins, the physico/chemical properties of the elements, etc., will be of importance for the conservation and recycling of the elements discussed above.

An example is given by Poland. The observed maximum range of the mixing zone of the Vistula river water was 44 km with a surface area of 1700 km^2. Winds from SW, S and SE considerably increase the extension, directing the water out of the Gulf of Gdansk into the Baltic. In about 50% of the observed cases the distribution of the water was eastward, in 25 % the water was transported in a northern direction and in 6 % of the cases the direction was westwards.

3. STATE OF THE COASTAL WATERS

Regarding the fate of the available information in the process of management and measures to be taken, the following should be observed:

* The information is spread over a considerable period of time.

* This is an effect of isolated research or control projects rather than routine monitoring programmes of coastal areas. The heterogeneity is not surprising. It is a result of the problems experienced or a reflection of specific interests and research in the various countries.

* For many reasons "historical" information is of utmost importance. It must be realized that the status might be uncertain to use as a basis for a detailed comparison between areas without an analysis of the time trend behind the actual situation.

* These problems were foreseen and accepted as a nuisance in the evaluation attempts.

Some of the national reports are given as general conclusions. Others are presented as large compilations of the coastal status or based on references combined with summaries or conclusions. In the following, the general pattern of problem areas in the coastal zone is extracted from the national reports.

In this interim report examples of the effects of eutrophication are limited to observations on phytobenthos. As for metals, some of the background information available is presented in a few examples. Some general observations are made on organic compounds and the recreational aspects are flagged in a short chapter. Additional comments to the above mentioned chapters are given in Conclusions. Some extracts from the existing background information are given in Annexes l-6.

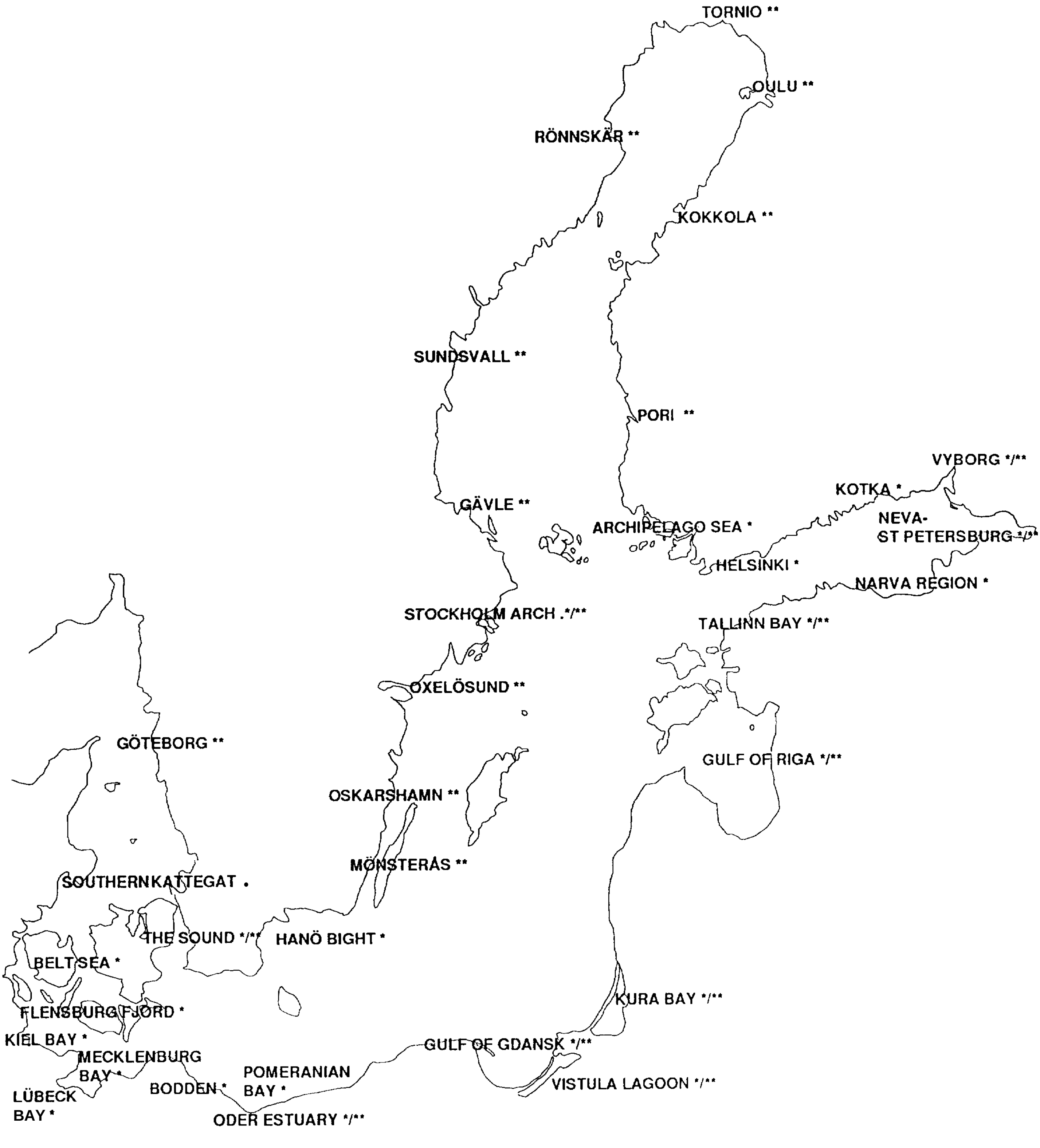
3.1 General Pattern of Eutrophication and Metals

Some coastal areas which are regarded as problem areas for eutrophication and/or metals can be selected from the information gained in the national reports. These areas are presented in ***Figure I,*** which should be looked upon as a first approach.

The evaluation is based on the national experiences and the comparison and normalization of the various results is ongoing. A mutual final agreement in the working group will be reached regarding limits to be introduced - the geographical extensions of affected areas, levels of concentrations, subjects to be completed, etc. when additional material is available. Some of the gaps in the information have been identified and will be answered by countries concerned.

It is easy to find a complexity of problems in many local areas. In wider terms, however, metals seem to be the major problem in the northern part of the Convention area - the Gulf of Bothnia and southward along the Swedish coast. The eutrophication problem is quite obvious in the western part of the Baltic Sea and Kattegat. Along the southern and eastern part of the Baltic Proper, including the Gulf of Finland, both eutrophication and metal problems are indicated.

Figure 1. Coastal areas identified in the national reports as problem areas for eutrophication and metals.



x = eutrophication
xx = metals

Eutrophication

In most cases, concentrations of nutrients are presented and, for some areas, the response in the free water mass and the benthos. The theme of eutrophication is still under preparation, which will include, i.a. the well-known blooms of toxic algae along several coastal areas. Examples could, however, be given to illustrate effects in the benthic vegetation zone reported from the various countries.

Long time series of observations of the macrophytes along the coasts provide useful indicators of changes in water quality. Two main processes are observed: a change in the species composition and a restriction of the depth range of the vegetation zone. The effects are quite obvious and mainly an effect of eutrophication and decreasing transparency of the water.

In the southern Bothnian Sea, Sweden reports a decrease of the depth distribution of the bladder wrack (*Fucus*) from 12 to 8 metres from the 1940s to 1984.

The same process is noted in the Kiel Bay where the biomass of benthic algae was doubled above the 12 m depth and decreased to a fourth below the same depth between the 1960s and the 80s. The extensive population of the red sea weed *Furcellaria* has been replaced by other species.

Also in Poland and the Gdansk Bay the biomass of *Furcellaria* dropped suddenly between 1957 and 1979. There has been a loss of about 40% of species over the past 70 years and a drastic restriction of the depth range from 25 m at the beginning of the century to about 6 m at present. In the open coasts of Poland the decrease of *Fucus* is a fact to the advantage of green algae like *Enteromorpha* and *Cladophora*. Such changes are also reported from the Swedish and Estonian coasts.

In Estonia, the macrophytobenthos of the Narva Bay is completely lacking, which is most likely due to the immediate effect of industrial waters. In Tallinn Bay the areas covered by *Fucus* have been considerably reduced and the bottom vegetation of the northern part of Pärnu Bay is suffering from poor light conditions with decreasing areas of vegetation.

A specific case is reported from the archipelago off S and SW Finland where ***Fucus*** disappeared in parallel with the increased production of tilamentous and planktonic algae; the changes being most clear in the outer archipelago and far from local pollution sources. The general increase of nutrients in the Baltic water masses was considered to have caused the initial change. Recent observations indicate, however, a recovery of the *Fucus* community.

Denmark reports a reduced deep range of benthic vegetation because of the growth of annual algae and plankton. In some areas, bottom vegetation has completely disappeared, as e.g. in the inlet of Ringkøping Fjord and the Nissum Fjord.

Benthic microalgae have so far not received much attention in the reports despite their important role, i.a. as primary producers. Nowadays work is going on in all countries and in many areas, among which can be mentioned the Åland archipelago, Seili, Tvärminne, Riga Bight, Gdansk Bay, Greifswalder Bodden, Schlei Fjord, Kiel Bay, Belt Sea, The Sound and a number of Swedish areas up to the northernmost archipelago of the Bothnian Bay.

The large and ecologically diverse species-pool of the microphytobenthos and the fast reaction of community composition to environmental changes is most valuable. Especially the diatoms have shown excellent qualities for studying pollution status. After the established intercalibration, benthic microalgae should be considered as a complement or substitute for planktonic algae as indicators of water pollution in selected, specific coastal areas of the Convention.

Metals

Information on concentrations of metals in sea water, sediments and organisms are not available from all countries. Data on backgrounds in all media, and especially in the sea water, suffer from analytical uncertainties, which is one of the reasons for the gaps in the reports. It is known that additional coastal data, e.g. from sediments, can be made available and acceptable even from old data banks.

Levels of metals in sea water are reported from Finland, USSR, Latvia, Lithuania, Poland, Germany and Sweden. No problems are indicated in the “background” areas of the coasts compared to the open Baltic. Increased concentrations for most metals are reported from the eastern part of the Gulf of Finland and especially in the Neva Bay, where some values might be considered as alarming. In other affected areas the concentrations are moderate with exceptions, e.g. near the mouths of polluted rivers or the concentration of mercury reported from Kura Bay.

The information on metals in sediments from polluted areas is rather scarce. The maximum values reported are of course dependent on the methodology of sampling, e.g. the distance from a local source, which is not possible to evaluate without more details being available. Metal levels in some areas are 5-10 times higher than the background assumed, e.g. for chromium, lead and mercury. The problem areas are indicated in ***Figure I.*** Along the coast of the Gulf of Bothnia, the sediments in local areas show high values of mercury, which to a large extent is a result of earlier emissions up to the 1970s.

The concentrations of metals in organisms are of interest both as indicators of pollution or for the blacklisting as human food.

A regional analysis of metals in the blue mussel *Mytilus edulis* from Helsinki along the Swedish and Danish coasts to Oslo shows a successive decrease of metals from the north-eastern to the western part of the Convention area. The material also illustrates the possibilities to detect locally affected areas along the coasts and the transition zone of The Sound between the Baltic Proper and the Kattegat for many metals. Results on this mussel are also available from Poland where the mean concentrations of metals do not differ in essentials from those of the Swedish Baltic coast with the exception of lead (Pb) which is higher in the Gulf of Gdansk.

Other indicators of metals used are *Fucus* or the “Baltic mussel”, *Macoma baltica*, which is used as a substitute for *Mytilus* in the Gulf of Bothnia. Again the available figures from the Gulf of Gdansk are rather moderate while maximum values from Sweden and Finland often refer to areas affected by local anthropogenic sources of metals.

Metals in fish have been analyzed frequently for the open sea areas and thus are not representative for the coastal zone. It can be noted that the concentrations of various metals often are analyzed in fish muscle, which does not reflect the concentrations in the medium of water or fish food.

There is one exception from this main rule mercury (Hg) - which is accumulated in fish muscle and followed up both for ecological and economic reasons.

It seems clear that mercury is not a problem for the open sea areas of the Convention but for the coastal zones. Many coastal areas are also blacklisted because of too high Hg-values in fish. A list/map of these areas will be presented when information is gained from all countries.

Looking at the results available it can easily be seen that the concentration of mercury increases for each step taken to the next trophic level; from vegetation to carnivorous fishes. Again, not many analyses have been made as a routine on fish species representing the coastal zone. One semi-coastal species is the flounder (*Platichthys flesus*) which migrates between shallow and deep areas during the year. The Sound is one of the areas known for its high values of mercury in, amongst others, the flounder, compared to the western Baltic Proper as well as the Kattegat.

High values of mercury in stationary fish species like pike *(Esox lucius) are* often noticed in polluted areas like in the Stockholm archipelago. For species like perch (*Perca fluviatilis*) or roach (*Rutilus rutilus*) comparison material is at present not known or available for the report.

A specific problem with metals is the estimation of ecological effects, especially long-term chronical effects of a relatively low but constantly increased level. One definite candidate for such a monitoring of biological effects is the fish *Zoarces viviparus* (eelpout), presented under the subheading of organic compounds.

3.2 Organic compounds

As was summarized for harmful organic contaminants in the Second Periodic Assessment of the State of the Baltic Sea, a non-persistent, bioavailable and toxic substance ought to give an ecological effect only in the vicinity of the discharge, whereas a persistent substance will affect also remote areas of the sea.

Local effects have been demonstrated, e.g. outside pulp and paper mills. Swedish investigations demonstrate two major environmental problems caused by the effluents. The eutrophication of receiving waters tends to be accompanied by large amounts of fish and there are high doses of the discharged toxic and, in many cases, bioaccumulating substances. The disturbances of the reproduction by extreme eutrophication and poisoning are serious especially when originally good recruitment areas are affected.

It can also be concluded that resident fish species in coastal areas, especially in sheltered archipelagos, are generally much less contaminated by organochlorines compared to the fish stocks of the open sea. This is mainly due to lower fat content, but also to a lowered availability of toxicants, as they are attached to organic material appearing in higher concentrations nearshore. One of the serious problems in the open areas of the Baltic the accumulation of organochlorines in the stocks of herring, cod, sprat and salmon thus seems to have moderated in fish species, typical for the coastal areas.

Some birds, like terns and gulls, feeding on fish in estuaries, e.g. in Germany, are reported to be heavily affected. Other carnivores like seal and guillemot living in the coastal zone, represent the situation in the open sea area and not that of the coast. They give, however, a good illustration of transport mechanisms, in this case a biological mechanism, from the open sea to the coast.

An ideal fish species should be mentioned for revealing effects on reproduction, which is one of the most important functions in the biosystem. The fish species is the viviparous blenny or eelpout (*Zoarces viviparus*) which, as the name indicates, keeps the fry within the female for several months before releasing them and thus easily can be checked individually for negative effects on reproduction. Its general life mode, e.g. a very stationary behaviour and the abundance especially along the hard bottoms of all coastal areas discussed here, make this species of special interest for routine monitoring.

Regarding petroleum hydrocarbons (PHC) there is a general difficulty in assessing the data or “oil” analyses as a result of two different techniques being used. In some countries the more sensitive fluorescence (UVF) technique was applied as recommended in the guidelines for the BMP areas, whereas in other instances the older and less sensitive infrared photometric (IR) technique has been used. Therefore the data are not to be compared between all subareas of the Baltic coastal waters. As an alternative a relative comparison will be used for each of the two types of PHC data. The reference used is thus the background concentration level reported for deep water of open sea stations with each analytical technique.

Data are given for the eastern part of the Gulf of Finland including the bays of **Neva,** Vyborg, **Luga** and Koporie, the Gulf of **Riga,** the ports of Ventspils and Liepaja at the Lithuanian coast, the Kura and Visla Bay and the War-now and Breitling estuaries. The general picture is that levels are near background values or slightly elevated except close to river mouths, ports and a shipyard, where high values have been observed. The data will be presented in detail when more material is available for the assessment.

Special attention will be given to effects of tanker/oil accidents reported within the Convention area.

3.3 Recreation

An overview will be given of the quality of the coastal areas for recreation. The sanitary conditions, including a classification system for the coastal areas, are given only by one country but are available from other countries according to discussions in seminars held, e.g. in Sweden.

The availability and quality of the coasts for recreation, like bathing, fishing or simply as a place where people like to be, is of evident relevance for the assessment. This availability varies between the countries and so do the interests reflected in the reports.

4. CONCLUSIONS

Some overall goals might be formulated as a guidance for the future work on the measures to be taken.

It should be possible to:

* enable a vigorous and balanced life in the coastal areas;
* enable a natural zoning of flora and fauna;
* prevent the occurrence of harmful oxygen deficiency;
* carry out regular, long-term fishing;
* consume fish and shellfish from these areas without risk to health;
* ensure that human activities do not restrict the recreational values of the coastal areas.

One of the main goals for the assessment of the status of the coastal zone is to deliver a base for a future monitoring programme. This requires three main approaches:

* a normalization of results into comparable magnitudes or units in space and time, which is under way in the ad hoc Working Group for the Coastal Assessment;
* a correlation between the results of this Assessment and the information on source terms which will be given in national reports; and
* a set-up of a special ad hoc Working Group for the development of purposes and guidelines for a Coastal Monitoring Programme.

A specific topic that has not been dealt with in detail within the monitoring of the open sea areas is the specific aspect of recreation connected to the coastal areas. This is one of the most important objects that has to be covered in the future programme.

Consideration should be given to the harmonization with other international monitoring programmes although the specific problems and characteristics of the Baltic Sea are the principle targets for the monitoring activities and the following-up by decisions on measures to be taken.

ANNEX 1.

By Denmark:

Danish Coastal Water Quality 1990; an extract from
"Environmental Impacts of Nutrient Emissions in Denmark, 1991"

Danish Coastal Water Quality 1990

National Agency of Environmental Protection

Source: Environmental Impacts of-Nutrient Emissions **in Den**mark, 1991

5.4. Marine areas

The monitoring of the environmental state of the marine areas has since 1974 been carried out by the National Agency of Environmental Protection and the National Environmental Research Institute in the open waters and by the counties in the coastal waters. In the coastal waters, the monitoring has been intensified during the 1980s and with the monitoring programme of the Action Plan for the Aquatic Environment, a nationwide coordinated effort has been established.

5.4.1. Hydrography and input of nutrients

The year 1989 was different in climatic terms from the *normal year«, with considerably less precipitation and runoff and other wind conditions. The water exchange between the internal waters and the surrounding waters was in 1989 less than normal. The runoff from

	Nitrogen		Phosphorus	
	1989	81-88	1989	81-88
	Tonnes	Tonnes	Tonnes	Tonnes
streams				
included waste water	43.000	77.000	2.120	3.000
Direct outlet:				
Municipal plants	9.950	9.950	2.510	2.510
Rainwateroutlet		2 2 0		50
Industry	3.000	3.040	330	330
Marine fish farming	300	260	40	40
Denmark (Rounded off)	56.000	90.000	5.050	5.900
Sweden				
Streams				
include-d waste water	22.000’	40.500	*	760
Direct outlet	4.400	4.800	500	770
Germany				
streams				
included waste water	6.600*	12.500	•	1.950
Direct outlet	>6.300	>6.300	*	> 670
Precipation	44.000	48.500	450**	500**
Total (rounded up)	139.000	203.000		10.500

Table 5.6

Annual input of nutrients directly to the internal Danish waters excluding input via sea currents.

* The load in 1989 from Sweden and Germany is only partly known, but is for nitrogen estimated under the same conditions as for the Danish estimates.

** Estimate from the Phosphorus Report (National Agency Environmental Protection 1988).

land to sea was in 1989 much less than in the years 1979-1988, and among the lowest since 1919. This was noticeable first of all in the eastern parts of the country, where the runoff was up to 50% less. As a result of this the marine areas have received significantly lower quantities of nutrients of especially nitrogen, than the mean quantity for the 1980s. In 1989, the input of nitrogen on an annual basis was about 50% less to the internal waters and 25% less to the North Sea.

Nutrients to internal waters

An overall overview of the input of nutrients from all sources to the internal Danish open waters, but without water exchange between the Baltic Sea and the Skagerrak, is shown in table 5.6 (Kristensen et al. 1990b, Leander 1990 and Olson & Löfgren 1990). The input in 1989 is compared with the average input in the years 1981-88.

In addition to the contribution from open land, the runoff via water-courses also includes discharges from waste water sources to water: courses and lakes, as described in section 5.2. The major part of this input is by way of inorganic nutrients which are available for the production of algae. Figure 5.18 shows the distribution of the input from Denmark by the main sources: Open land, waste water treatment plants (indirect and direct discharges) and industry, together with marine aquacultures and fish farms. Figure 5.19 show the distribution of input to internal waters from the three surrounding countries, Denmark, Sweden and Germany for the years 1981-1988..

Nutrients to the North Sea/Skagerrak and the Baltic Sea

The inputs to the North Sea/Skagerrak and to the Baltic Sea are shown in table 5.7, but only as a mean for the 1980s, as the 1989 inputs are known only for Denmark.

	Nitrogen		Phosphorus	
	The North Sea	The Baltic Sea	The North Sea	The Baltic Sea
	Tonnes	Tonnes	Tonnes	Tonnes
Denmark				
Screams included waste water	25.000	4.000	950	54
Waste water, direct outlet	1.200	370	290	90
Industry	1.700	20	850	1
Denmart total	27.900	4.400	2.090	145
Other countries, approx.	1.180.000	370.000	104.000	36.000
From this Elben + Weser	(270.000)		(15.900)	
Precipation a.o. (estimated)	3-600.000	4 - 500.000	B-9.000	4-5.000
Total	1.5 - 1.800.000	8 -900.000	115.000	40.000

Table 5.7 Annual mean input of nutrients for the 1980s to the North Sea and the Skagerrak, and to the Baltic Sea.

Nutrients to the internal waters from other marine areas

The Baltic Sea retains and converts a large part of the added nutritive substances as mentioned in section 3.4.2. The amount flowing out to the Danish open waters is difficult to calculate For nitrogen, the quantity in normal years is estimated to be in the range of 100-130,000 tons per year (Wulff et al.1990), but *only* a smaller part is, as inorganic nitrogen, available for the production of algae and, moreover, the major part of this has always existed. For phosphorus the amount flowing out in a normal years is estimated to be about 5,000 tons per year.

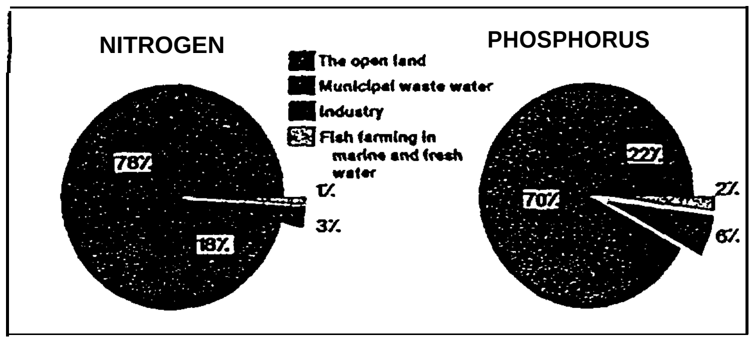


Figure 5.18 **Distribution of discharge and runoff of nutrients to the internal waters from Denmark in the years 1981-88.**

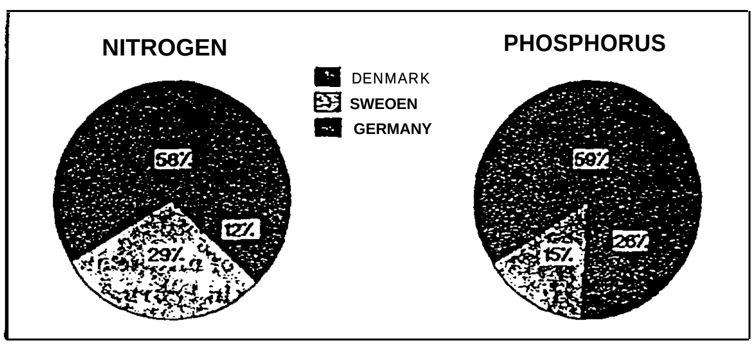


Figure 5.19 **Distribution of discharge and runoff of nutrients to the internal waters from Denmark, Sweden and Germany in the years 1981-88.**

Since the 1950s, the outflow of phosphorus has increased, and after the 1960s, a smaller increase has been seen in the outflow ofnitrogen. During the 1980s, the outflow seems, however, to have stabilized on a new level. In 1989, the outflow of nitrogen was close to the minimum of this level, if not lower.

In connection with the inputs to the North Sea, the input to the German Bight, from the Elbe, the Weser and the Ems, is of special interest, in so far as part of the runoff from those areas affects the conditions along the Jutland North Sea coast and at times, with the »Jutland current«, can contribute to the input of nutrients to the internal Danish waters. In 1989, this situation occurred, and it is estimated that 13-17,000 tons inorganic nitrogen above the normal flowed in which is estimated to be much more than the average for such inflows (Ærtebjerg et al. 1990).

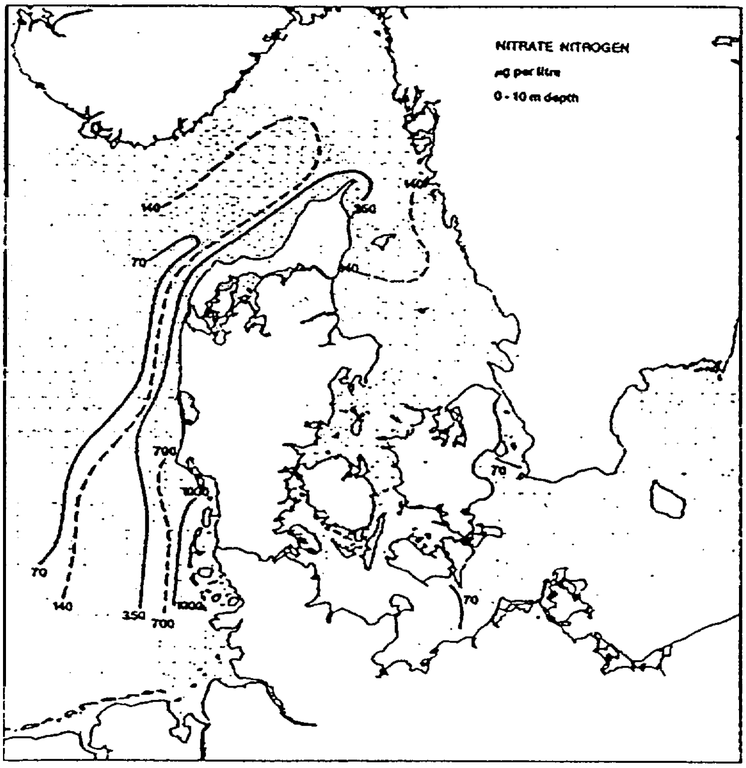


Figure 5.20

Concentration of nitrate along the west coast of Jutland and in the Kattegat in February 1989. (According to Ærtebjerg et al. 1990).

Annual variations in input of nutrients from land

It varies how much of the added nutrients from the various coastal waters reaches the open waters. The coastal waters, and especially the closed inlets, can like the Baltic Sea retain and decompose the nutrients. However, this usually takes place in the summer period, wherefore the major part of the nitrogen runoff during the winter months reaches the open waters where it has the most important effect.

The input of nitrogen during the summer period is of decisive importance to the state of the coastal waters. During the period May to

Scprcmber 1989, the contribution of thc Danish point sources as a whole was a little below 60% ofthc input. The variation is big, ranging from some few percent in areas with relatively small loads to more than 90% in strongly loaded areas.

5.4.2. Nutrients in open marine areas

In the open parts of the internal waters, the winter concentration of inorganic nitrogen (nitrate, nitrite and ammonia) has shown to have a decisive importaucc for the algae production in the following summer. Throughout the period 1980-1989, the winter contribution has been highest in the Belt Sea and southern Kattegat and lower in the Skagerrak and in the areas ofthc Kattegat where the water is most frequently mixed up with water from the Skagerrak. The lowest concentrations – about half as high as in the Belt Sea-have been found in the Baltic Sea area, i.e. south and east of the bottom thresholds betwecn the Belt Sea and the Baltic Sea.

During the period 19754989, there has been a general increase in the nitrate concentration, largest in the Belt Sea and the southcm Kattegat and lowest at Arkona in the Baltic sea and the southern part of the Øresund. Duringthesccondpartofthe 1970s, à fall took place, and the most important increase took plaa at the beginning of the 1980s, whereafter the level has generally been high without further development. The increase follows the same pattern as the development which has taken place in the runoff of nitrogen from the Danish land areas, which marked itself from the end of the 1970s and the beginning of the 1980s (Ærtebjerg et al. 1990 and Kristensen et al. 1990b).

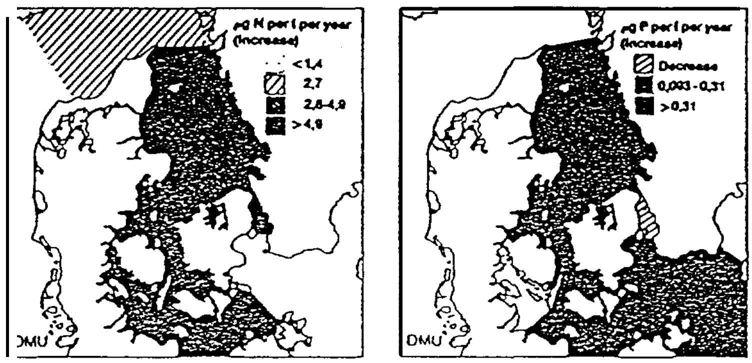


Figure 5.21 The annual increase of winter concentration of nitrate and phosphate in the surface layer during the period **19754989** (Ærtebjerg et al. 1990).

The development in the concentration of phosphorus also shows an increase during the period 1974-1989, although the picture is not as clear as in thc case of nitrogen. The increase is largest in the Bclt Sea, but most clear in the areas which have the closest contact wirh rhc adjacent waters, thc Baltic Sea and the Skagerrak. The Øresund area shows a fall which may bc an expression of a reduced local input from waste water and industries (especially from Sweden). in spite of this, the primary production of plant plankton in the Øresund shows an increase concurrently with the increase in the nitrogen concentration.

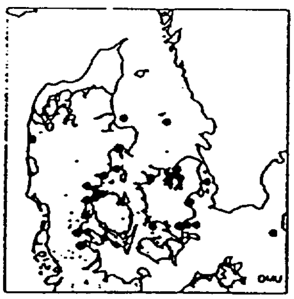


Figure 5.22
Mass occurrence of plankton algae in Danish marine waters in 1989.

5.4.3. Extreme growth of algae

Heavy growth of algae is especially in the spring period a common phenomenon in Danish open waters. The frequency and distribution of mass occurrences of algae, however, seem during the 1980s to have increased also at other times of the year, and with greater emphasis on certain types of algae, in some cases toxic. This has become an annual phenomenon in many inlets and bays.

The development in the growth of algae in 1989 did not differ from previous years. However, in 1989, there was no exceptional growth in the open waters, but only local blooming in inlets and bays. The reason is probably the lower input of nutrients in 1989 than in the 1980s as a whole Figure 5.20 shows areas with mass occurrences during the year. Some of the algae are potentially toxic and as a consequence fishing of mussels was in periods prohibited in eastern inlets of Jutland and in the Little Belt.

5.4.4. Oxygen deficit, bottom animals and fish

There has always been, now and before, depletion of oxygen in exposed parts of Danish waters, but in most waters oxygen depletions in the 1980s have been more frequent, longer lasting and stronger than before. During the past nine years, the oxygen concentration in the bottom water has generally shown a fall, as seen for the northern Little Belt in figure 5.23. Oxygen depletions in the individual years

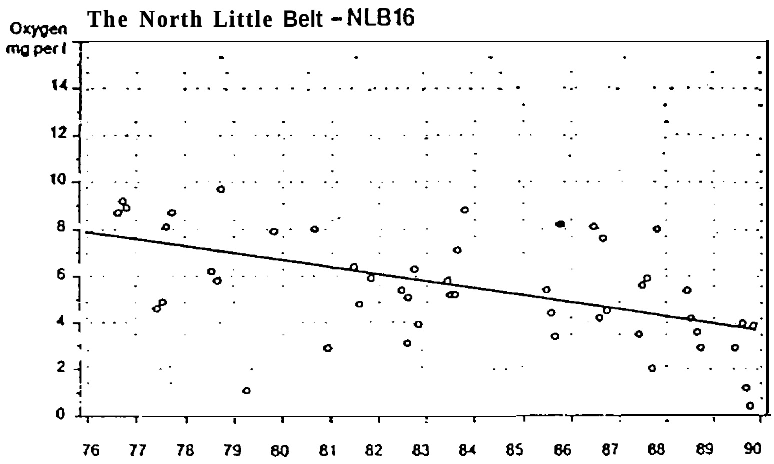


Figure 5.23

Development of the oxygen concentration in the bottom water of the northern Little Belt (Funen County 1990).

can be clearly **related** to the nutrient concentrations and the water **transportation (Sehested-Hansen et al. 1990).**

The biomass of bottom animals has fallen in the southern parts of the Kattegat and in other areas which have been significantly affected by critical oxygen conditions in the 1980s. Since 1981, fish mortality has been reported almost every year. The decrease in catch figures and stock of cod and plaice in the Kattegat and the Belt Sea seems **to be connected to the increasing eutrophication and to mom frequent depletions of oxygen, especially because the feeding basis is changed or disappears.**

The first serious oxygen depletion with fish and bottom animal mortality in large areas even of the open waters, including the North Sea, and development of hydrogen sulphide in the southern Belt Sea, took place in September 1981 (National Agency of Environmental Protection 1984b). Since 1985, the stock of langoustine has been reduced in the Swedish part of the southern Kattegat, and in 1988 the last catchable stocks were almost exterminated.

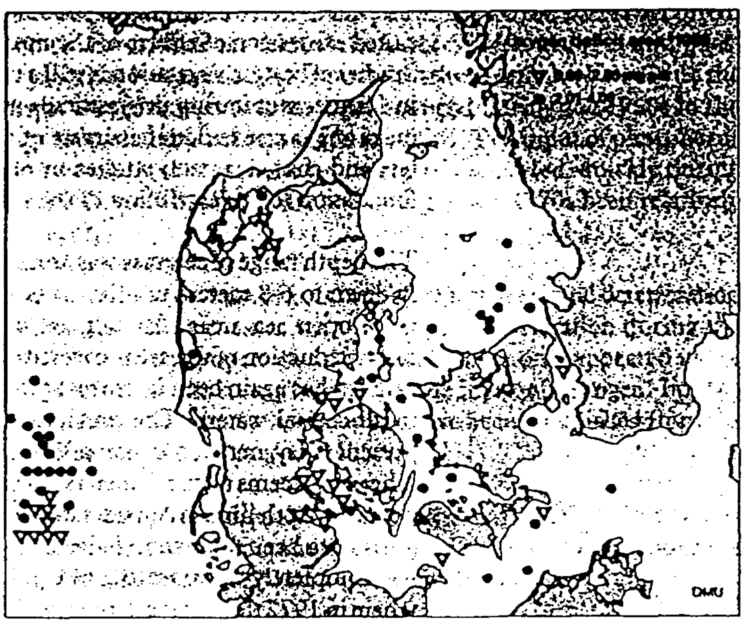


Figure 5.24 **Oxygen deficit in** 1989 (Ærtebjerg et al. 1990).

In some water areas, as e.g. the deep soft bottom areas of the inlet Limfjorden and in the southern Little Belt, oxygen depletion and bottom animal mortality are natural phenomenon of older date. But even in these areas there is no doubt that the frequency and duration have increased and that larger areas than before are affected.

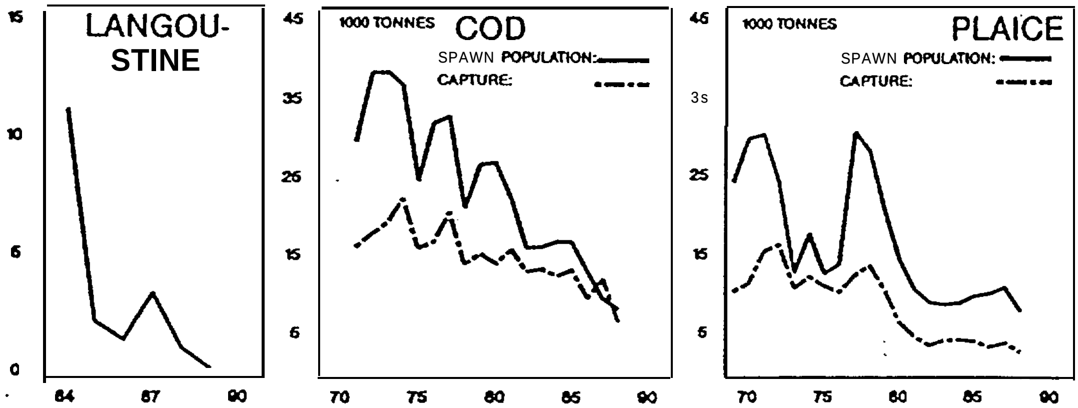


Figure 5.25

Development in spawning stock and catch of cod and plaice, and standardized catch (CPUE) of langoustine in the Kattegat (ICES 1989 and Baden et al. 1990).

5.4.5. Distribution of eelgrass

The depth range of eelgrass is, as mentioned in section 3.4.5, a well-suited expression of effects of the nutriousness of the coastal waters. Studies of bottom vegetation is still a relatively new activity as routine in Danish monitoring programmes, and, therefore, it is too early to make any larger national estimate of the development. For some inlets and coastal waters, studies in recent years, however, provide a foundation for a describtion of the present state.

The depth range of eelgrass was around the turn of the century usually down to 6-S meters in inlet areas and down to 9-12 meters in the more open sea areas. An eelgrass disease 1932-1934 resulted in a heavy reduction of the areas covered by eelgrass, but from the 1960s, eelgrass has again been in normal growth and has been reestablished in all coastal waters. The previous depth ranges are, however, not present today, not even in non-affected areas, where the highest depth range now seems to be 6-8 meters. In the major parts of the inlets, this possible depth limit is considerably reduced and areas covered by eelgrass have been more than halved. In some areas, bottom vegetation has completely disappeared, as e.g. in the inlet Ringkøbing Fjord, where in 1972 them was a dense stand of bottom vegetation and where today such is not found in depths of more than 80 cm. Figure 5.26 shows a picture of the decline of the eelgrass in the inlet Nissum Fjord since 1966.

In the inlets changes are observed of the vegetation in through the inlets with reduced number of strains, less cover degree and depth range and a higher dominance of annual algae. All signifying an increasing deterioration of the biological state in through the inlets.

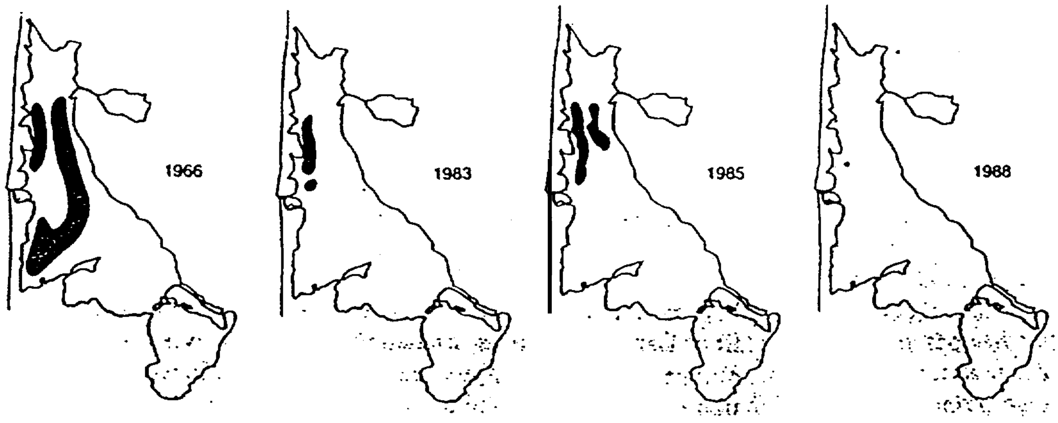


Figure 5.26 **Development of range of bottom vegetation in Nissum Fjord from 1966 to 1988 (Ringkøbing County** 1990).

54.6. The cause of the eutrophication effects

The eutrophication effects in the Danish waters must be considered to be a result of the *changes* (i.e. the increases) which has taken place in the input of nutrients **from** the period before **the effects occurred,** and till now. Since the 1930s, the input of both nitrogen and phosphorus has increased. The input of **nitrogen** only rose slowly at the beginning of the period, most pronounced during the 1960s to the higher level in the 1980s, see section 5.2.5. The input ofphosphorus also increased slowly in the beginning of the period, quickly during the 1960s, and has since the beginning of the 1973s been relatively constant.

In the coastal waters the effects have shown by a gradual deterioration of the state, in most cases with the largest deterioration during the 1970-1980s. In the open waters the effects have only appeared in the 1980s, i.e. after the strong increase in the input of nitrogen. For the internal Danish waters, the following have been established from the beginning of the 1970s to the 1980s:

- The atmospheric deposition of nitrogen has doubled. The largest increase occurred from the beginning of the 1960s to the end of the 1970s (Hovmand 1990 and Grundahl 1990).

- The runoff of nitrogen from Danish land areas increased by about 50%, more in the western areas than in east Denmark (Kristensen et al. 1990b).

- The input from waste water sources have been unchanged, but the preceding increase to the present level had its effect, first and foremost in the coastal waters.

- Them has been a small increase in the input of both nitrogen and phosphorus from the Baltic Sea.

- The inflow from the ● Jutland current« to the Kattegat give at times a considerable nitrogen contribution, which has probably also increased about 50% during the past IO-20 years.

The increase in the annual input of nitrogen to the internal waters during the period 1970-1989 is shown in table 5.8.

In a ● normal year« in the 1980s (see table 5.6) the runoff of nitrogen from Danish land areas, excluding waste water, was about 70,000 tons per year. Of this input, the background runoff, without cultivation contribution, is about 15,000 tons per year, and the increase from the end of the 1970s is estimated to be 15-25,000 tons per year (Kristensen et al. 1990a). This increase in the runoff from the Danish land areas is responsible for 30-35% of the total increase. Besides, if the Danish contribution to the increase in the atmospheric deposition, 8-10,000 tons (Hovmann 1990) is included, Denmark itself is responsible for 40-50% of the total increase in the runoff of nitrogen to the internal Danish waters.

The increase of runoff of nitrogen from the Danish land areas since the end of the 1970s corresponds to 20-35% of the present total mean runoff from Denmark to the internal waters (table 5.6). The increase on account of the contribution from cultivated areas is 40-50% of the part of the runoff, exceeding the background runoff.

Increase for:	Tonnes per year
Atmosphere deposition	15 - 20.000
Runoff from the Danish countryside	15 - 25.000
Runoff from other countries	
Sweden and Germany	10 - 14.000
Input from the Baltic Sea	3 - 5.000
The Jutland current (From time to time)	5 - 10.000
Total (rounded off)	50 - 70.000

Table 5.8 Increases in input of nitrogen to the internal waters in the period 1970 - 1989.

The discharge of waste water in 1970-89, about 20,000 tons nitrogen per year from Denmark, and at least the same from Sweden and Germany, is in the same range as the increase in the input of **nitrogen from the Danish land areas.**

5.4.7. Fulfilment of quality objectives

Compared with the general objectives of an unaffected or only slightly affected flora and fauna, the state of Danish open water areas is considerably deteriorated in many parts. In the coastal waters this shows i.e. in a decline of the rooted bottom vegetation, more frequent and larger range of special types of algae – sometimes toxic, change and impoverishment of the fauna and a decline in fishing.

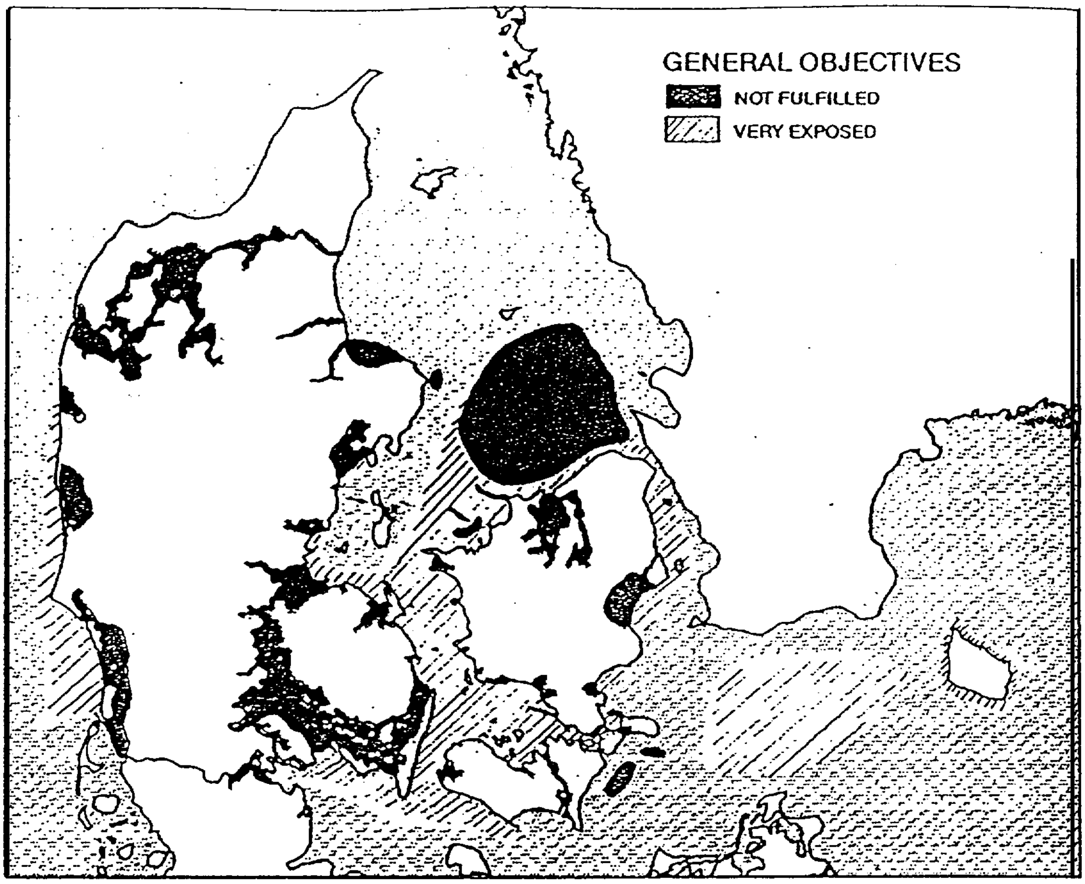
In the open waters, the deteriorations show first and foremost in a larger production of algae – here also with more frequent occurrences of special types of algae, but most important by larger and more widespread oxygen depletion and resulting changes in the fauna of the bottom and consequences for the fishing of certain species of fish. The important deteriorations have to different degrees 'taken **place** during the **past** 20-30 years. First in the closed inlets and, in the 1980s, in the open waters too.

Summing up, there is no doubt that an increase has taken place in the average nitrogen concentration in the internal Danish waters. The increase rate is largest in the Belt Sea and the southern Kattegat and smallest in areas where mixing takes place with water bodies coming from the outside.

Fulfilment of the general objectives

The general objective are not fulfilled in most of the near-shore waters, along the southern part of the west coast of Jutland and in the southern part of the Kattegat, and not at all in the more closed bays **and inlets. The objective is besides threatened or strongly threatened** in large parts of the more open waters, such as the sea surrounding the small southern islands, the Great Belt, the southern Belt Sea, the Arkona Basin (in the Baltic Sea), the Øresund, the northern Kattegat and the western North Sea. In figure 5.27, it is shown to whichdegree the general objectives have been fulfilled for the marine areas, and where it is estimated that the fulfilment of the objective is most threatened.

The main reason for the deteriorations can be ascribed to an increased input of nutrients, first and foremost nitrogen and in part phosphorus. This increase has taken place gradually since the 1930s, but primarily within the past 20-30 years. For the internal waters, the inputs from the adjacent land areas i.e. from Denmark, Sweden and Germany, have been of decisive importance, whereas the present remote transportation from the North Sea, and to a lesser degree from the Baltic Sea, may play a role at times. The major part of the important input of nutrients comes from Denmark which can also be held responsible for about halfofthe increase which during the past LO-20 years has resulted in the most important deteriorations of the environ-



Fii 5.27 **The state in relation to the general objectives** for the environmental quality in the Danish waters.

mental state. The total increase has its main emphasis on the runoff from land areas and **the** atmospheric contribution. The input from point sources has not increased considerably within the period, but the total contribution from these sources is of the same order as the increases mentioned.

Possibilities for improvements

It is still difficult to predict precisely how large improvements in the open waters will bee seen as a result of a reduced input of nutrients.

The effects of the implemented measures are only now beginning to show and the measures of the Action Plan for the Aquatic Environment are only to be fully carried out during the next few years. To this comes that nature, after the implementation of the measures, will need a reaction time The first improvements must, however, be expected in the coastal waters, but the extent and course of time will depend on how big damage has to be corrected.

The effect of a reduced nitrogen input was indicated in 1989. The input to the internal Danish waters was in this year considerably lower than in mean for the 1980s, as a result of much lower precipitation and runoff compared to normal years. The effect first of all showed in some coastal waters as e.g. the inlet Limfjorden, where an improvement for the bottom vegetation was seen.

Besides, for the open internal waters model calculations show that a 50% reduction of the nitrogen runoff to these waters - from both Denmark, Sweden and Germany, will improve the oxygen conditions in the bottom water so that oxygen depletion will occur less frequently. However, oxygen depletion under special critical conditions as in 1981 will not be avoided. Certainty against such occurrences presupposes that the contribution from the atmosphere and the input from the Skagerrak/»Jutland current« is reduced too (Sehested-Hansen et al. 1990).

ANNEX 2.

By Finland:

An extract from “The State of the Finnish Coastal Waters in 1979-1983”
and the national report
“The State of the Finnish Coastal Waters in the late 1980s”

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VESI- JA YMPÄRISTÖHALLINNON JULKAISUJA

8

HEIKKI PITKÄNEN, PENTTI KANGAS.
VEIJO MIETTINEN, PETRI EKHOLM

THE STATE OF THE FINNISH COASTAL WATERS IN 19794983

Suomen rannikkovesien tila vuosina 1979-1983

VESI- JA YMPÄRISTÖHALLITUS

Contents

7 CONCLUSIONS

This chapter presents the main conclusions that can be drawn from the survey. More detailed conclusions are given in chapters 3-6.

During 1979-1983 the Finnish coastal waters received 5 100 t a^{-1} of phosphorus, 80 000 t a^{-1} of nitrogen and 340 000 t a^{-1} of organic matter, expressed as BOD_7. A large part of the loading was directed to the NE Bothnian Bay, the middle of the Bothnian Sea and the eastern Finnish waters of the Gulf of Finland. On an average, the river loads increased during the 1970s and early 1980s, largely due to increasing trends in water flows and possibly also to increased diffuse loading. On the other hand, the industrial and municipal loading of phosphorus and organic matter decreased, especially during the early 1970s. It seems that, despite the increased river loading, the total loading of these substances during 1979-1983 was at a lower level than in the late 1960s and early 1970s, i.e. before intensified measures were taken to control water pollution. The total loading of nitrogen has, however, increased.

The loading of heavy metals was mainly concentrated off Pori and Kokkola and in the estuaries of some rivers, especially the Kokemaenjoki. The industrial loads have generally been decreasing since the early 1970s. Waste waters from the pulp and paper industry were discharged off Kemi, Oulu, Pietarsaari, Kaskinen, Pori, Rauma and Kotka-Hamina. The waters off Porvoo received harmful substances from the oil refinery and petrochemical industry.

The chemical water quality differed from that of the open sea in practically the whole coastal water area, due to geomorphological and hydrographical factors, and loading from the land. The most extensive areas with increased nutrient and chlorophyll levels and a decreased oxygen level were the NE Bothnian Bay, the waters off

Kokkola-Pietarsaari, the archipelago in the Quark, the waters off the Kokemäenjoki estuary, the inner Archipelago Sea, the waters off Helsinki-Espoo and the eastern Gulf of Finland.

In the outer and the unloaded inner coastal waters, the water quality did not change greatly after the early 1970s. The increased nutrient levels of the open sea were clearly reflected only in the coastal waters of the Gulf of Finland. In the most heavily loaded inner coastal waters, where the clearest decrease in the loading took place, the water quality has improved.

The biological variables of the water quality corresponded well with the chemical variables. They also showed clearly that nearly the entire Finnish coastal water area is eutrophicated, at least to some extent, compared with the open sea. Strong eutrophication is, however, limited to the heavily loaded enclosed inner bays. In some inner areas the eutrophy seemed to remain lower than might be expected from the nutrient loading and concentrations, probably because of toxic industrial effluents. In spite of the decreased point loading, the general trend seems to be towards increasing eutrophication. In some small heavily loaded inner areas, however, the degree of trophy has decreased, due to reduced loading.

Pollution has also had clear effects on the bottom fauna in nearly all the areas studied. In the Bothnian Bay, where the mixing conditions are favourable, the effects have been least pronounced. In some of the innermost waters earlier receiving heavy waste water discharges, the state of the bottom has improved and the bottom fauna has recovered.

Chlorinated hydrocarbons and heavy metals in the biota had no clear concentration gradient between the unloaded coastal waters and the open sea. The only exception was the zooplankton, in which the highest PCB and DDT concentrations were measured in waters adjoining the Baltic Proper.

The concentrations of PCB and DDT in zooplankton and fish were clearly lower in the Gulf of Bothnia than in the Archipelago Sea and the Gulf of Finland. Since the beginning of the 1970s, the PCB and DDT concentrations in zooplankton, fish and seals have shown a clear decreasing trend.

In the water areas loaded with heavy metals, elevated concentrations were found in the biota, water and sediments. Due to the water pollution control measures, the loading has decreased in the 1970s and a decreasing trend can be observed in the metal concentrations of the surface layers of bottom sediments. The reduction in the loading of mercury has resulted in decreased concentrations in predatory fish.

The main problems concerning the coastal waters seem to be the eutrophication and its consequences, caused largely by loading from the land, and the pollution by harmful substances, which originate partly from their use in industry, agriculture etc. and partly from the atmosphere.

In some of the heavily loaded innermost waters the reduced loading and decreased phosphorus concentration have resulted in the decrease of some variables related to eutrophication, but according to the existing data, the primary production has not clearly decreased.

The slightly eutrophicated waters seem to be increasing in extent. In these waters, however, the changes in the chemical and biological quality are difficult to assess, due to insufficient information. At least in the coastal waters of the Gulf of Finland the consequences of the general rise in the nutrient level of the Baltic Sea seem to be clear.

The concentrations of PCB, DDT and heavy metals are decreasing, due to various control measures. However "newly detected" organic compounds, such as chlordane and toxaphene, have been observed in fish. The concentrations of chlordane in fish have been shown to be increasing. There is an urgent need to clarify the occurrence of these compounds in coastal waters, to determine the extent and sources of loading and to study the effects on the biota.

Manuscript
August 19, 1991

THE STATE OF THE FINNISH COASTAL WATERS IN THE LATE 1980s

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1 INTRODUCTION

The present document is based on the latest papers and scientific reports on the state and loading of the Finnish coastal waters (see references). In the previous assessment concerning water quality trends in 1970-1983, and loading and spatial water quality variations in 1979-1983, a thorough attempt was conducted to clarify the general state of the whole Finnish coastal water area. The main focus of the present report will be in areas where extensive water quality problems or undesirable phenomena have emerged (Fig. 1). The figures for riverine loading presented in the text are mean values for the period 1984-88 in most cases. For point-source loading the figures are most often for 1989.

2 GENERAL LOADING CONDITIONS

For the late 1980s the total nutrient loading into the Baltic Sea from the Finnish territory can be evaluated as 80 000 t/a of nitrogen and 4 800 t/a of phosphorus. The values are very close to those calculated for the early 1980s. Detailed statistics on the areal loading conditions are presented in Tables 1 and 2.

On an annual base about 50% of the total land-based loads of both nitrogen and phosphorus, have been estimated to originate from coastal point-sources and agricultural diffuse loading. Based on recent estimates on natural leaching of nutrients, and taking into account, that efficient retention of nutrients take place in the large lake-rich drainage basins (especially in the Kokemäenjoki and Kymijoki basins), natural background would probably explain about 40 % of the nitrogen and about 30 % of the phosphorus transport into the coastal waters. The remaining 10 % to 20 % would be the contributions of the diffuse sources others than agriculture and scattered population, e.g. forestry and atmospheric deposition.

The point-source load of easily degradable organic matter into the lower courses of discharging rivers and directly into the coastal waters totalled 68 000 t/a as BOD, in 1989. The pulp and paper industry is responsible for ca. 80 % of the load. A decrease of ca. 40 % took place in the total BOD-load during the 1980s, due to the introduction of biological purification at several pulp and paper mills. For the same reason the load of halogenated organic substances (measured as AOX) has also considerably decreased. With the activated sludge treatment ca. 50 % of the waste water AOX can be removed.

The decrease in the point-source loading of heavy metals which took place in the 1970s and early 1980s has further continued in the late 1980s.

3 THE GULF OF FINLAND

Finland contributes 1 000 t/a of phosphorus and 21 000 t/a of nitrogen from land-based sources, corresponding only 11 and 13 % of the total land-based loads of phosphorus and nitrogen, respectively, into the Gulf. In the mid 1980s the Finnish point-source load of organic matter was estimated as ca. 47 000 t/a as BOD,. At that time Finland was responsible for 16 % of the total land-based BOD-load into the Gulf.

The most important source of anthropogenic loading by the whole sea area is the Neva-Leningrad region at the easternmost end of the Gulf, contributing 5 400 t/a of phosphorus, 77 000 t/a of nitrogen and 210 000 t/a of organic matter as BOD, into the Gulf (estimations for 1985-86).

Both total and point-source loads of nutrients from Finland have slightly increased during the 1980s. By contrast, a decrease from 47 000 t/a to 32 000 t/a in the BOD-loading took place at the end of the decade, after the introduction of biological purification in some pulp and paper plants.

From the Finnish land-based nitrogen and phosphorus loads 30 and 38%, respectively, originate from point-sources on the coast and by the lower courses of the discharging rivers. Diffuse loading from agriculture and scattered population has been estimated to be responsible for 26 and 35 % of the loads of nitrogen and phosphorus, respectively. The rest (44 % of nitrogen and 27 % of phosphorus) originates from natural leaching, atmospheric deposition and forestry. The pulp and paper plants in the Kotka-Kymijoki region contribute ca. 80% of the total Finnish point-load of organic matter into the Gulf.

3.1 Eastern archipelago

The easternmost Finnish archipelago of the Gulf of Finland represents the highest general degree of trophy within the Finnish coastal waters. Blue-green algal blooms have been observed in the whole Gulf, but especially in the easternmost Finnish waters. Strong vernal blooms take place regularly.

The primary reason to eutrophication is the enormous inorganic nutrient reserve in the water, probably originating largely from the heavy loading of the sea area. In summer the general hydrography of the Gulf (flow and mixing conditions) regulate the availability of subthermocline nutrients and trophic conditions in the surface layer, except in the innermost coastal waters and enclosed bays, where local loading keeps the planktonic production continuously on an elevated level.

Formed by several semi-enclosed basins, the eastern archipelago probably retains (via sedimentation and denitrification) a part of nutrients and organic matter transported into it from the land, via the atmosphere and from the outer Gulf, thus acting as a filter between the land and the open sea.

3.1.1 **Inner coastal waters and the Kymijoki estuary**

In the inner archipelago the undesirable effects on water quality are in the first place governed by the local loading from the Kotka region and via the river Kymijoki, and by the coastal morphometry and hydrography.

The shallow and enclosed Virolahti Bay at the Finnish-Soviet border, loaded by fish farms in the Finnish side (in 1987 phosphorus: 9 t/a, nitrogen: 60 t/a), is the most strongly eutrophied part of the inner archipelago, when assessed on the basis of phytoplankton biomass and primary productivity. Although increased phytoplankton biomasses caused by local nutrient inputs are evident in the innermost archipelago, especially in the Kymijoki estuary and off the town of Hamina, increased primary production and phytoplankton biomasses are not the primary water protection problems in the area. A more undesirable issue is the consequences of the high loading of organic matter and harmful substances from the several pulp and paper mills by the coast and by the lower course of the river Kymijoki.

High loads of organic matter have been observed to reflect as strongly increased biomasses of heterotrophic organisms in the Kymijoki estuary. Although not studied, the same situation probably prevails also elsewhere in the inner coastal waters off the Kotka-Kymijoki region. Low primary productivities immediately off Kotka may be due to inhibitory effects of effluents from the pulp and paper mills by the coast. Despite of decreased nutrient concentrations of the innermost waters during the 1970s and the early 1980s, the phytoplankton biomasses increased simultaneously. This was most probably due to the strong decrease in industrial discharges of substances inhibiting algal growth. Due to the general improvement in the water quality of the river Kymijoki, also the avoidance effects of toxic compounds on fish now seem to be small, since salmon immigrates to the Kymijoki estuary and to the lower reaches of the eastern branch of the river.

Concentrations of mercury and PCB's in the biota off the Kotka-Kymijoki region continued to decrease during the 1980s, but they still are elevated from the background level.

Because the basic level of inorganic nutrients both in the coastal and open waters of the northeastern Gulf is very high, the intensified removal of nutrients of municipal and industrial origin would clearly improve water quality only in the inner archipelago. On the other hand, the recent measures in the local pulp and paper industry have decreased the organic load by 30 %, from ca. 40 000 t/a of BOD_7 in 1980-88 to 27 000 t/a in 1989. Although the BOD-load still is substantial, already the performed load reduction (13 000 t/a as BOD,) will result in a decline of heterotrophic production and concentrations of harmful substances in biota and sediments, as well as in an improvement in the general state (e.g. turbidity, oxygen conditions, hygienic quality, smell and odour disadvantages) at least near the pollution sources.

3.1.2 The middle and outer archipelago

Because of the great subthermocline nutrient reserves (see Chapter 2), hydrographical and weather conditions are the key factors regulating the actual trophic conditions outside the inner archipelago. Phytoplankton biomasses of the whole archipelago and also of the adjacent open waters have been on a clearly increased level when compared with the western Gulf. Vernal plankton blooms have been very strong at least during the whole 1980s. Nuisance blue-green algal blooms have been observed occasionally, especially during late summers and autumns. According to the intensive monitoring performed in the area, nutrient concentrations and the general trophic degree have not essentially changed in the area during the 1980s. Older nutrient data indicates that an increase in the trophic degree took place already in the 1970s.

The occurrence and origin of the blue-green algal blooms have been difficult to define. This has been, for a part, a national problem concerning the sufficiency of research and monitoring resources. The problem has, however, also largely caused by the very restricted information available on the state of the bordering waters in the Soviet Union. The situation decisively improved in 1990, when Finnish scientists were allowed to study the Soviet territorial waters of the eastern Gulf.

According to the results obtained in these studies, the primary and immediate eutrophying effects of the heavily loaded Neva-Leningrad region seemed to cover the waters east of the island Seskar (Seiskari, ca. 50 km southeast from the Finnish-Soviet border), but they did not reach the Finnish waters or the middle open parts of the eastern Gulf at least under warm and light-winded late summer conditions.

However, results of the intensive monitoring conducted in the easternmost Finnish waters have indicated that in winter nutrient-rich waters originating from the easternmost Gulf flow below the ice towards the easternmost Finnish archipelago. Although the basic wintertime level of inorganic nutrients is high throughout the Gulf, the nutrient-rich waters flowing towards west and northwest evidently further increase the vernal planktonic production in the whole northeastern Gulf.

Efficient sedimentation of vernal phytoplankton biomasses transfers high amounts of nutrients into the deeper water layers and to the bottom. Thus trophic conditions of the succeeding summer decisively depend on the stability of the density stratification in the water mass: strong vertical mixing (caused especially by winds between N and W) returns a part of the remineralized nutrients to the surface layer which immediately leads to intensified planktonic production.

A strong reduction in the nutrient loading from the Neva-Leningrad region would decrease the trophic degree in the easternmost Finnish archipelago in spring. In summer such reductions would probably not immediately reflect in the state of the Finnish waters, because the enormous nutrient reserves below the surface layer (which partly originate from the western Gulf and the Baltic Proper) and weather conditions (which regulate mixing and thus availability of subthermocline nutrients) largely regulate actual planktonic production.

It can be estimated that the summertime subthermocline nutrient reserves of the whole eastern Gulf (area ca. 20 000 km^2) are of the same order of magnitude than the annual total loads of nitrogen and phosphorus into the this area. Thus, in the long run, efficient removal of phosphorus and nitrogen, especially in the Soviet Union, would evidently improve the state of the whole eastern Gulf of Finland (and probably the whole Gulf) both directly and indirectly, particularly via restricting the accumulation of subthermocline nutrient reserves.

3.2 Coastal waters off Porvoo

The inner waters off Porvoo are loaded by agricultural and municipal nutrients via two small but nutrient-rich rivers, while the middle and outer archipelago receives effluents including harmful organic compounds and nutrients, especially nitrogen, from oil and petrochemical industry.

As a result of the water protection measures performed, the total point-source loading of nutrients and harmful substances clearly decreased in the early 1980s. Although phosphorus discharges decreased substantially already during the 1970s, due to the intensified purification of municipal waste waters, nutrient discharges into the water area still are locally significant. Additionally, the riverine nitrogen transport has continuously increased, because of the lack of effective removal of nitrogen from municipal waste waters, and leaching of nitrogen from agriculture.

The loading of oil by the oil refinery and petrochemical industry in Porvoo has decreased by ca. 20 % during the 1980s. However, the bottom area affected by oil discharges has not decreased. In the near-by coastal waters the discharges have been observed to somewhat affect physiology of fish. Also concentrations of oil residues in fish are elevated from the background level.

The grounding of M/S Antonio Gramsci off Porvoo in March 1987, spilling 570 t of raw oil into the ice-covered outer waters, led to only minor effects on biota and fisheries in the adjacent coastal waters.

3.3 Coastal waters off Helsinki

The sea area off the Helsinki region (ca. 800.000 inhabitants) received in 1989 a municipal load of 100 t phosphorus, 3 600 t of nitrogen and 1 800 t of BOD,. About 90 % of the load was led to the outermost archipelago via two tunnels. Nutrient loading via the river Vantaa, mainly of agricultural and municipal origin and quantitatively almost equal to the municipal loads of the Helsinki region, is affecting especially the inner waters east of the city.

The effects of the local loading and changes in it have clearly reflected in biota. Trends indicating eutrophication have been observed in most of the variables measured, i.e. in nutrients, phytoplankton, primary productivity, benthos and phytal vegetation. The strong decrease (ca. 75 %) in the municipal phosphorus loading during the 1970s improved the state of the innermost waters. However, in the outer archipelago the degree of trophy has strongly increased from the early 1970s till the late 1980s. This is most probably connected with the facts that both nitrogen concentrations of the open sea and the land-based nitrogen loading have increased during the recent decades.

Since 1986 most of the purified waste waters of the Helsinki region has been led to the outer archipelago instead of the inner bays. Outlets of the waste water tunnels situate below the thermocline. The only result of this procedure, for the present, confirmed by the monitoring studies, has been the declining hygienic status of the outer archipelago with an improvement in the innermost water areas.

Although especially the nitrogen load into the outermost archipelago off Helsinki is locally substantial, the question on the benefits of the possible reduction of the present municipal load is complex, because of the great nutrient reserves of the open Gulf water, possibly counteracting the positive effects of the load reductions. Together with corresponding reductions from all the greater nutrient sources around the Gulf, a decrease of the nutrient reserves would happen in the long run, and consequently a decline in the eutrophic effects would emerge. More accurate answers on the role of nitrogen discharges will be obtained, when results of a 5-year research project, concerning the effects of nitrogen discharges on the coastal waters, started lately as a co-operation between the National Board of Waters and the Environment and several other Finnish research units, are available.

Decreasing the agricultural and municipal load into the river Vantaa would evidently enhance the state of the inner waters east of the city.

4 THE ARCHIPELAGO SEA

The sea area receives annually 440 t of phosphorus and 5 500 t of nitrogen from its small but intensively cultivated catchment area. The point-source BOD,-load is relatively small, ca. 4 000 t/a. Especially the loading of nitrogen increased during the 1970s, mainly due to the agricultural loading. The increase in the phosphorus loading was not as steep, because the effective removal of municipal phosphorus partly counteracted the increase in the loading from agriculture. In the 1980s no great changes has been taken place in the total nutrient loading. However, the role of fish farming as a nutrient source has grown prominently.

About 50 % of the annual land-based nitrogen discharges and 60 % of the phosphorus discharges originate from agriculture. Point-sources contribute 29 % of nitrogen and 28 % of phosphorus discharges. The remaining 10 to 20 % is, for the most, explained by natural leaching. In the middle and outer archipelago, fish farming is the most important direct source of nutrients contributing (1988) 8 % of the land-based nitrogen and 16 % of the phosphorus discharges, Direct atmospheric loading into the Archipelago Sea seems to be prominent and has been estimated as 6 000 t/a of nitrogen and 110 t/a of phosphorus.

The increase in the nutrient concentrations of the middle and outer archipelago which was observed in 1970-1983 has continued during the late 1980s.

4.1 The inner archipelago

The inner Archipelago Sea is loaded by nutrients mainly from coastal point-sources (municipalities) and from agriculture via several small rivers discharging into the sea area. As a result of the loading and the very complex morphology, the area is clearly eutrophied.

In an annual scale, the biggest single source of nutrients is agriculture, especially field cultivation. The percentages of agricultural land in river drainage basins varies from 20 to 40 %. Additionally, most of the drainage basins are very poor in lakes, resulting in direct and rapid transport of leached nutrients into the inner archipelago.

The biggest areal point-source of nutrients is the Turku region (ca. 200 000 inhabitants). As in all greater municipalities in Finland, also in Turku the removal of phosphorus has been effective during the whole 1980s, whereas only a small part of the waste water nitrogen has removed. Diffuse nutrient loading via the numerous small rivers increased especially in the 1970s. As a result only minor decline has been detected in the trophic degree of the innermost archipelago off Turku, whereas in other parts of the Archipelago Sea signs of increasing eutrophication have been evident during the recent decades.

Under average hydrological conditions, most of the nutrients discharged by the rivers reach the coastal waters before the beginning of April, and are fixed by primary producers during the vernal production maximum, in April and early May. Because of the efficient sedimentation of this vernal bloom, and relatively stable hydrographical conditions in the archipelago, effects of the diffuse loading do not largely affect the summertime trophic conditions, except in the innermost shallow (unstratified) parts of the archipelago, where exchange of nutrients between sediments and water is effective. However, in rainy summers increased riverine nutrient inputs result in increased eutrophication more extensively.

Almost complete point-source removal of phosphorus added by effective removal of nitrogen would evidently improve the state of the inner archipelago off the Turku region. Concerning the whole inner Archipelago Sea only effective measures aimed at agricultural loading would decline the trophic degree there.

4.2 The middle and outer archipelago

The middle and outer waters of the Archipelago Sea are directly affected by intensive fish farming practiced in floating and anchored cages. During average (dry) summers, when the contribution from diffuse sources is small, fish farming is the biggest single “land-based” source of nutrients in the whole sea area, discharging annually (1988) 64 t of phosphorus and 480 t of nitrogen into the archipelago. Additionally, nutrients from fish farms can be easily utilized by primary producers, while only a part of the riverine nutrients are inorganic or simple organic compounds. As fish cages are usually located in unloaded and geomorphologically sheltered places in the archipelago, and the whole nutrient loading is discharged during the productive season, eutrophic effects are immediate and visible. As a result undesirable consequences to other uses of near-by waters and shore areas take place.

Because the farms, ca. 120 by number including the Åland archipelago, are scattered in the middle and outer archipelago, it is possible that the general trend towards increasing eutrophy observed there is at least partly caused by the extensive fish farming. The reduction of aquacultural loading would surely decrease eutrophic effects locally near the farms, but possibly also more extensively in the archipelago.

5 THE BOTHNIAN SEA

During the late 1980s, the average annual land-based loading into the coastal waters of the Bothnian Sea has been 1 200 t of phosphorus and 18 000 t of nitrogen. The figures are near to those of the early 1980s. The point-source BOD-loading, 13 000 t/a (mostly from pulp and paper mills), has decreased by ca. 20 % during the 1980s. Also the substantial heavy metal loading of the sea area has been decreasing.

Agriculture has been estimated to contribute about 40 % of both the land-based nitrogen and phosphorus loading. Direct point-source loading into the lower courses of the rivers or directly into the coastal waters represents 21 % of the nitrogen and 29 % of the phosphorus load. However, in practice the proportion of point-source nutrients is larger because the lake-rich upper part of the drainage basin evidently is incapable to retain totally the heavy loading discharged into it, Thus a more reliable proportion of point-source loading would be around 30-40 % for both nitrogen and phosphorus.

The middle part of the coastal water area off the town of Pori is the most heavily loaded of all Finnish coastal waters, receiving nutrients, organic matter and heavy metals from two major sources: via the river Kokemaenjoki and directly from the titanium dioxide factory at the mouth of the Kokemaenjoki estuary. Additionally, the coastal waters of the Bothnian Sea are loaded by several towns (Vaasa, Kaskinen, Pori, Rauma and Uusikaupunki), pulp and paper mills at Rauma and Kaskinen and a fertilizer plant at Uusikaupunki.

5.1 Kokemäenjoki estuary and adjacent coastal waters

The river Kokemaenjoki is the biggest riverine source of nutrients and heavy metals within the Finnish coastal waters. Additionally, this coastal water area is loaded by a titanium dioxide plant. The anthropogenic load into the river Kokemaenjoki and its estuary originates from municipal and industrial (metal, chemical and wood processing industry) sources as well as from intensive agriculture especially by the lower reaches of the river. The effects of the loading have been remarkable both on water, biota and sediments of the estuary.

Due to extremely favourable mixing conditions immediately outside the river estuary, the water area with clear land-based effects is surprisingly small (ca. 300 km^2) in relation to the magnitude of the riverine loading.

The water area where clear effects of the titanium dioxide plant, discharging several heavy metals and sulphuric acid, have been observed, cover an area of about 300 to 400 km*. The contaminated waters are partly the same as those affected by the riverine loading. The area of totally dead bottom near the outlet of the effluents (6 km from the coast-line) has been ca. 10 km^2. The total area of eutrophic (riverine) effects and/or metal contamination in biota cover an area of ca. 500 km^2.

The discharges of iron and sulphuric acid from the titanium dioxide plant have decreased by 15 % during the 1980s. The loading of heavy metals has also decreased which has led to decreased heavy metal concentrations in local biota Also the area of totally dead bottom has somewhat decreased.

The decrease of the present nutrient and organic matter discharges from the river Kokemaenjoki would, in the first place, improve the state of the outer estuary and adjacent waters. No clear effects on primary productivity can be expected in the inner estuary (the Pihlavanlahti Bay), because physical factors rather than nutrients limit the algal growth there. However a decrease on heterotrophic production as well as on hygienic and aesthetic state of the Pihlavanlahti Bay would be prominent.

6 THE BOTHNIAN BAY

During the late 1980s the sea area received 35 000 t/a of nitrogen and 2 200 t/a of phosphorus from the Finnish territory. The estimates are ca. 10 % lower than those for the early 1980s. The point-source BOD-load (19 000 t/a) which mainly originates from pulp and paper industry has decreased by 60 %, during the 1980s, due to the introduction of the biological treatment of waste waters.

About 25 % of the total land-based nitrogen and phosphorus transport has been estimated to originate from agriculture. The corresponding proportion for industrial and municipal loads are 7 % and 14 % for nitrogen and phosphorus, respectively. Natural leaching evidently is the largest single nutrient source. The natural contribution can be estimated as ca. 50 % of the land-based nutrients, when average values of 6 kg/km^2a for phosphorus and 100 kg/km^2a for nitrogen are applied as average areal coefficients for net leaching.

Point-source heavy metals are discharged into the waters off Kokkola, Raahe and Tomio. Due to the relatively large emissions to the air, a substantial part of this loading enters the coastal waters, as well as the open sea, via atmosphere. Especially in the southern part of sea area, the riverine loads of heavy metals are considerable due to effective leaching from the Litorina alum soils.

6.1 Coastal waters off Kokkola-Pietarsaari

In spite of locally quite high riverine and direct loads of nutrients into the archipelago off these two towns, eutrophic effects on phytoplankton have mainly restricted to the waters off Kokkola which are loaded, in addition to municipal waste waters, by heavy metals and nitrogen from the metal industry. Due to process changes, the loading of both nitrogen and heavy metals has substantially decreased during the 1980s.

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The waters off the town of Pietarsaari are affected by waste waters from a pulp and paper mill, the effluents of which seemed to inhibit phytoplankton growth in the inner archipelago in the early 1980s. On the other hand, the heterotrophic production has evidently been prominent, because of the high load of organic matter (BOD, load ca. 9 000 t/a before the mid 1980s) and low oxygen concentrations observed in the water area. The effects on the receiving waters decreased considerably during the late 1980s due to the introduction of the biological purification system. The annual BOD,-load was 1 500 t in 1989.

Naturally, the decrease in the industrial loading, containing inhibitive effects for phytoplankton growth, has created more favourable conditions for primary production. As a result, a clear increase has been observed in the chlorophyll values off Pietarsaari. Thus under the present loading conditions, efficient removal of nutrients (at least that of phosphorus) would decrease the degree of trophy in the whole archipelagic area off Kokkola-Pietarsaari. The great excess of inorganic nitrogen in the open waters of the Bay makes it difficult to predict the possible effects of nitrogen removal.

Due to the enforcement of waste waters and the refuse gas purification methods at the zinc and cadmium plants in Kokkola, the direct discharges of heavy metals into the coastal waters have considerably decreased during the 1980s: zinc by 70 %, nickel by 40 %, copper by 85 %, cobalt by 70 % and arsenic by 95 %.

Concentrations of heavy metals in bottom fauna (Mesidotea), except that of mercury, have strongly declined. During the 1980s no toxic effects on bottom fauna have been observed and the recovery of benthic communities continues.

6.2 The northeastern Bothnian Bay

This large but shallow water area is strongly affected by fresh waters from four large rivers (summed mean flow ca. 1 500 m^3/s). The rivers do, however, not have any clear, geomorphologically restricted estuaries. When the coastal morphometry is relatively simple, mixing between river waters and the open Bay water is efficient during open water season. Nutrient and organic matter loads are high from the rivers and from the towns and industries of Oulu, Kemi and Tornio. However, the organic load (both BOD and harmful substances) from the pulp and paper industry has decreased strongly during the late 1980s.

The majority, ca. 75 %, of the riverine nutrients enters the coastal waters as organic (mainly humic) compounds, which do not induce such immediate eutrophication as do the same amounts of pure inorganic nutrients. Additionally, nutrient concentrations of the discharging river waters are generally low. On the other hand, the large freshwater inflow spreads the riverine and coastal point-source nutrients effectively. Further on, the coastal retention is evidently negligible due to the simple morphometry, shallowness and favourable mixing conditions. As a result, the eutrophic impacts are relatively modest but the area where eutrophic effects can be observed is large, approximately from 1 000 to 1 500 km’.

The strongest effects on planktonic production, oxygen conditions and aesthetic state have been observed immediately off the towns and industrial plants. However the efficient removal of organic matter (and toxic substances) in pulp and paper industry, as well as the closing of one sulphite pulp mill, has clearly improved the state of the waters near the loading sources (Kemi, Oulu). Simultaneously, however, an increase in chlorophyll values, indicating increased phytoplankton biomasses, have been observed. Thus a decrease of the present nutrient (at least phosphorus) and organic load would further enhance the state of the inner waters.

The role of nitrogen is an open question in the whole coastal water area of the Bothnian Bay, because large and increasing amounts of free inorganic nitrogen exists in the open parts of the Bothnian Bay, causing continuous inputs to the coastal waters. Additionally the riverine inputs include nitrogen in excess for primary producers.

The loading of heavy metals to water and air by the ferrochromium and steel plant in Tomio has considerably decreased during the 1980s due to purification measures. The direct loads of chromium and zinc has decreased by over 50 % and 90 %, respectively. At the same time the atmospheric loads of chromium and zinc have decreased by 50 % and 70 %, respectively. In the receiving near-by waters the chromium concentrations have been on an elevated level both in water, sediment and bottom fauna. In fish fillets elevated concentrations have not been found. However, severe reproduction disturbances have been observed in burbot, and studies on reasons of this phenomenon have been recently started.

7 CONCLUSIONS

For the late 1980s the land-based nutrient loading of the Finnish coastal waters is estimated as 4 800 t/a of phosphorus and 80 000 t/a of nitrogen. The figures are very close to the corresponding estimations for the early 1980s. On the contrary, the total point-source load of organic matter has decreased from ca. 110 000 to 70 000 t/a during the 1980s, mainly as a result of the introduction of biological treatment of pulp and paper effluents. The activated sludge treatment has substantially decreased the load of halogenated organic compounds too. The greatest decrease have taken place by the Bothnian Bay. Also the point-source loading of heavy metals has decreased during the 1980s.

The coastal water areas where considerable impacts caused by the land-based loading can be seen are the same introduced in the previous assessment, covering the years 1979-83. Problems caused by nutrient loading are the most extensive in the eastern archipelago of the Gulf of Finland, in the inner and middle Archipelago Sea and in the northeastern Bothnian Bay. Pollution load from the pulp and paper industry extensively affects the inner and middle archipelago off the Kotka-Kymijoki region and the northeastern Bothnian Bay. However, in these areas the harmful effects have declined, due to the very strong decrease in the pollution load from the local pulp and paper mills. The waters off Pori by the Bothnian Sea still are the most heavily loaded of all Finnish coastal waters as regards nutrients and heavy metals. However, due to the favourable mixing conditions, the water area under harmful and/or eutrophic effects is relatively small. The metal loading and consequently its effects further decreased during the 1980s.

In the **Gulf of Finland,** especially in the easternmost Finnish archipelago, a strong reduction of land-based nutrients and organic matter would improve the water quality and decrease the trophic degree in the inner coastal waters. As Finland, however, contributes only 10-15 % of the total land-based loads of nutrients and organic matter into the Gulf, significant improvements in coastal waters and in the whole Gulf can be expected only if efficient measures are taken also in the Soviet Union where the most important loading source is the Neva-

Leningrad region. Because of the large nutrient reserves in the subthermocline water of the Gulf, the positive effects of such measures in the Finnish waters would probably happen relatively slowly.

In the **Archipelago Sea** efficient removal of nutrients from point sources would probably lead to improvements in the innermost waters of the off the Turku region. On the other hand, a decrease in the degree of trophy in a wider area, or in the whole Archipelago Sea can be expected only if the nutrient loading from the intensive agriculture in the catchment area, as well as in the aquaculture in the middle and outer archipelago can be effectively reduced.

Because of efficient mixing of river waters with the open sea water off Pori in **the Bothnian Sea,** the load reductions would probably not largely decrease the area under adverse effects. However, the trophic degree would evidently decrease. A further reduction in the toxic load from the local pigment plant would enhance the state of the adjacent waters.

More efficient reduction in industrial and municipal nutrient loading, particularly for phosphorus, would have positive effects in the inner coastal waters of the **northeastern Bothnian Bay.** The strong decrease in the organic loading from pulp and paper industries, recently introduced at most of the plants by the Bay, have improved the state of the waters near the sources of loading. The existence of the increasing storage of inorganic nitrogen in the surface layer of the open sea makes it difficult to assess the benefits of nitrogen removal in the coastal water area of the Bothnian Bay.

All marked reductions in loading would have positive effects locally near the pollution sources. In the Gulf of Finland and in the Archipelago Sea decreasing the trophic degree more extensively demands a strong reduction of loads from all major sources. The organic load from pulp and paper industries still causes problems at several coastal water areas, although the loading has strongly decreased during the 1980s. The water protection measures performed have shown that immediate improvements can be expected especially in the state of the water areas near the loading sources. Simultaneously, however, an increase in the primary productivity may take place. Thus decreasing the discharges of nutrients is important as well.

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Table 1. The point-source loading of phosphorus, nitrogen and organic matter as BOD ($t\ a^{-1}$) from mainland directly into the Finnish coastal waters and into the two main rivers in 1989 and the corresponding annual means for the period 1979-1983.

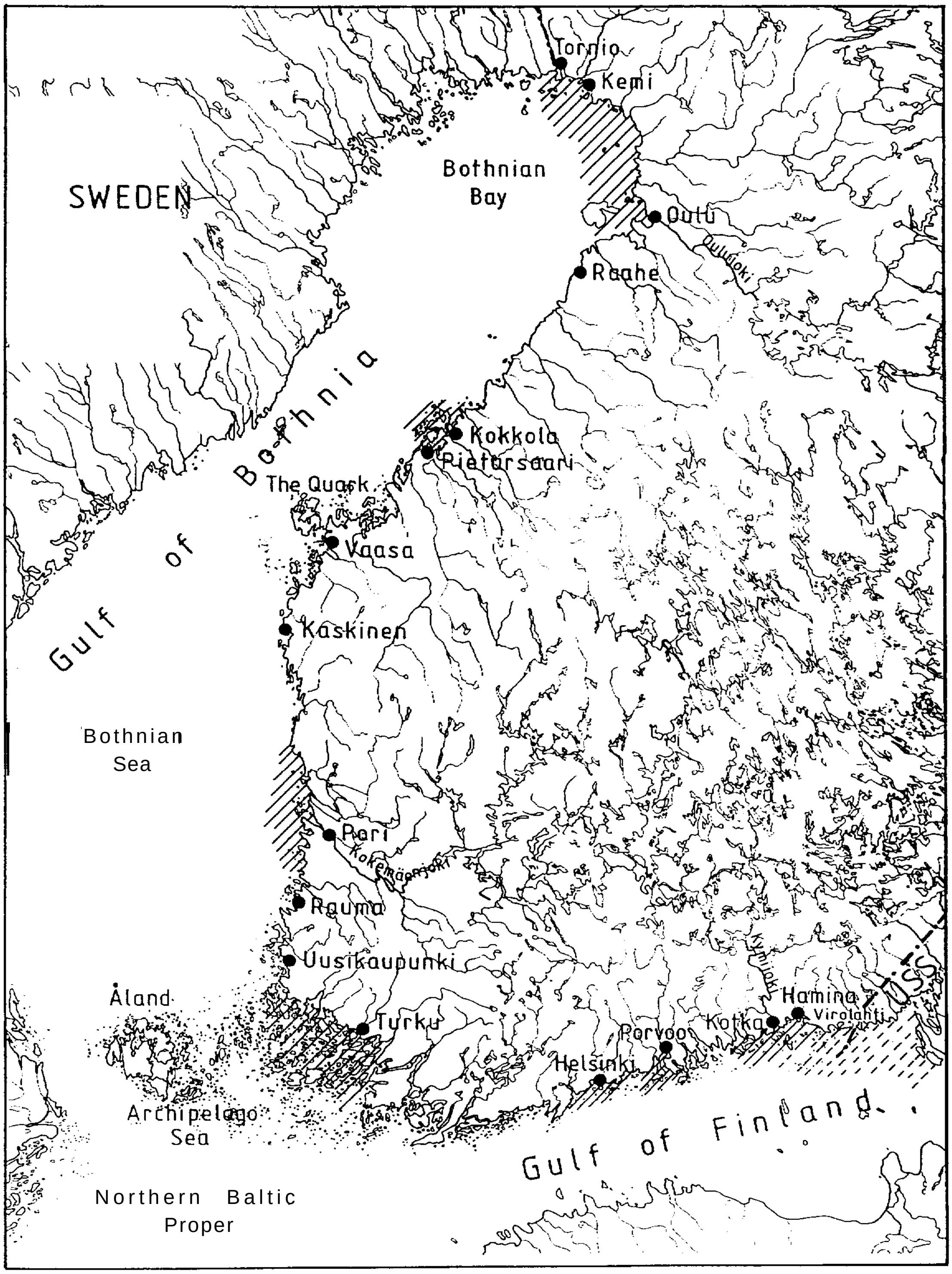
Coastal region	Phosphorus						Nitrogen						Org. matter					
	1989			1979-1983			1989			1979-1983			1989			1979-1983		
	Mun.	Ind.	Sum	Mun.	Ind.	Sum	Mun.	Ind.	Sum	Mun.	Ind.	Sum	Mun.	Ind.	Sum	Mun.	Ind.	Sum
Kotka-Hamina																		
Direct disch.	8.8	39	48	35	31	66	233	232	464	260	220	480	186	14381	14567	890	20000	21000
River Kymijoki	9.4	104	113				273	451	724				355	14271	14626			
Porvoo	3.4	4.1	7.5	6.2	5.6	12	125	102	227	120	210	330	114	258	372	150	240	390
Helsinki-Espoo	102	-	102	120	0.0	120	3627	-	3627	3100	1	3100	1890	-	1890	3500	2	3500
Turku	31	0.8	32	29	2.2	32	961	179	1140	900	110	1000	715	133	848	1200	340	1300
Pori																		
Direct disch.	6.2	4.6	10.8	12	13	25	299	49	348	300	56	360	1278	2284	3562	1000	3800	4800
River Kokemäenj.	6.7	6.3	13				176	18	194				88	9.1	97			
Pietarsaari	1.9	43	45	8.1	32	40	130	199	329	110	140	240	24	767	791	240	8600	8800
Kokkola	1.1	3.9	5.0	2.1	7.6	9.7	129	606	735	110	1100	1200	137	-	136	260	13	280
Kemi[1)]	5.5	69	75	19	54	73	110	287	396	110	280	380	230	17000	237	460	19000	20000
Oulu[1)]	9.9	49	59	25	28	53	521	276	797	510	150	660	911	4060	4971	1100	15000	16000
Tornio[1)]	13	0.08	41	5.9	0.2	6.1	-	93	93	51	77	130	670	0.6	671	55	11	130
Total direct load from coast[2)]	226	368	594	340	270	610	6942	2533	9475	6500	2700	9200	6870	56089	62959	10000	82000	92000

1) The municipal and industrial load into these rivers is negligible in relation to the direct load into the Bothnian Bay.
2) Does not include loads into the rivers.

Table 2. The total direct discharges of nutrients and organic matter as BOD, (ta-l) from municipalities and industries into the different Finnish sea areas in 1989 and corresponding annual means for 1979-1983.

Sea areas	1989			1979-1983		
	Mun.	Ind.	Sum	Mun.	Ind.	Sum
Phosphorus						
Gulf of Finland	120	49	169	180	40	220
Archipelago Sea	33	3	36	51	5	56
Bothnian Sea	35	130	165	42	97	139
Bothnian Bay	34	180	214	67	130	197
Total	220	360	580	340	270	610
Nitrogen						
Gulf of Finland	4200	330	4530	3700	460	4160
Archipelago Sea	1000	190	1190	1100	160	1260
Bothnian Sea	740	340	1080	650	350	1000
Bothnian Bay	970	1700	2670	1000	1700	2700
Total	6900	2600	9500	6500	2700	9200
BOD,						
Gulf of Finland	2400	15000	17400	5000	21000	26000
Archipelago Sea	750	230	980	1500	750	2250
Bothnian Sea	1700	18000	19700	1700	17000	18700
Bothnian Bay	2000	23000	25000	2300	43000	45300
Total	6900	56000	63000	10000	82000	92000

Fig. 1. The most important problem areas of the Finnish coastal waters (hatched).



ANNEX 3.

By Germany:

Conclusions from "National Coastal Assessment of the Federal Republic of Germany; First draft"

National Coastal Assessment
of the Federal Republic of Germany
First draft

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Contents

4. CONCLUSIONS

As there is no major fresh water inflow of rivers polluted with harmful substances into the German Belt Sea, the concentrations observed correspond to the low values from the Baltic Proper. Concentrations of airborne pollutants, like the trace metal Lead (Pb), are somewhat higher, due to the vicinity of densely populated land with traffic. Recent monitoring results of organochlorines show a downward trend in concentrations, which has been continuous in the last years.

There are some gaps in knowledge of the burden of harmful substances, but so far the coastal waters of Mecklenburg-Vorpommem do not show any extremely high trace metal contamination and significant load of toxicologically relevant organochlorines. But this statement must be taken with care, as there are only very few data available. The only “areas of special concern” in German coastal waters seem to be the Wamow and the Oder estuary. In the Oder estuary, most of the measured residue values exceeded the limits for egg consumption by man and correlation calculations indicated egg thinning due to DDT compounds.

In German coastal waters and especially in the surrounding semi-enclosed inlets eutrophication is the main problem. The increase in nutrient levels produced a rise in primary production, prolongation of extensive algal blooms and change in phytoplankton species composition.

Changes in light climate (decrease of Secchi depth) might be responsible for distinct changes in biomass and species composition during the past 20 years in sublittoral vegetation of Kiel Bay. An increase of biomass above the 12 m level is accompanied by a decrease below.

Due to greater sedimentation of organic matter, oxygen consumption in deep water and bottoms has increased. Deficiency of oxygen has occasionally been observed in the western Belt Sea at least during the last 100 years. But since the early 80ies, bottom water is affected by oxygen depletion almost every year. This leads to widespread oxygen depletion followed occasionally by hydrogen sulphide formation (H_2S) in the bottom water. As a consequence bottom animal and fish kills occur in Kiel, Liibeck and Mecklenburg Bay and especially the adjacent fjords are affected nearly every year. So species number and composition of bottom animals is partly reduced to some well adapted species.

The shallow sediments above the summer-halocline show a rich species spectrum dominated by polychaetes and molluscs and an elevated biomass compared to the 60ies, that remained nearly stable throughout the last years.

Despite the above mentioned ecological problems, bathing water quality at the Schleswig-Holstein beaches is of a high standard and deeps within the requirements of the EC-Bathing-Water-Guidelines. From Mecklenburg-Vorpommem data based on the EC-Guidelines are not yet available.

Due to effective measures in the reduction of nutrient input from urban areas in Schleswig-Holstein, considerable reduction of nutrients has been achieved. This is not the case in the area of the former GDR. But in both areas nutrient levels in coastal waters are still high. There has to be put more attention in reducing the inputs of nutrients coming from the adjacent land and from air.

In future, a coordinated monitoring in all Baltic Sea States with elaborated guidelines should be emphasized, to achieve comparable information for a second assessment of the ecological state of the Baltic Sea coastal waters.

ANNEX 4.

By Poland:

General conclusions based on “Assessment of the Effects of Pollution on the Polish Coastal Area of the Baltic Sea 1984-1989” and an extract from “Assessment of the Effects of Pollution on the Polish Coastal Area of the Baltic Sea 1984-1989”

GENERAL CONCLUSIONS

Polish drainage and coastal area.

Poland has about 38 mln of inhabitants and over 99 per cent of the country belongs to the drainage area of the Baltic Sea.

Most of the coastal area consists of sandy beaches and dunes. The shoreline is more then 500 km long, opened and exposed to sea actions, therefore the shallow waters are well mixed and saturated with oxygen throughout the whole column. Sea floor along the Polish coast down to the depth of about 40 m consists of different types of sends, occasionally pebbles and stones. Sandy, easily mobilised sediments limit development of bottom organisms.

Coastal currents as well as direction and extention of Wiska and Odra river water mostly depend on anemobaric conditions.

Polish agriculture is based on artificial and natural intensive fertilization and application of biocides. Industry which is mostly located in the southern and central part of Poland applies to the large extent old and "dirty" technologies.

The major parts of nutrients and contaminants from the drainage area of Poland is discharged into the sea by rivers of which 70 per cent is discharged directly and 30 per cent through lagoons, where partial neutralization of pollutants takes place.

Among all Polish rivers, Wiska and Odra bring the highest quantity of water. Outflow of water varies considerably throughout a year.

As regards water movement along the Polish coast, wave currents form the major force; under north-west direction of waving these currents faciliate transport of pollutants to the Polish central and western coast.

Eutrophication and contamination.

Poland discharges considerable loads of organic material and nutrients into the Baltic Sea. In 1988-1989 the annual load amounted to 341 thou. tons of BOD_5, 222 thou. tons of nitrogen and 21 thou. tons of phosphorus. However, unit loads in relation to the area and the number of inhabitants are relatively small.

Phosphate, nitrate and silicate concentrations in the Polish coastal zone of the Baltic Sea did not change significantly in 1985- 1989, as compared with 1979-1983. The Pomeranian Bay and the Gulf of Gdansk are the most eutrophic basins, affected by great loads of nutrients from river outflow. This is also evidenced by intensive primary production. Central Polish coast does not differ in this respect from the open sea water of the Baltic, although there are local symptoms of increased eutrophication.

A decrease of winter accumulation rate of phosphates and silicates was noticed in the surface water of the Gulf of Gdansk, but the rate of nitrate accumulation remained high. Such situation leads to an increase of the N/P ratio in water and renders possible abundant plankton blooms in spring.

There has been observed certain regionalization of the Polish coastal zone as regards the N/P ratio: in the Gulf of Gdansk and partly at the central Polish coast nitrogen is still the limiting nutrient for primary production, while in the Pomeranian Bay phosphorus seems to take this role in spring.

There is no efficient waste treatment along the sea shore and inside the country. This results in sanitary pollution of many beaches and near shore water.

Contamination of fish cought in the Polish coastal zone does not exceed the national and international standards. The content of Zn and PCB remains stable while the concentrations of Hg, Cd, Pb, and DDT show a decreasing trend.

Coastal zone is exposed to accidental oil spillages and intentional spillages of unwanted remains of oil. Port and shipyard channels collect considerable load of petroleum hydrocarbons.

Biological effects.

There are a number of unfavorable changes in the coastal ecosystems, resulting in unfavourable biological succession leading to replacement of certain species by others more persistant to eutrophicated and contaminated environments.

Clearly marked changes in flora structure of the coastal biocenosis have been noticed during the last several decades. The blooms of blue-green algae have intensified with **more** frequent **appears of Microcystis *aeruginosa*** and blooms of ***dinoflagellates,*** which did not happen earlier. A dramatic decrease of species variability occurs in phytobenthon and simultaneously, tallophytic algae of ***Ectocarpacae*** develop abundantly. The area of sea floor implanted with sea-grass ***Zostera marina*** **has** diminished drastically. Plants appear in a very narrow water belt of 6 m depth, while until 50s they occured down to about 25 m.

No essential changes in zooplankton have been noticed in the coastal area of Poland. The changes linked with the increase of pollution have been observed in the bottom fauna in the Gulf of Gdańsk, morever the drastic changes in zoobenthos have been observed in the Puck Bay.

There are changes in species composition of ichthyofauna and fish catches; many species perish, while other proliferate. The reasons lay in the deterioration of living conditions: degradation of spowning grounds, pressure of predatory fish, immature fish hauling.

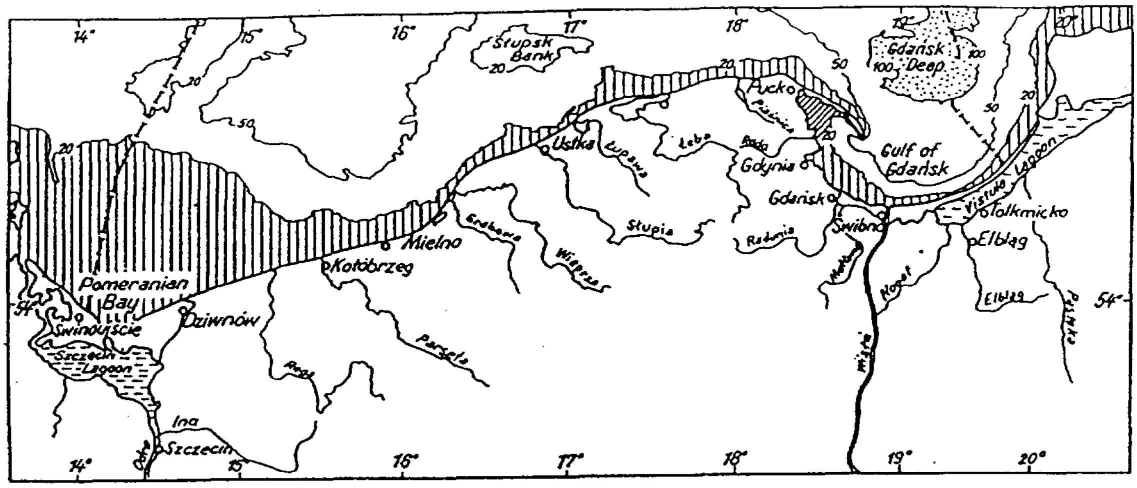
The most profond decrease of fish catches has been noted in the Puck Bay, where mass mortality of eels happend in early 1980s followed by considerable decrease of stock of commercial fish.

It seems that this unfavourable changes appeared to be due to excessive eutrophication rather then the intoxication, however this opinion is not scientifically proved.

Hot spots.

The Gulf of Gdańsk and the Pomeranian Bay receive pollutants from the entire country via the Wisła and Odra rivers and via some smaller river and streams.

They also receive urban sewage from big local agglomerations as well as some industrial discharges. Therefore they are recognized as the "hot spots" - the most polluted parts of the Polish coastal area.



ASSESSMENT OF THE EFFECTS

OF POLLUTION ON THE POLISH

COASTAL AREA OF THE BALTIC SEA

1984 - 1989

EDITORS:

Anna Trzosińska

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GDYNIA, 1991

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ANNEX 5.

By Sweden:

"National Coastal Assessment of Sweden; A Summary"

NATIONAL COASTAL ASSESSMENT OF SWEDEN; A SUMMARY.

BACKGROUND MATERIAL

The coastal assessment of Sweden is based on a series of reports covering different objects of relevance for the understanding of the state and functions of the coastal zone. The reports form the basis for the national action programme drawn up by the Swedish National Environmental Protection Agency in "Marine Pollution ´90". The main background reports are presented in the references, e.g., Borg et al. 1991, Ceder-wall & Larsson 1988, Grimås & Suárez 1989, Persson 1990, Thorman 1987, SNV 1988. The information covers about 1000 pp of text. To these reports should be added the National Plan for the Swedish Marine Environment based on, e.g. on 10 reports by the Regional Authorities regarding the status of those marine areas for which they are responsible. In addition to this information, reports and scientific papers are utilized, of which some are added to the reference list in this preliminary report.

The possibility to submit a detailed national report from Sweden to the EC is limited, especially taking into account the time schedule given for the whole project and the role of Sweden as responsible for the summary. Information on the Swedish material has been given to and has been discused by the members of the Ad Hoc Group of Coastal Assessment. Thus, there has been an exchange of experiences and discussions between those among the national contact persons, who have had the opportunity to take part in the announced meetings.

CONCLUSIONS

General backaround

One of the general properties responsible for the coastal conditions is the salinity in the various main basins surrounding Sweden; from the sea areas diluted by river water in the northern Bothnian Bay, via the brackish Baltic Proper to the purely marine character of the Skagerrak. The capacity of the coastal ecosystems to endure disturbances are considered to vary with the salinity. The degree of sensibility is still under discussion.

Another main property is the retention time of water in the various basins, which varies from several decades in the Baltic to a few months in the Sound and Kattegat and affects the rate of degradation, sedimentation and evaporation of importance for the coasts.

The coastal zone is affected by properties of both the land and the sea. The morphometry of the coastline has a key function of the status and the various transport systems to and from the land and the open sea. About 50% of the Swedish coastline is bordered by an archipelago, divided in five main areas. The largest one covers the area from the southern Bothnian Bay down to the central Baltic Proper. The others are situated in the northern part of the Bothnian Bay and Bothnian Sea, the southern part down to the Baltic Proper and the coast of the Skagerrak on the west coast. The retardation of the water transport and the sink of material affects the quality of the system of basins and acts as a filter for the open sea.

On the other hand, if the archipelagos are overloaded by organic or toxic substances, these areas might function as a source rather than a cleaning resource in the future.

Problems

It is easy **to find so-called problem areas around the Swedish coasts. The problems are relative and depend on the definition and the impact of quality and/or quantity of harmful substances in the waters and areas covered. Another problem is the correlation between concentrations of hazardous substances** in the media and **the** reactions of the ecosystem.

It seems reasonable to sort out local affects which might prohibit a multiple use of the water around a city, e.g. for bathing, fishing, etc; a type of disturbance that has to be rectified by local authorities. On the other hand, it may be interpreted as a main problem on an international level if a series of plumes from local areas are intergrated and add to each other in a compact stream, often pressed against the coastline or linked off for recirculation into the main basin.

Such examples can be given from the coastal areas of the Bothnian Sea where the discharges from a series of pulp and paper industries can be followed by the content of EOCI in the sediments southwards and even as a recirculation in the basin. These and other results from investigations on ecological effects are given by a series of experts, e.g. Sandström et al (1991) concerning ecology and otherwise summarized in SNV 1988.

Concerning metals there are often difficulties to find a direct correlation between concentrations and ecological effects; acute as well as chronic. It has been shown that increased concentrations of various metals can be demonstrated in organisms hundreds of kilometers southwards from one big source, the factory at Rönnskär, in the southern Bothnian Bay. An increased burden of arsenic has also been demonstrated in zooplankton in the whole Gulf of Bothnia. A disturbed benthic fauna was demonstrated ten years ago in an area of about 100 km^2 outside Rönnskär and southwards. The discharges of arsenic as well as other metals have decreased substantially during the last decade. In spite of that it is, however, difficult to be sure that the ecosystem we now see in the Gulf of Bothnia is of the original composition in quality and quantity. The question is if the whole Gulf of Bothnia, which has a low concentration of phosphorus, still is damaged, e.g. by the high concentration of arsenic during several decades.

The influence of salinity seems to be part of the explanation of different concentrations of metals in organisms in the eastern and western waters, e.g. in mussels from the Baltic - about five times higher concentrations of many metals compared to the western basins like the Kattegat.

Effects of a general eutrophication of the sea can be seen in the Swedish coastal zone as well as local effects. The lower limit of the zone of large algae along the coasts has moved upwards as an effect of a decreased transparency of the water, e.g. the bladderwrack (Fucus) in southern Bothnian Bay, from 11.5m to 8.5m. Another example is the decreased transparency of light in the water from 9m to 5m in a central area of the Baltic coast, not affected by local pollution. The net catch of the herbivorous cyprinid fishes has been more than duplicated during the same period of the two decades. This is an obvious effect of eutrophication, reported in the overview on the general aspects of fishery in the Baltic Sea, given by Neuman et al (1988) .

The benthic fauna is a good indicator of a disturbance. An analysis of 31 coastal areas along the Swedish east coast from the Åland Sea to the southernmost part of the Baltic Proper shows that a serious reduction of benthic animals is found in the Stockholm archipelago covering an area of more than 50 km^2 (Cederwall et al 1988). In other areas along this large coastline, including the archipelago mentioned above, a disturbed benthic community can be observed in just a few areas and covering less than 5 km^2. This might indicate problems to be solved on a local basis and of less international interest as “hot spots”. The same type of information is given for input of nutrients in 36 areas, divided into totals and point sources like sewage plants. The reactions,

translated as an increased production of algae, are described by Persson (1990) to occur **in five areas along the same coastline.**

Other examples of local effects are given by measurements of the phytoplankton biomass along the coast during late summer, e.g. August/September when "clean" areas show relatively low background values compared to those areas fed by a surplus of nutrients.

In the main report a specific chapter will demonstrate changes observed as a trend in time. For Sweden it *includes* 45 local areas along the east coast from the Bothnian Bay to The Sound. Areas suspected to be polluted by industries, communities or river outlets have been studied . During the 1970s improved environmental conditions were observed in 15 areas, worse conditions in 6, no specific changes in 4 areas, and no reliable material from 20 areas. During the 1980s the general trend of improvement of the environmental situation continued with better conditions in 13 areas, worse in 2, no changes in 3 and question marks for 27 areas (SNV 1988). It is hoped that a number of areas wilt be included in a common monitoring routine in the future.

Besides these main areas of concern - eutrophication and potential toxic substances like metals and chlorinated organic compounds - there is a series of specific activities which will be covered in the main report, as was demonstrated at the EC-Meeting 1991.

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ANNEX 6.

By the USSR:

The State of the Coastal Waters of the Former USSR:

The State of the Coastal Waters of the Eastern Part of the Gulf of Finland (incl. Neva Bay, Vyborg Bay, Luga Bay and Koporie Bay) in the 1980s; General Conclusions

The State of the Estonian Coastal Waters in the 1980s; General Conclusions

The State of the Coastal Waters of the Gulf of Riga in the 1980s; General Conclusions

The State of the Coastal Waters of the Western Coast of Latvia, Lithuania and Kaliningrad region in the 1980s; General Conclusions

THE STATE OF THE COASTAL WATERS OF THE EASTERN PART OF THE GULF OF FINLAND (INCL. NEVA BAY, VYBORG BAY, LUGA BAY AND KOPORIE BAY) IN THE 1980s; GENERAL CONCLUSIONS

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1. INTRODUCTION

The present paper is based on the results of observations carried out within the USSR national monitoring programme by the Northwestern Hydrometeorological Service (Leningrad). There are altogether 63 stations in the area: 36 to the east from the Kotlin Island (between the mouth of the Neva River and the dam under construction); 17 in the open part (from the Kotlin I. to the Hogland I.); 8 in the Vyborg Bay; and 2 in both the Luga and Koporie bays. The sampling frequency for hydrography and hydrochemistry is, in general, 3-4 times a year. In more polluted areas the observations have been made every month.

2. GENERAL CHARACTERISTICS

The Eastern Part of the Gulf of Finland can be determined as the sea area to the east from the meridian 28°E. Geomorphologically the border is marked by 25 miles-long submarine ridge to the north from the Kurgali Peninsula. To the north from the Mochnyi Island (Lavansaari) there is a large (~ 20 miles) free connection (depths 25-35 m) with the central part of the gulf.

The area from 28°E to 29°10'E is often named as "deep area" in the Soviet hydrographical literature; the area from 29" 10'E to the Kotlin Island is named as "shallow area".

The Neva Bay (or Marquise Bay) is the area to the east from Kotlin Island, now almost separated by the famous Leningrad dam. The depths are less than 5 m in general, only the navigational channel has been deepened up to 10 m. Salinity is normally as low as 0.05 - 0.1 PSU.

The Vyborg Bay is the shallow (mostly less than 5 m) sea area with complicated configuration and many islands. The salinity in the bay is influenced by the inflow of the Saima River and has the value 0.2 - 3.5 PSU.

The Luga Bay at the southern coast has a good connection with the "deep area". The depths are mainly less than 20 m, salinity 3 - 4 PSU.

The Koporie Bay at the southern coast also, but to the east from the Luga Bay, has a free connection with the "deep area" too. The depths are up to 25 m, mean salinity 3 - 4 PSU.

The "shallow area" can be characterized with depths ranging from 5 m in the east to 30 m in the west (at 29°10'E). Typical salinity in the surface layer of this area is 1 PSU, in the bottom layer 4 PSU. There is no natural border between the "shallow" and "deep area".

The "deep area" is 30 - 50 m deep, but the bottom topography is complicated with lots of reefs and shoals. Typical values of salinity are 2 - 4 PSU in the surface and 5 - 6 PSU in the bottom layer.

All the Eastern Part of the Gulf of Finland is strongly affected by discharge of the Neva River, greatest in the Baltic Sea catchment area with mean inflow of 80 km^3a^{-1}. Seasonal variability and year-to-year changes in the Neva inflow can be noticed in the variations of the hydrological and hydrochemical parameters of seawater also.

3. POLLUTION LOAD

According to (1), the pollution load to the Eastern Part of the Gulf of Finland has been assessed as follows (t a^{-1}):

- Neva River (incl. waste waters of Leningrad)

BOD,	248 000
COD	2 000 000
tot N	49 000
NO,-N	21 000
tot P	3 200
PO,-P	1 500
Susp. solids	800 000

- Luga River (into the Luga Bay)

BOD,	8 900
COD	109 000
tot N	7 000
NO,-N	4 800
tot P	280
PO,-P	120
Susp. solids	17 700

- Vyborg (municipal and industrial discharges)

BOD,	4 500
tot N	1 820
tot P	22

The last estimations of the pollution load, made for HELCOM Task Force Group in 1991 by the USSR Environmental Business Association, are slightly different and can be found in papers of the Second Meeting of HELCOM TF, Stockholm, 6-9 May 1991.

Since 1985 the Leningrad waste waters treatment plant on Island Belyi (1.5 million m^3d^{-1}) has been in operation. At present three biological treatment plants are under construction: additional treatment plant of 0.25 million m^3d^{-1} on Island Belyi, Northern treatment plant of 1.5 million m^3d^{-1} and South-Western treatment plant of 0.5 million m^3d^{-1} (2).

4. HYDROCHEMISTRY

Oxveen conditions have been nearly normal in "deep area" and "shallow area". In late summer in the bottom layer (deeper than 20 m) oxygen deficiency (20-30 % of saturation) has been observed in some years (1980, 1982, 1985).

In the Vyborg Bay the oxygen conditions are normal in the open part, but near the port during winter the saturation % less than 30 is measured often. The BOD, values have been always higher than 2 $mgO_2\,l^{-1}$ (often 4 - 6 mg) in the port area and 2 - 4 $mgO_2\,l^{-1}$ in the open part of the bay.

In the Luga and Koporie bays the oxygen conditions have been good in all water layers, only in August 1982 oxygen deficiency (19-30 %) has been observed at the 10 m level.

It seems to be surprising, but in the Neva Bay according to used data the oxygen conditions have been also favourable. Near the Leningrad port area only the oxygen deficiency (20-40 % of saturation) has often been measured.

Nutrients concentrations in the Neva Bay have been also at relatively low level. Depending on the distance from sewage outputs, the mean values in late autumn and winter during years 1986-1988 have been (mg m^{-3}):

PO,-P	20......40
tot P	30......50
NO,-N	350.....450
tot N	1200.. ..1800
SiO_4-Si	500.....700

The clear decreasing trend for phosphorus compounds in 1979-1988 can be estimated (about 2 - 3 mgP $m^{-3}a^{-1}$).

In the Luga, Vyborg and Koporie bays the nutrients content has been approximately on the same level.

In the "deep area", where the winter observations are missing, during late autumn the concentrations of the nutrients have been (mg m^{-3}):

PO,-P	20......30
tot P	25......50
NO,-N	100.....300
tot N	400.....800
SiO_4-Si	300.. . ..400

The level of heavy metals can be characterized by following values ($\mu g\ l^{-1}$):

- Neva Bay

  Cd from < 0.4 (analytical limit) to 1.2
  Hg from < 0.05 (analytical limit) to 0.5
  Cu from < 0.4 (analytical limit) to 10
  Pb from < 4 (analytical limit) to 10

There are some cases, when the mentioned levels have been exceeded, e.g. in October 1982 by Hg (more than 2 $\mu g\ l^{-1}$); in August 1987 by Cu (more than 30 $\mu g\ l^{-1}$); in summer months in 1984 by Pb (more than 50 $\mu g\ l^{-1}$).

In the Vyborg, Koporie and Luga bays the typical level of heavy metals has been the same, but in November 1988 extraordinary high values were measured in all bays (as well as in the "deep area"). It seems to be a methodological error.

The mean concentrations in the "deep area" have been slightly lower than in the bays:

Cd	< 0.4....0.8
Hg	< 0.05...0.3
Cu	< 0.4....7
Pb	< 4.....10

The concentration of petroleum hydrocarbons has been determined using IR-spectroscopy and the data are not comparable with BMP data.

In the Neva Bay the concentrations have been mostly less than the detection limit 0.08 mg l^{-1}, but values up to 0.20 can be found too. Extraordinary high (> 2 mg l^{-1}) concentrations of PHC have been observed in some cases (August 1981, March 1985) at single stations.

In the "deep area" the PHC is nearly always less than 0.08; only three observations have the values of 0.13...0.14 mg l^{-1}. The same can be concluded for the Vyborg, Luga and Koporie bays. Only in the Vyborg port area there are three cases of high PHC level: Feb. 1986 0.50; Sep. 1986 0.44 and 4.2 (!) in Feb. 1984.

The analytical limit for phenols determining is 0.003 mg l^{-1} (since 1986). In the whole Eastern Part of the Gulf of Finland the measured values have been between this limit and 0.008 mg l^{-1}. An exception is the Leningrad port area, where the phenols concentration 0.010 - 0.015 has been often observed.

5. HYDROBIOLOGY

In the deep-water stations in the Eastern Part of the Gulf of Finland as well as in the mouths of Koporie and Luga rivers the chlorophyll *a* concentrations exceeded 20 mg m^{-3} during the vernal diatom blooms. In summer period the chlorophyll *a* content increases in the shallow-water stations to 50 mg m^{-3} and decreases in the deep-water stations. The same relations continue in October by maximum concentrations of about 10 mg m^{-3}.

In the freshwater inflow areas the diatoms ***Diatoma elongatum*** and ***Melosira islandica ssp. helvetica*** dominate in spring. The highest values of abundance (to 10' cells l^{-1}) and biomass (to 10 mg l^{-1}) were measured in the deep-water stations and in the mouth of Luga River.

In August the phytoplankton reaches annual maximum in shallow-waters by dominating of small flagellates, blue-green and green algae. In autumn the freshwater diatoms reappear. As before, the shallow-water areas have more abundant phytoplankton.

In the Neva Bay in spring period the content of chlorophyll ***a*** is somewhat higher in the southern part. In summer it is not possible to distinguish different parts due to large varying of concentrations. Nevertheless, according to maximum values measured in the southern and south-eastern parts (to 60 mg m^{-3}) the processes of eutrophication there seem to be quicker than in the other parts of the bay.

Neva Bay has a lake-type phytoplankton. In spring the phytoplankton abundance varies from 10^4 to 10^7 cells l^{-1} and biomass from 0.1 to 10 mg l^{-1} (due to very uneven development of vegetation). In that time the diatoms ***(Melosira islandica ssp. helvetica, Diatoma elongatum, Asterionella formosa)*** and ***Xanthophyceae v. Heterocontae Tribonema depauperatum*** dominate.

In summer there is a rich phytoplankton species composition by lacking of distinct dominants. Almost all groups of phytoplankton are represented. The values of abundance fluctuate about 10^6 cells l^{-1}, except in 1986, when in the southern part of the Neva Bay those numbers reached 5.5×10^7 cells l^{-1}. In October small cryptomonads and ***Melosira islandica ssp. helvetica*** dominate. There cannot be distinguished different parts according to quantitative characteristics. Still, in the southern part the role of *Euglenophyta* seems to be more important. Algae of this group are known as inhabitants of eutrophicated waters.

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THE STATE OF THE ESTONIAN COASTAL WATERS IN THE 1980s; GENERAL CONCLUSIONS

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1. INTRODUCTION

The present document is based on the latest relevant scientific papers (see references) and results of observations carried out in the Estonian coastal sea areas mostly by Estonian Hydrometeorological Service. The land-based pollution load has been estimated using data obtained from National Board of Waters, Ministry of the Environment.

2. THE GULF OF FINLAND

As regards the whole Gulf of Finland, Estonia is responsible for ~ 15 % of the total land-based load of nutrients (1 400 t of phosphorus (17 %) and 23 000 t of nitrogen (13 %)) and for 19 % of the organic load (76 000 t as BOD,) into the gulf. These values are comparable with analogous data from Finland and are considerably smaller than corresponding figures obtained in Neva-Leningrad region.

Of land-based pollution load 20 % of nitrogen, 35 % of phosphorus and 44 % of BOD originate from point-sources located on the coast: towns Tallinn, Kohtla-Järve, Sillamäe (including industry). Among rivers the most important polluter is the Narva River with town Narva in its lower course - about 40 % of all mentioned ingredients.

The state of the coastal sea is determined not only by local pollution sources, but also by the background level of the open part of the Gulf. It is important to underline the fact that during last 14 years there was no notable inflows of saline, but oxygen-poor bottom waters from the Northern Baltic Proper into the Gulf of Finland. As the result the oxygen conditions in deep (70-100 m) layers have been improved; salinity has been decreased in all layers, but more rapidly in bottom waters. Thus, the vertical density gradient between different water layers is decreasing and the intensity of the mixing processes increases. The large nutrient deposits in the bottom layers can be transported to the surface thus increasing the danger of eutrophication. The upwelling phenomenon, frequently observed at the Estonian coast during eastern winds, can be mentioned as one mechanism for vertical transport.

Until 1984 a remarkable positive trend in nutrient concentrations has been noted in the Gulf of Finland (as well in the whole Baltic Sea). During last five years the phosphorus content has remained at relatively high level, but the winter nitrate concentrations are continuously increasing.

Fig. 1 indicates the temporal changes of NO,-N concentrations in the surface (a) and bottom **(b)** layers in 19751989. From the surface layer data the seasonal variability is eliminated using Fourier coefficients with periods 1; 0.5 and 0.33 years.

The most polluted areas in the Estonian coastal waters **(summarized** inorganic nitrogen is used as indicator) are represented in Fig. 2.

2.1. The **Narva Bay and Sillamäe- Kohtla-Järve industrial region**

The major pollution source in the region is the Narva River (including the discharges from Narva): 35 000 t BOD,, 9 200 t NO,-N, 670 to tot-P and 91 700 t of suspended solids annually. The estimated load from industry (Oil-shale Chemistry Production Association in **Kohtla-Järve,** Chemistry-Metallurgic Production Association in Sillamae) is considerably smaller, but special ingredients like phenols, benz(a)pyrene etc. have been found in the sewage. The leaking from the dumping sites of untreated waste water in Sillamae contains large amounts of nitrogen (discharge ~ 5 000 t N annually during last two years).

The concentrations of the nutrients in the sea water in this region are in winter 2-4 times higher than in the central part of the Gulf: the inorganic nitrogen $(NO_3+NO_2+NH_4)$ 150 to 200 $mgN\ m^{-3}$, the phosphate 25-30 $mgP\ m^{-3}$.

On the basis of episodical observations of the concentrations of heavy metals it can be stated that their content in coastal waters may be 2-3 times higher compared to that of the open Gulf. For example, in the Narva River the following mean concentrations have been measured (μg/l): Cu 4.4; Pb 1.5; Cd 0.29; Hg 0.02. These figures are much higher than typical values in the sea water. It is impossible at present to explain any temporal trend or regional differences in the heavy metal concentrations because they are masked by natural variability and inaccuracies during sampling and analysis.

The concentrations of heavy metals in biota are thousands times higher. As an example typical values for these concentrations in the plankton organisms in the Gulf of Finland are (mg/kg): Cu 25; Pb 16.5; Cd 1.3; Zn 340. The concentrations increase, in general, from west to east and from open part to coastal areas.

The macrophytobenthos in this area is greatly influenced by human activity. In some parts in the Narva Bay vegetation is completely lacking, which is most likely due to the immediate harmful effect of industrial waste water. Remarkable changes have taken place in the floristic composition and biomass, as well as in the morphological properties of the algal thallus. In connection with increasing eutrophication, changes in species composition take also place, the role of some species in communities decreases and they may finally completely disappear, and are replaced by other species, preferring strongly eutrophic waters.

The mean values of chlorophyll a concentrations in the Narva Bay during summer months are similar to the levels in the open part of the Gulf (2-3 mg m^{-3}) and it is impossible to indicate any trend in this data collection.

The dominating phytoplankton species in spring are diatoms ***Achnanteles taeniata, Diatoma elongatum*** and others. During blooms the biomass can be as high as 10 mg l^{-1}. During summer months the dominating group is blue-green algae ***(Aphanizomerwn flos-aquae*, *Microcystis aeruginosa, Oscillatoria spp.). The*** biomass is varied from 0.1 to 10 mg l^{-1}, depending on the strength of the late-summer blooms. In autumn the fresh-water diatoms ***Melosira, Stephanadiseus*** et al. and blue-green algae are dominating with low biomass ~ 1 mg 1“ (exceptionally 10 mg l^{-1} in 1988).

There are reported some cases, when fish having unpleasant odor and taste of phenols have been caught in this area.

2.2. The **Tallinn Bay**

The municipal and industrial waste waters of Tallinn are discharged after mechanical-chemical treatment via the sea outlet directly into the sea. Until 1990, the industrial untreated waste water from the Pulp and Paper Mill was discharged into the sea near the Passenger Port; at present the Mills sewage is discharged into city sewer system. The total load placed on the bay has been estimated to be 30 000 t BOD,, 3 800 t N, 350 t P annually. The water quality near the coastline is also influenced by the Pirita River and some stormwater outlets.

The nutrient concentrations in sea water are relatively high in the inner part of the bay (between the Passenger Port and Pirita beach), which is the most polluted region of the bay.

The mean values for nitrogen compounds are: higher than 200 μg/l NH,-N (indicator of recent domestic pollution!), 10-15 μg/l NO,-N and 70-80 μg/l NO,-N. In the open part of the Tallinn Bay these concentrations are 3-4 times lower. All the nitrogen compounds have indicated a slightly increasing trend during 1984-1990. The distribution of the phosphate concentrations is analogous: 15-20 μg/l in the inner part and 10 μg/l PO,-P in the open part of the bay, the trend, although low, is decreasing. In the narrow coastal zone (l-2 km) the values of BOD, higher than fishery standards (3 mgO_2/l) have been observed. The sources of organic pollution were the River Pirita and the outlet of the pulp and paper mill. During some winters (e.g. 1987) the oxygen disappearance under the ice cover in the same region has been noted.

There are only episodical analyses of heavy metals and chlororganic compounds in the Tallinn Bay. It can be estimated that the concentrations of the hazardous substances (excluding DDT) in the seawater and in biota of the bay are 3-4 times higher than in the open part of the Gulf of Finland. Some typical values for the Tallinn Bay water: heavy metals (μg/l): Cu 3.2; Pb 2.0; Cd 0.23; Hg 0.04; chlororganic compounds (ng/l): DDT 0.16; PCB 6.

The bottom vegetation is now practically completely absent in the southern part of the Tallinn Bay. Some species, described near Kadriorg (the southern tip of the bay) earlier, are now found in the open parts only. The area of *Fucus vesiculosus* has been considerably reduced since the species are replaced by ***Cladophora glomerata*** and ***Ceramium tenuicoma. Elachista fucicola***, a typical epiphyte on ***F. vesiculosus,*** has been found to have already disappeared in slightly polluted areas. When in moderately polluted areas of the Tallinn Bay one can meet 6 species of green algae, 2 species of brown algae and 1 species of red algae, these figures are 6, 8 and 7, respectively for its open part.

The chlorophyll ***a*** concentrations observed in the Tallinn Bay have the maximum values during spring months (10 mg m^{-3} and higher). In summer and autumn the concentrations do not exceed 1 mg m^{-3}. The species composition of the phytoplankton in the Tallinn Bay is similar to that in the western Gulf of Finland. Nevertheless, in some spring blooms the fresh-water ***Diatoma elongatum*** dominated. The maximum biomass has been observed usually in the central part of the bay, minimum in the western part (the Kopli Bay). During summer months the phytoplankton distribution is homogeneous, the biomass l-5 mg l^{-1}. In autumn the role of blue-green algae decreases and diatoms ***Skeletonema costatum*** and ***Thalassiosira baltica*** with low biomass values (- 1 mg 1“) dominated.

3. THE GULF OF RIGA

The total pollution load on the Gulf of Riga has been estimated as a first approximation only. Therefore the role of Estonia in the pollution of the Gulf can be presented as a rough estimation.

The point-sources located on the coast are towns Pärnu, Haapsalu and Kuressaare, as well as some small fish processing factories and fish-farms. The amount of Estonian annual land-based pollution load discharged into the Gulf of Riga and percentage from the total load can be characterized by the following figures: 8 000 t BOD, (12 %), 20 000 t of suspended solids (7 %), 10 000 t NO,-N (20 %) and 100 t PO,-P (7 %). The contribution of Estonia to the nitrogen load seems to be overestimated or underestimated for Latvia. From the Estonian point of view the situation in the Gulf of Riga is similar to that in the Gulf of Finland, where the major polluter is somebody else - Riga and Leningrad, respectively. Regardless of this fact it must be underlined that the state of pollution in the coastal areas is first of all depending upon local polluters. The great polluters located hundreds of kilometers from the area can influence the water quality in this case only, if the local water is excessively clean.

During last 10 years the following tendencies in the whole Gulf of Riga can be mentioned:

- the salinity is generally decreasing, the fresh-water run-off has been rather large during 1980s;
- the winter concentrations of total phosphorus and nitrate are increasing in the surface layer; the nitrate accumulation is roughly 70 times higher than phosphate;
- the oxygen concentrations in all the water layers in the central part of the gulf show significant negative trend; the trend coefficient is higher in the near-bottom layer;
- the heavy metal concentrations in plankton organisms in the Gulf of Riga are lower than these in the Gulf of Finland and in the Baltic Proper for Cu, Pb and Zn; only Cd concentrations are 4-5 times higher.

3.1. The Pärnu Bay

The Pärnu Bay is the most polluted area at the Estonian coast of the Gulf of Riga. Until 1990 only the mechanical treatment of domestic and industrial sewage existed; part of the sewage has been directed into the River Pärnu or into the sea untreated. For last 3 years the previously internationally well-known swimming beach was closed due to microbiological pollution. Valid in Estonia USSR standard Coli index for sea water for swimming is 25 000. In summer the Coli index in the Bay exceeded 1 000 000. The nutrient concentrations in sea water are high and the positive trend can be seen for both nitrogen and phosphorus compounds. As an exception, the silicate has also increasing trend in the bay (silicate concentrations have been decreasing in all regions of the Baltic Sea but are on stable level in the surface layer of the open part of the Gulf of Riga).

The bottom vegetation in the northern part of the bay is suppressed above all by bad light conditions, the Secchi disk transparency of the water often being less than 1 m. The shading effect is caused by a high content of seston, mainly of bottom particles. It was established that the area lacking vegetation is increasing. The general trends have definitely been established in species composition - a decrease in the number of species of charophytes, brown and red algae, and an increase in the number of species of blue-green algae.

The concentrations of the chlorophyll ***a*** have been as high as 20 mg m^{-3} or higher in spring and up to 15 mg m^{-3} in autumn. Among the phytoplankton species diatoms are the dominating group in spring; in summer - blue-green algae ***(Aphanizomenon flos-aquae)***, in autumn - both of them.

3.2. The **other polluted areas**

The Haapsalu Bay is very shallow and badly connected with the open sea. Domestic and industrial (food processing) waste waters have been discharged after mechanical purification into the inner part of the bay, which is strongly eutrophicated. In winter the oxygen is often lacking under the ice cover. In the outer part of the bay the nutrient concentrations are lower, but the microbiological pollution is so high, that swimming beach at Paralepa has been closed for last two summers. The bottom flora and fauna are strongly affected by pollution.

The Matsalu Bay is also very shallow and the seawater quality is influenced by the Kasari River runoff. The pollution load from river is estimated to be annually 2 000 t BOD,, 3 000 t N and 60 t P as diffuse pollution from agriculture. More than half of the bays surface is covered by ***Phragmites australis*** communities and the normal phytobenthos is lacking. The high level of heavy metal (Hg) concentrations have been measured in some pikes caught in the Matsalu Bay.

The Kuressaare Bay at the southern coast of Saaremaa Island is under the influence of untreated domestic and milk-meat industrial waste waters from the town Kuressaare (annual load 1 000 t BOD,, 100 t N, 10 t P). The bay was largely used as a recreational area before the Second World War. At present the water in the bay is heavily polluted by organic substances (BOD_7 values higher than 3 $mgO_2\ l^{-1}$), nutrients and bacteria. The bottom vegetation has changed.

As an example for the whole area of the Gulf of Riga the drastical diminishing of the *Fucus vesiculosus* in all coastal waters, including regions with relatively clean waters, can be mentioned. *Fucus* has largely been used by the Estonian coastmen as a good fertilizer. The first victims of toxic blue-green algae *Nodularis spumigena* in Estonia were registered during the summer bloom of 1983 - three heifers that had been drinking sea water at the north-east coast of Saaremaa.

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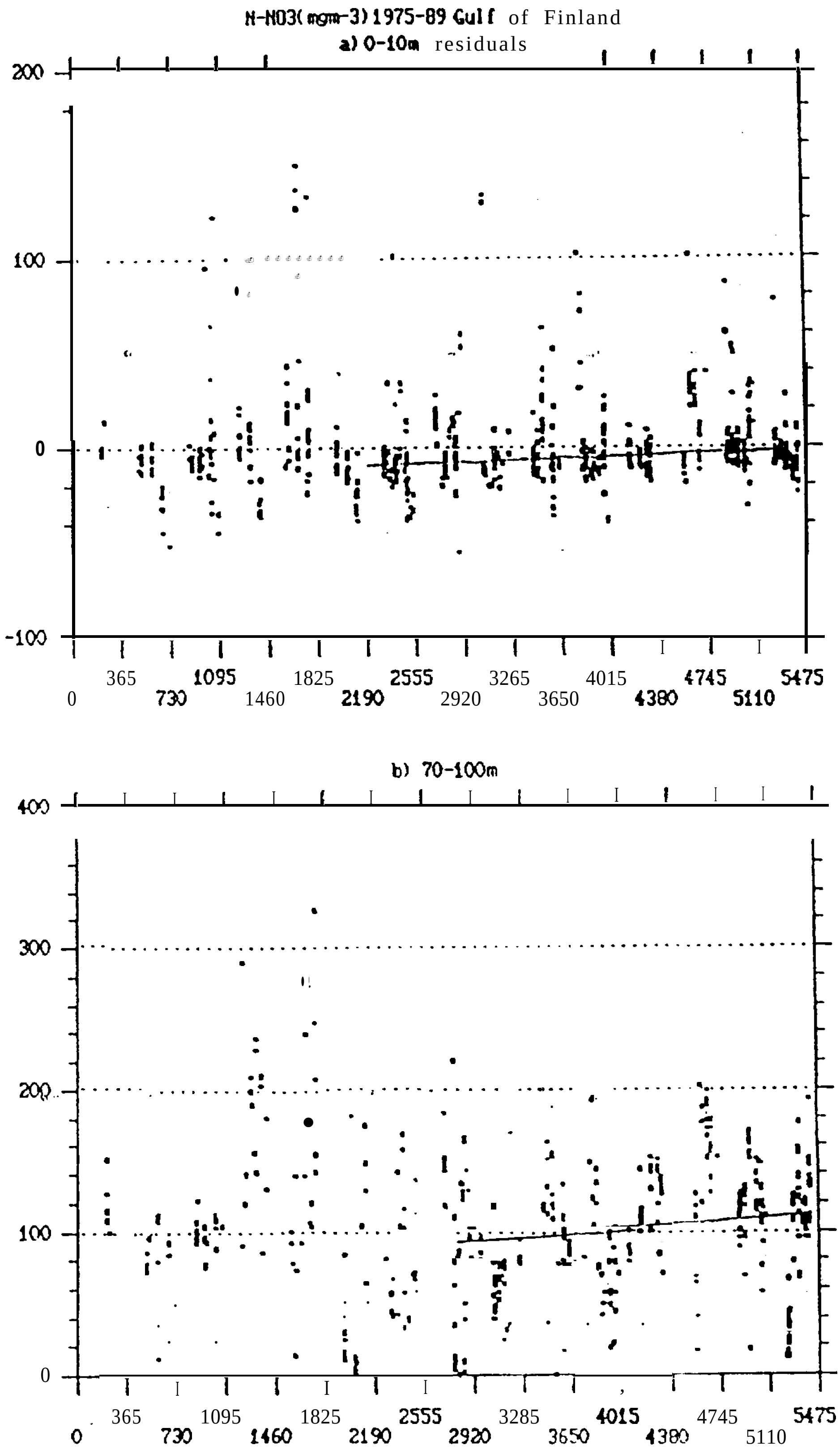

Fig. 1. Nitrate concentrations in the surface (a) and bottom (b) layers of the southern part of the Gulf of Finland. Time scale in days: from (a) the seasonal variability is eliminated.

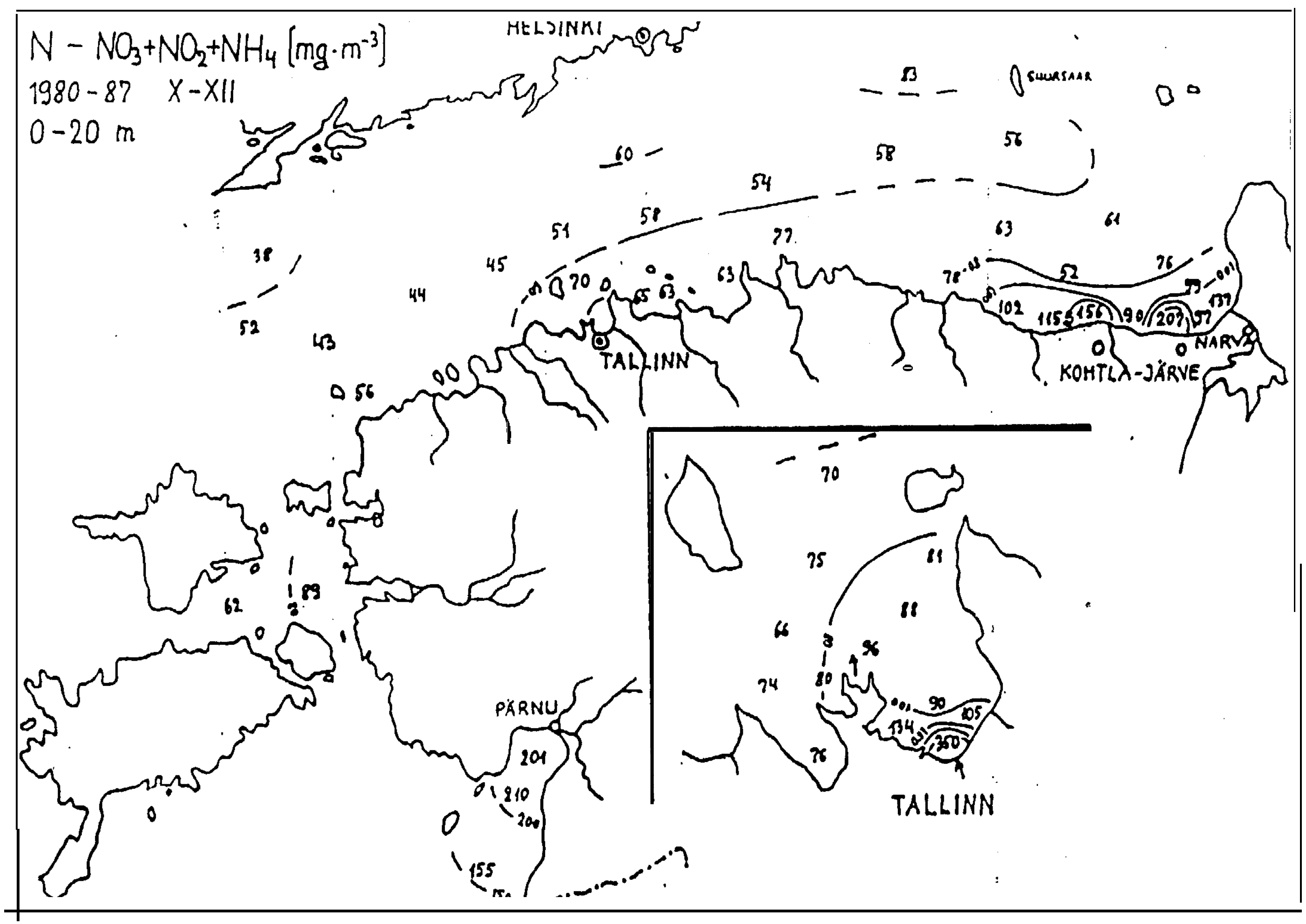

Fig. 2. Distribution of inorganic nitrogen in Estonian coastal waters (winter long-term means).

THE STATE OF THE COASTAL WATERS OF THE GULF OF RIGA IN THE 1980s; GENERAL CONCLUSIONS

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1. INTRODUCTION

The present document is based on the results of observations carried out within the USSR national monitoring programme by Latvian Hydrometeorological Service. There are 13 stations in the open part and 16 stations in the coastal regions of the gulf, mainly near the estuaries of the Daugava and Lielupe rivers. The sampling frequency for hydrography and hydrochemistry is 4 times a year in general. For comparisons also data collected and interpreted by Baltic Fishery Research Institute have been used.

2. GENERAL CHARACTERISTICS

The Gulf of Riga is a semi-closed, shallow reservoir, which is connected with the open sea by the Irben Strait (maximum depth is 10 m). The area of the gulf is 17 913 km^2 with the drainage basin of 127 400 km^2. The mean depth is 23 m, maximum 51 m. River inflow into the gulf is 23 $km^3 a^{-1}$ (1).

Hydrological regime of the Gulf of Riga differs from the open sea hydrological regime by increased ratio of rivers outflow to water volume (7.3 %) and by peculiarities of water mass stratification. In the warm half of a year (from May to October) a two-layered stratification prevails, and variations in temperature, salinity and dissolved oxygen in the upper and near-bottom layers (30.. .50 m) are of different intensity, the trends of variations in these layers are often contrary. In the cold half of a year water masses of the Gulf of Riga are mainly vertically homogeneous.

Salinity of the Gulf of Riga changes from 0.5 PSU in spring on the surface near the Daugava mouth to 7.5 PSU near the bottom of the Irben Strait in spring and summer. As in the whole Baltic Sea, the decreasing trend in salinity has been observed in the gulf during last 15 years. This trend is masked by high salinity in 1984 and 1985, caused by local saline water inflows through the Strait of Irben (2).

3. POLLUTION LOAD

The total pollution load on the Gulf of Riga, as estimated in NOPEF study (3) (1989), is ($t\ a^{-1}$): 61 400 of BOD,; 322 000 of suspended solids; 48 500 of NO_3-N and 1 800 of PO,-P. The major pollution sources are the Daugava and Lielupe rivers, which contribute more than 60 % of total pollution. From the discharges of Riga, situated at the mouth of the Daugava River, only 10 % are treated biologically, 26 % mechanically and 64 % of waste waters is discharged into the river without any treatment.

4. HYDROCHEMISTRY

Oxygen conditions in the surface layer at all (including polluted) areas of the Gulf of Riga are normal. In spring at the maximum of phytoplankton bloom oxygen content increases to 13.5 ml l^{-1} (160 % of saturation). In the bottom layers (40-50 m) of the central part at the end of autumn the oxygen content often decreases to 10 % of saturation.

The long-term (1963-1986) negative trend, mentioned in near-bottom water layer by V. Berzins (4), cannot be identified using data of 1979-1988.

Nutrients have been measured in the central part three times a year only; the winter observations are missing. According to Yurkovskis and Mazmachs (5) the winter concentrations of total phosphorus and nitrate have been increasing in the surface layer during 1972-1989. The nitrate accumulation is roughly some tens of times higher than for phosphate.

During the vegetation period the typical values in the central part of the gulf are:

- surface layer	PO,-P	2.....6 mg m^{-3}
	NO,-N	10....20 mg m^{-3}
- bottom layer	PO,-P	10....20 mg m^{-3}
	NO,-N	60.. .120 mg m^{-3}

The significant positive trend in both phosphate and nitrate concentrations can be identified in all layers. The concentrations of phosphate equal to analytical zero, often measured in summer until 1984, are missing in last years. In August 1987 very high concentrations of PO, (9-10 mg m^{-3}) in the surface layer have been observed in all central stations of the gulf.

The mean silicate concentrations in the surface layer are 100-200 mg m^{-3} and no trend can be seen during last 10 years. In deep water the decreasing trend is described (5).

In the coastal area near the mouths of the great rivers (Daugava, Lielupe, Gauja) the observations have been made more frequently (up to 12 times a year) and more variables have been determined. Typical values for nutrients in the mouth of the Daugava River during last 5 years are:

- in winter	PO,-P	60....80 mg m^{-3}
	tot P	> 100 mg m^{-3}
	NO,-N	> 1000 mg m^{-3}
	tot N	> 3000 mg m^{-3}
	SiO_4-Si	~ 2500 mg m^{-3}
- in summer	PO,-P	25.. ..40 mg m^{-3}
	tot P	50.. ..70 mg m^{-3}
	NO,-N	200... 500 mg m^{-3}
	tot N	1400.. 1600 mg m^{-3}
	SiO_4-Si	600... 900 mg m^{-3}

The clear increasing trend for all P and N compounds has been identified. The estimated values of trend coefficients are so high as 4 mg $m^{-3}a^{-1}$ for tot P and 90 mg $m^{-3}a^{-1}$ for tot N. At 3 miles from the river mouth all the nutrient concentrations are, in general, two-three times lower, at 6 miles form 4 to 6 times.

The level of heavv metals in the mouth of the Daugava River can be characterized by following values (mg l^{-1}): Pb 0.3 - 1.2; Cu 1 - 6; Hg 0.002 - 0.07; Cd 0.01 - 0.39. In the central part of the gulf the corresponding values are: Pb 0.00 - 0.05; Cu 0.3 - 3; Hg 0.000 - 0.05; Cd 0.00 - 0.10.

Petroleum hydrocarbons are determined using IR-spectroscopy. The mean level of PHC concentration in Daugava River is 0.02 - 0.25 $\mu g\ l^{-1}$; at 3 miles 0.01 - 0.08 and in the central part of the gulf 0.00 - 0.06 $\mu g\ l^{-1}$.

5. HYDROBIOLOGY

In spring period the chlorophyll a content varies within large ranges (2-20 mg m^{-3}), the maximum concentrations were measured in estuarine waters of Daugava, Lielupe and Gauja rivers. Also in summer similar distribution of chlorophyll a concentrations were observed except in the offshore stations, where the content is somewhat lower as in spring. In autumn the maximum values (5-15 mg m^{-3}) were obtained in mouths of rivers, which refers to eutrophication.

In May the distribution of the diatoms ***Achnanthes taeniata, Melosira ssp.*** and also ***Diatoma elongatum*** in coastal zone is characteristic. In Pärnu Bay also ***Chaetoceros spp.*** and dinoflagellate ***Gonyanlax catenata*** dominate at the same time (6). Maximum abundance was obtained in the offshore areas and in the mouth of Gauja River. In the estuarine waters of Daugava and Lielupe rivers the phytoplankton was backward.

In summer the blue-green algae *Aphanizomenon flos-aquae* reaches absolute maximum in the open part of the gulf, while the freshwater diatoms (*Melosira, Cyclotella*) and green algae dominate in the near-shore areas. The highest values of abundance and biomass are counted in the mouths of Daugava and Lielupe rivers: to 10' cells l^{-1} and 10 mg l^{-1}, respectively. In October the diatom ***Cosinodiscus granii*** and small flagellates (*Cryptomonas* and *Pyramimonas*) co-dominate.

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THE STATE OF THE COASTAL WATERS OF THE WESTERN COAST OF LATVIA, LITHUANIA AND KALININGRAD REGION IN THE 1980s; GENERAL CONCLUSIONS

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1. INTRODUCTION

The present paper is based on the results of observations carried out within the USSR national monitoring programme by the Lithuanian (Kura and Visla bays) and Latvian (ports Liepaja and Ventspils) Hydrometeorological Services. There are 17 stations in the Kura Bay, 13 in the northern (Soviet) part of the Visla Bay, 7 stations near the Liepaja port and 2 in Ventspils port area. The samples have been collected once a month in 12 stations in the Kura Bay and in 11 stations in the Visla Bay and in 2 - 7 stations near ports Ventspils and Liepaja. In practice lots of observations in winter months are missing.

2. GENERAL CHARACTERISTICS

The Kura and Visla bays are almost closed estuarine areas, separated from the open Baltic Sea by Kura and Baltic spits, correspondingly. The dominating depths are less than 10 m. Salinity changes from zero in the river mouths to 7 - 8 PSU in the "gates" of the bays. The main rivers, discharging into the bays are Nemunas (18.2 km^3a^{-1}), Deima and Matrosovka (Kura Bay) and Pregolia as a waste water collector of the town Kaliningrad (Visla Bay).

The near-shore area to the north from Klaipeda, where the ports Liepaja and Ventspils are situated, has a good connection with the open sea without any shallows or reefs. The salinity of the surface layer in this area is 6 - 8 PSU.

3. POLLUTION LOAD

The pollution load on the Kura and Visla bays (1) can be estimated by following values (t a-‘):

- Kura Bay

BOD,	137 000
NO,-N	24 000
PO,-P	450
Susp. solids	470 000

- town Klaipeda

BOD	8 900
tot N	1 400
tot P	80
Susp. solids	6 650

- Visla Bay - from the Kaliningrad region (partly into the Kura Bay)

BOD	92 400
tot N	6 730
tot P	1 860

Open coast

the Venta River

BOD,	5 000
NO,-N	4 540
PO,-P	137
Susp. solids	35 800

town Ventspils

BOD,	70
tot N	121
tot P	22.5
Susp. solids	100

town Liepaja

BOD,	1 800 (?)
tot N	299
tot P	29
Susp. solids	1 800

4. HYDROCHEMISTRY

Oxygen conditions in the Kura Bav have been normal (more than 100 % of saturation) in spring, but the minimum can be mentioned in August (50-60 % in the southern part of the bay and 70-90 % of saturation near the "gates" of the bay). In the Visla Bay near the mouth of the Pregolia River the oxygen content has been terribly low during summer months. The absence of the oxygen has been mentioned in 1979, 1982 and 1983 summers too, but in 1988 the zero-level of oxygen has been observed during the period from May to November. The concentration of H_2S has been as high as 1.0 mg l^{-1} (in the surface layer !). In the other parts of the bay the oxygen conditions due to mixing with seawater have been generally normal (more than 100 % of saturation in spring, slightly less in summer). In the open coastal areas (ports Ventspils, Liepaja and near Palanga) the oxygen conditions have been normal.

Nutrients

In the Kura Bav the most polluted areas are the south-east part (near the mouths of the rivers Deima and Matrosovka), the mouth of the Nemunas River and the area close to the Klaipeda port. The western part of the bay near the Kura spit has been relatively clean.

It is impossible to find any reliable trend in nutrient concentrations in the Kura Bay during last 10 years. The following mean values of nutrients can characterize the pollution situation in the Kura Bay (mg m^{-3}):

	NO,-N	PO,-P	tot P
a) summer			
- western part	< 10...100	0 . . . 10	40.. ..80
- the gate to the bay	10...100	5 . . . 10	20....50
- near the mouth of the Nemunas River	10...100	5 . . . 15	40....60
- near Klaipeda	3 10	3 . . . 15	40....60
- near the mouth of the Deima River	40...100	30...60	50...100
b) autumn & winter			
- western part	400...600	40...80	100...160
- the gate to the bay	150...250	40...80	60...120
- near the mouth of the Nemunas River	200...300	30...60	80...120
- near Klaipeda	250...400	40...60	80...140
- near the mouth of the Deima River	250...400	80..100	140...220

In the Visla Bay the role of the Pregolia River as the main source of pollution can be seen in the distribution of nutrient concentrations also. Because the winter observations are missing, the late autumn and early spring data have been used for following conclusion.

The PO,-P concentrations have been changed from 100-200 mg m^{-3} in the mouth of the Pregolia River to 20-50 mg m^{-3} in the center of the bay and to 40-90 mg m^{-3} in the Baltic Strait. The tot P concentrations changed from ~ 200 mg m^{-3} to 30-60 and to 50-100 mg m^{-3}, correspondingly. The NO,-N concentrations have been (in the same order): ~ 300, 50-200 and 140-200 mg m^{-3}.

Near Ventsnils in the stations of 5 m depth the following mean nutrient concentrations in winter have been measured (mg m^{-3}): PO,-P 20-40; tot P 40-70; NO_3-N 800-1000; tot N 2000-4000; SiO_4-Si 1000-1500. The concentrations of nitrogen compounds are unusually high, but measured near-zero values in summer indicted the correct methodology of observations.

During 1979-1986 the concentration of nitrogen has increased, in 1986-1988 decreased. In the phosphorus compounds as well as in the silicate concentration the slightly increasing trend can be observed.

Near the Liepaja port the characteristic values for nutrients in late autumn have been (mg m^{-3}): PO,-P 10-30; tot P 30-40; NO_3-N 200-500; tot N 1000-1500; SiO_4-Si 500-1000. The long-term changes have been analogical to them in the Ventspils area, but the silicate content seems to be stable during last 10 years.

From heavy metals in the Kura Bay only Hg content has been observed. In 1980 high concentrations have been measured in the whole bay area (0.10 - 0.30 $\mu g\ l^{-1}$). during other years the concentrations less than 0.10 $\mu g\ l^{-1}$ have been prevailed.

In the Visla Bay very high concentrations of Hg have been observed at the mouth of the Pregolia River (0.66 $\mu g\ l^{-1}$) and in the Baltic Strait (2.02 $\mu g\ l^{-1}$), in other years the content has been < 0.10 $\mu g\ l^{-1}$.

Near Ventspils and Liepaja the typical heavy metal concentrations have been ($\mu g\ l^{-1}$): Pb 0.1 - 0.8; Cu 0.4 - 6.0; Hg 0.002 - 0.10; Cd 0.06 - 0.50.

The IR-spectroscopy has been used to determine the petroleum hydrocarbons (PHC) content. In the Kura Bay the PHC has been distributed roughly homogeneously over the area with characteristic values of 0.02 - 0.10 $\mu g\ l^{-1}$. In 1983 values up to 0.54 $\mu g\ l^{-1}$ have been observed near the Klaipeda port and up to 0.18 $\mu g\ l^{-1}$ in the other parts of the bay.

In the Visla Bay the PHC concentrations have been from 0.02 to 0.15 $\mu g\ l^{-1}$; at the mouth of the Pregolia River from 0.02 to 0.30 $\mu g\ l^{-1}$. In summer 1982 and 1987 the bay was polluted by PHC - the content has been measured in the whole bay 0.13 - 0.28 $\mu g\ l^{-1}$.

Near Ventspils and Liepaja ports the typical value of PHC concentration has been less than 0.05 $\mu g\ l^{-1}$. Some cases of higher concentration have been observed nearly every year.

5. HYDROBIOLOGY

Regular measurements of chlorophyll a in the Kura Bav were carried out from 1986. The maximum concentrations were obtained in the southern part of the bay and at the mouth of the Matrosovka River ($>$ 100 mg m^{-3} in spring and summer and about 50 mg m^{-3} in autumn).

The annual maximum of phytoplankton coincides with the blue-green (*Aphanizomenon flos-aquae, Microcystis spp.)* and green algae *(Scenedesmus communis)* blooms in July-August. Already in spring period the phytoplankton abundance reaches up to 10^6 - 10' cells l^{-1}.

Freshwater diatoms ***Diatoma elongatum, Stephanodiscus hantzschii, Asterionella formosa, Melosira islandica*** and ***Cyclotella comta*** dominate. In August 1986 the maximum concentrations were found in the southern part of the bay, near the mouth of the Matrosovka River (**$4.2x10^8$** cells l^{-1}) were obtained in central and northern parts by abrupt decreasing of abundance in the southern part of the bay. In spring period the freshwater diatoms were dominating. Once, in the year 1984 the mass occurrence of green algae ***Geminellopsis fragilis*** was noted.

According to chlorophyll and phytoplankton data the Kura Bay has the most unbalanced ecosystem.

Near the harbours of Liepaja and Klaipeda the chlorophyll ***a*** concentrations reached 100 mg m^{-3} in spring and more than 10 mg m^{-3} in summer. In autumn the content was low for the whole area (2 - 4 mg m^{-3}).

In several springs the phytoplankton biomass values reached 10 mg l^{-1} near Liepaja, Ventspils an Baltiysk. The list of dominant species differs by years. Both in offshore areas and estuarine and coastal waters the diatoms ***Skeletonema costatum, Achnantes taeniata*** and ***Chaetoceros spp. are*** dominating. In addition the freshwater diatoms ***Cyclotella spp.*** and ***Diatoma elongatum*** dominate in coastal zone. The role of dinoflagellates ***(Gonianlax, Protoperidinium*** and ***Glenodinium)*** has also increased during last years.

In summer period, by dominating blue-green (*Aphanizomenon flos-aquae*, ***Anabaena spp, Gomphosphaeria lacustris***) and green algae ***(Scenedesmus communis)***, the abundance of phytoplankton is greater in the near-shore areas. In the open waters the small flagellates are also abundant.

In autumn all quantitative values of phytoplankton decrease, a distinct domination cannot be observed.

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