BALTIC SEA ENVIRONMENT PROCEEDINGS

No. 35 A

SECOND PERIODIC ASSESSMENT OF THE STATE OF THE MARINE ENVIRONMENT OF THE BALTIC SEA, 1984 – 1988; GENERAL CONCLUSIONS

BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION
– HELSINKI COMMISSION –

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SECOND PERIODIC ASSESSMENT OF THE STATE OF THE MARINE ENVIRONMENT OF THE BALTIC SEA 1984–1988; GENERAL CONCLUSIONS

CONTENTS **Page**

P R E F A C E

Within the framework of the Baltic Marine Environment Protection Commission -Helsinki Commission –, marine environment monitoring data have been collected since 1979. The guidelines for the programme agreed by all seven Baltic Sea States (Denmark, Finland, the German Democratic Republic, the Federal Republic of Germany, Poland, Sweden and the USSR) and the methodology are published by the Helsinki Commission every five years. The Third Stage of the Baltic Monitoring Programme (BMP) started in 1989 and the Guidelines were published in Baltic Sea Environment Proceedings (Nos. 27A, B, C, D). The monitoring data provided by all Baltic Sea States are stored and processed in the HELCOM Data Base established by the Commission on a consultant basis. The aim of the common data bank is to serve as a source of current information on the state of the Baltic Sea. The evaluation is published by the Commission as a comprehensive scientific overview and as general conclusions drawn on the basis of this scientific overview. The previous assessments were published in Baltic Sea Environment Proceedings Nos. 5A and 5B (1981) and Nos. 17A and 17B (1986/1987).

This document contains the summarised conclusions of the scientific material published as the Second Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1984-1988; Background Document in Baltic Sea Environment Proceedings No. 35B. The group of experts established by the Commission for the preparation of this assessment (GESPA) has been chaired by Professor Sebastian A. Gerlach from the Federal Republic of Germany, who also acted as editor of the scientific background document (BSEP No. 35B). Experts from all Baltic Sea States have actively participated in the work of the group during 1987-1990, as well as representatives of the International Council for the Exploration of the Sea (ICES), the Baltic Marine Biologists (BMB), and the Conferences of Baltic Oceanographers (CBO).

The conclusions attached hereto were adopted by the last meeting of the expert group (GESPA 4), held 2-5 April 1990 in Sopot, Poland, and published as authorised by the eleventh meeting of the Helsinki Commission, held 13-16 February 1990 in Helsinki, Finland.

CONVENERS AND AUTHORS OF TEE SECOND PERIODIC ASSESSMENT OF THE STATE OF THE MARINE ENVIRONMENT OF TEE BALTIC SEA, 1984-1988; BACKGROUND DOCUMENT (Baltic Sea Environment Proceedings No. 35B)

The conclusions drawn in this document have mainly been based on the scientific results presented in the scientific background document, published in the Baltic Sea Environment Proceedings as a separate volume, No. 35 B.

The authors of the scientific chapters are the following:

Chapters	**Authors**
Introduction	Sebastian A. Gerlach ***
1. Hydrography	Villu Astok ** Wolfgang Matthäus * Vesturs Berzins Stig Carlberg Barbara Cyberska Juri Elken Wolfgang Lange Jouko Launiainen Avo Nõmm Ylo Suursaar Rein Tamsalu Timo Vihma
2. Oxygen, hydrogen sulphide, alkalinity, pH	Anna Trzosiiiska ** Matti Perttilä * Gunni Aertebjerg Vesturs Berzins Barbara Cyberska Stig Fonselius Hans Peter Hansen Dieter Körner Wolfgang Matthäus Dietwart Nehring Heye Rumohr
3. Nutrients	Dietwart Nehring ** Hans Peter Hansen * Leif Albert Jsrgensen Dieter Körner Mikelis Mazmatchs Matti Perttilä Anna Trzosiiiska Fredrik Wulff Aivars Yurkovskis

*** Editor
** Convener
* Co-convener

4. Pelagic Biology	Sigurd Schulz ** Juha-Markku Leppänen * Gunni Aertebjerg Gerda Behrends Giinter Breuel Ulrich Horstmann Kaisa Kononen Elena Kostrichkina Flemming Mshlenberg Olof Sandström Paulin Ciszewski Markku Viitasalo Torbjörn Willen
5. Zoobenthos	Ann-Britt Andersin ** Hans Cederwall * Fritz Gosselck Alf Josefson Gunars Lagzdins Jsrgen Nørrevang Jensen Heye Rumohr Jan Warzocha
6. Baltic fish stocks	International Council for the Exploration of the Sea (ICES), Janet Pawlak **
7. Micro-organisms	Klaus Gocke ** Anne Heinänen Karl-Otto Kirstein Modesta Maciejowska Alla Tsyban
8. Trace elements	Uwe Harms ** Lutz Brügmann *
9. Organic contaminants	Olof Svanberg ** Horst Gaul * Gerhard Dahlmann Mats Olsson

** Convener
* Co-convener

EXECUTIVE SUMMARY

The present assessment of the Baltic Sea Area concerning primarily the years 1984-1988 deals mainly with observations made in the open Baltic Sea and, consequently, the statements do not reflect findings in coastal areas, which will be assessed separately. In addition, a specific assessment on the state of Baltic sediments is in the final stage of preparation under the International Council for the Exploration of the Sea (ICES), which also prepares assessments on the state of Baltic seals on a regular basis. Furthermore, the document only occasionally covers information on the health of fish, birds and marine mammals.

Due to the ban in the use of some harmful substances, positive changes were observed; DDT and PCB concentrations in biota have decreased since the 1970s and are now on a lower and steady level, although comparable data on herring indicate that the levels are still higher in the Baltic than in the Skagerrak area. After the ban on technical hexachlorocyclo-hexane (HCH), the decrease of a -HCH concentrations in water is still continuing. Concentrations of organochlorine residues in fish from the Baltic Proper are still 3 to 10 times higher than in fish from around the Shetland Islands. Among the "new contaminants", there has been an increasing number of organic substances identified which are potentially harmful to the environment.

Trace element concentrations in fish and shellfish have not changed remarkably since the early 1980s. Generally, it can be stated that mercury concentrations in biota do not significantly differ now from those in the North Sea and the North-East Atlantic. Compared with actual background levels, elevated mercury concentrations were only found in the Øresund and in the southern Bothnian Sea. For the latter area, however, a considerable decrease of the concentrations could be identified during recent years.

A still upward trend of cadmium concentrations was observed in fish from the northern part of the Bothnian Bay. The reason for this is not fully understood. Other elements, such as zinc and copper, showed similar trends.

Fish and shellfish from sampling locations in the Kattegat and the Belt Sea showed tendencies for decreasing lead concentrations. It is possible that this is already an effect of the increased use of unleaded gasoline.

Meteorological conditions during the period 1984-1988 are characterized as variable: three unusually cold winters (1984/85 to 1986/87) with heavy ice conditions followed by two warm ones. The river runoff to the Baltic Sea was, in general, higher than the long-term mean, except the years 1985 and 1986.

Salinity continued to decrease mainly due to lack of major inflows of highly saline water from the North Sea during the last 13 years. Furthermore, temperature and density have decreased in the deeper layers of the Baltic Proper. The current stagnation period in the Eastern Gotland Basin is regarded as one of the longest and most serious stagnation intervals recorded during this century. This has caused the most extreme changes in the deep layers that have been observed since the beginning of oceanographic observations in the Baltic Sea.

The area with insufficient oxygen conditions for macrofauna (about 70 000 km^2 with less than 2ml/l oxygen in bottom water) has fluctuated in extent from year to year, but has not increased for 25 years in the Central Baltic Sea and the Gulf of Finland. However, due to the long stagnation period, the oxygen concentrations in the deeps of the Baltic Sea have continuously decreased and hydrogen sulphide concentrations in the deepest areas of the Eastern Gotland Basin are now the highest ever measured. Due to decreasing salinity and consequent lowering of the halocline associated with increased vertical exchange, oxygen has penetrated more deeply into the intermediate layers, at about 90-100 m in some areas, and has improved life conditions at the sea floor in this depth range.

In many areas of the Baltic Sea, the strong increase of phosphorus and nitrogen concentrations, which was observed in the 197Os, has stopped, with the exception of the Kattegat and the Gulf of Riga. Phosphorus and nitrogen concentrations, although no longer increasing in all parts of the Baltic Sea area since 1978, have recently been at such a high level that the increasing biological production and its subsequent sedimentation, followed by the microbial destruction of the biogenic organic material, cause further deterioration of the oxygen conditions in Baltic deep water. The high phosphate accumulation rates identified in the near-bottom water layers of the Central Baltic deeps since 1977 mainly result from phosphate remobilisation from the sediments due to the increasing hydrogen sulphide concentrations. Silicate concentrations have recently been decreasing, on average, in the surface layer of the Baltic Sea area.

Unusual algal blooms appear to occur more frequently in the Kattegat and the Belt Sea. There is evidence that phytoplankton primary production has doubled within the last 25 years in the area from the Kattegat to the Baltic Proper, with a similar doubling of phytoplankton biomass and its subsequent sedimentation. In the 1980s phytoplankton was at a high level, fluctuating from year to year according to the weather. The decomposition in the benthic system decreases oxygen levels in bottom waters. Consequently, low oxygen concentrations during late summer and autumn have often been observed in the southern Kattegat, the Belt Sea, the Öresund and the Arkona Sea in the eighties.

The increased frequency of poor oxygen conditions in the deep water has had a serious impact on the zoobenthos in the area from the southern Kattegat to the Arkona Basin, and on demersal fish and Norway lobster, pushing northwards into the Kattegat the southern boundary for commercial fishery of Norway lobster.

INTRODUCTION

As a background to this assessment, it can be noted that in the 1970s, the salinity and the concentrations of phosphorus and nitrogen in the Baltic Sea surface water continued to increase. There was evidence that phytoplankton biomass and productivity also increased during that period. Episodic inflows of high salinity water from the Kattegat renewed the oxygen content in the bottom water in the Baltic deeps. Macrofauna recolonization took place in many of the deep areas. Concentrations of DDT and mercury in fish and birds began to decrease as a consequence of reduction measures. At that time, changes both positive and negative were occurring fairly rapidly; for example, larger portions of the deep areas in the Baltic Sea became anoxic. The main overall observation for this period of the 1970s was the increasing eutrophication due to the anthropogenic inputs of organic matter and nutrients.

During the period covered by the Second Periodic Assessment, 1984-1988, the changes have been less marked. Since 197711978, salinity has gradually decreased because there have been no major inflows of high salinity water from the Kattegat. Consequently, for 10 years there has been no oxygen in the Gotland Deep. The main overall observation from the Second Periodic Assessment is that the situation in the Baltic has remained fairly stable, except for salinity, in spite of the fact that the climatic conditions during the monitoring period 1984 to 1988 were not average: three winters were abnormally cold, and two abnormally warm.

In the 1980s nutrient concentrations were at a high level and caused the phytoplankton to flourish, but nutrient concentrations did not further increase. This does not indicate that anthropogenic inputs have not further increased, but shows that hydrographic conditions play an important role. The impact of a future major salt water inflow on eutrophication cannot be predicted. Regarding riverine transportion of heavy metals and organic contaminants, a higher proportion of fresh water in the Baltic Sea could possibly imply higher concentrations of these contaminants compared to a situation when the Baltic Sea water has a higher salinity.

There is no simple relationship between anthropogenic inputs of nutrients and contaminants (both organic and inorganic) and their concentrations in the various compartments of the Baltic Sea environment, owing to the complex interaction of hydrographic processes, chemical transformations, and biological uptake and metabolism on the distribution and fate of nutrients and contaminants in the Baltic environment.

This document contains brief conclusions based on the scientific evaluations published in the Second Periodic Assessment of the State of the Marine Environment of the Baltic Sea, 1984-1988; Background Document (Baltic Sea Environment Proceedings No. 35B).

The evaluations concentrate on the results of open sea monitoring and research activities, while assessment of the state of coastal areas will be presented individually by the Baltic Sea States as national reports, as requested by the Helsinki Commission.

In the conclusions, data are presented chapter-wise regarding changes observed during the assessment period 1984-1988 compared to the findings presented in the earlier assessments published by the Commission (BSEP Nos. 5A, 5B and 17A, 17B). In addition, a summary of proposals for future activities is presented in chapter "Action required".

GENERAL CONCLUSIONS

1. HYDROGRAPHY

The meteorological conditions during the assessment period 1984-1988 can be characterised as variable; there have been three very cold and weak-wind winters (1984/1985 to 1986/1987) with heavy ice conditions (maximum ice coverage between 81 % and 98 %), followed by two warm and windy winters (1987/1988, 1988/1989). The winter 1989/1990 was extremely mild. The summer seasons were rather cool, the radiation poor and the winds weak at the beginning of the assessment period, but the summers of 1988 and 1989 were warm and calm.

The freshwater run-off into the Baltic Sea was equal to or higher than the mean (472 km^3/a) during the whole period with the minimum in 1986 (470 km^3/a) and the maximum in 1988 (530 km^3/a).

The most prominent phenomenon in the hydrography of the Baltic Sea was the continuing decrease in salinity in nearly all regions and water layers. This process is mainly caused by the lack of major inflows of highly saline water during the last 13 years. The last effective major Baltic inflows occurred at the turn of 1975/1976 and in fall 1976. The small inflows in spring 1980, at the turn of 1982/1983, in spring 1986 and fall 1988 have only had effects on salinity and temperature in the deep layers of the Arkona, Bornholm and Gdansk Basins.

During the assessment period, a general decrease in salinity has been observed in the surface layer of all regions of the Baltic Sea, starting in 1977. The mean annual trend varied from -0.02 psu/a *) in the major gulfs and -0.05 psu/a in the central Baltic to -0.15 psu/a in the Arkona and Bornholm Basins. Any salinity trends in the Kattegat and Belt Sea waters are strongly masked by the predominant annual cycle in both the surface and deep layers.

In the deep layers of the Baltic Sea, the salinity decrease has been considerably greater since 1977. The mean annual trends during 1984-1988 are -0.05 to -0.09 psu/a for the Gulfs of Bothnia, Finland and Riga; and -0.1 to -0.2 psu/a for the eastern and western Gotland Basins and the Landsort Deep. The trend is as high as -0.4 psu/a in the near-bottom layer of the Bornholm Basin.

Temperature and density in the deeper layers of the eastern Gotland Basin have also decreased considerably and the halocline and isohaline depths have noticeably descended. Owing to the diminution of vertical density gradients, the vertical mixing processes between the different layers have enlarged.

The current stagnation period, at least in the eastern Gotland Basin, must be regarded as one of the largest and most serious stagnation intervals ever recorded during this century and this has caused the most extreme changes in the deep layers that have been observed since the beginning of oceanographic observations in the Baltic Sea.

The transparency, according to Secchi depths readings, in the northern Baltic Proper (1969-1985) shows a pronounced decrease compared with that during the first half of the century (1914-1939).

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*) psu = practical salinity unit $\approx 10^{-3} \approx$ ‰

2. OXYGEN, HYDROGEN SULPHIDE, ALKALINITY, pH

Oxygen conditions

Stagnant periods with decreasing oxygen concentrations have been observed in the deep waters of the Baltic Proper since the end of the last century, when hydrographic measurements were started. Due to the present exceptionally long stagnation period, the current oxygen conditions at the bottom are now even worse than during the assessment period 1980-1985. There is, however, some improvement in the oxygen conditions in the intermediate water layers of some central and northern basins of the Baltic Proper. This can be attributed, in addition to the transport of oxygen-rich water into the intermediate layers, to the increasing vertical exchange across the primary halocline due to the decreasing vertical salinity gradients and to the significant sinking of the halocline.

No clear overall trends could be found in the Kattegat and the Øresund bottom waters for the period 1964-1988, but there has been a significant decrease in oxygen concentrations during the last five years. The most serious oxygen deficit occurred in the southern Xattegat in autumn 1988. Since 1974, the autumn oxygen minimum has gradually become lower and an additional oxygen minimum has developed in the spring time.

In the Xiel Bight, the Fehmarn Belt and the Mecklenburg Bight, hydrogen sulphide was occasionally reported close to the bottom during the late summer/early autumn of 1981 to 1985. The most probable explanation is that the increased eutrophication has increased both the production of organic matter and the utilization of oxygen for its decomposition.

Although no significant trend was found for the Arkona Basin, there were still some indications of decreasing oxygen concentrations near the bottom from 1965 to 1988.

After the last major inflow in 1975 and 1976, the overall negative trends in the oxygen concentrations ranged from -1.8 ml/l in the Bornholm and the Gdansk Deeps to -4.7 ml/l in the Gotland Deep (at 200 m depth). The later inflows had minor effects on the oxygen conditions at the bottom; their positive influence could, however, be traced in the intermediate water layers. The current stagnation period has caused the highest concentrations of hydrogen sulphide ever recorded in the bottom layer of the Gotland Deep.

The main reason for the decreasing oxygen concentrations in the bottom waters of the deep basins is obviously the long stagnation period. It is quite clear that this kind of stagnation is a natural phenomenon associated with river runoff and meteorological conditions.

In the Gulf of Riga, there has been a significant decrease of oxygen concentrations in the deep water layers during 1963 to 1987 due to the increasing nutrient load from land. Due to decreasing salinity gradients during 1969 to 1988, the oxygen conditions improved in the deep waters of the Gulf of Finland.

In the Bothnian Sea, there has been a significant decrease in the oxygen concentrations in the bottom waters from 1965 to 1988. The rate of decrease has been especially rapid during the last five years. The reason for this may be the lack of vertical convection down to the bottom during the winters. In the Bothnian Bay, the trend is weakly negative and insignificant. The large supply of fresh water and the weak stratification of the water prevent the basin from developing signs of stagnation.

Studies carried out on the occurrence of hydrogen sulphide and low oxygen concentrations in the bottom waters of the Baltic Sea showed that the total area of seabed covered by waters with oxygen concentrations below 2 ml/l decreased significantly during the period 1963-1987, while areas covered by hydrogen sulphide-containing water showed a weak non-significant increase. The bottom area suitable for benthic fauna has not diminished in the Central Baltic and the Gulf of Finland during the last 25 years. However, a clear deterioration has taken place in the Arkona and Bornholm Basins because the duration of periods with favourable oxygen conditions has become shorter.

Variations in alkalinity

The alkalinity of sea water, caused mainly by dissolved carbonates, is closely related to the salinity. On the other hand, the carbonate system of sea water is influenced by the primary production process. The growing uptake of CO2 due to the eutrophication occurring in the Baltic Sea implies a decrease in total carbonate concentrations. To investigate long-term alkalinity variations produced by biological factors, salinity-normalized values of specific alkalinity, expressed as A/S ratios, were used in order to eliminate any alkalinity changes induced by the changes in salinity.

Negative trends in the specific alkalinity (A/S), indicating high phytoplankton production, have been found in the surface waters of the Bornholm Basin, the eastern Gotland Basin, the northern Central Basin and the Åland Sea during the period 1964-1987. They are, however, very weak and in most cases hardly significant. The deep waters showed a constant specific alkalinity (A/S) in all investigated areas. In the absence of a proper time series of alkalinity data, not all Baltic regions could be studied in terms of long-term variations.

Variations in pH

Significant positive trends have been found in the long-term pH variations observed in the surface waters in most of the Baltic Sea areas during the past three decades. They might be attributed to the intensified assimilation of CO2 via eutrophication. In this connection, the pH of sea water seems to be a more sensitive indicator than alkalinity for a shift in the carbonate system associated with growing CO2 uptake. The mean increase ranged from 0.03 pH units/a in the eastern Gotland Basin and the Gdansk Deep to about 0.01 pH units/a in the northern Central Basin, the Bothnian Bay and the Kattegat. No evidence has been found for long-term trends of pH in the surface waters of the Åland Sea, the Arkona Basin, the Belt Sea and the Øresund.

The positive pH trend found in the intermediate layers of some deep water areas in the Baltic Proper is possibly associated with rising oxygen concentrations in these layers.

A significant increase of pH in deep waters was observed during 1964-1987 in the Baltic Proper, except for the Arkona Basin. These trends were similar to those in the surface and intermediate water layers with regard to their mean annual coefficients and inter-regional differences. Among possible reasons, a denitrification process and the weathering of rock carbonates due to acid rain, should be taken into account.

3. NUTRIENTS

Phosphorus and nitrogen compounds are the driving forces in eutrophication. Studies on long-term variations beginning, as early as 1958 in some cases, indicated, on average, increasing winter concentrations of these nutrients in the surface layer of all sub-regions in the Baltic Sea Area until 1988. These trends often result from the strong increase that occurred during the period 1969 to 1978. Thereafter, the phosphate, and sometimes also the nitrate, concentrations have remained at their relatively high level. Exceptions are the Kattegat and the Gulf of Riga, that have been characterized by a further increase in nutrient concentrations. Increasing nitrate concentrations have been observed in the Bay of Gdansk and in the whole of the Gulf of Bothnia, as well as in the Gulf of Finland.

Trend changes observed in the surface layer are also reflected to a certain extent in the oxic deep water of the central Baltic basins.

High phosphate accumulation rates have been observed in the near-bottom water layers of the central Baltic Deeps, with predominant anoxic conditions in the recent stagnation period beginning in 1976/1977. They mainly result from the remobilisation of phosphate from the sediments caused by the increasing hydrogen sulphide concentrations and consequently decreasing redox potential.

Since there is no indication of considerable changes in land-based and airborne inputs, the insignificant increase in phosphorus and nitrogen concentrations recently observed, on average, in the winter surface layer in most parts of the Baltic Sea Area can be interpreted as follows:

- Steady state has developed between inputs, biogeochemical sinks, recycling, and the exchange of nutrients through the entrances of the Baltic Sea.
- Inter-annual 3- to 4- and 6- to 7-year cycles, attributed to changes in the atmospheric circulation create variations in the river run-off and are also reflected by changes in the nutrient trends.

The phosphorus and nitrogen concentrations included in the biogeochemical cycle have recently been at such a high level in the Baltic Sea Area that the sedimentation and microbial destruction of biogenic material produced in the euphotic layer cause further deterioration of the oxygen conditions and spreading of the anoxic areas in the deep water. Areas covered by unfavourable developments are the Kattegat, the Belt Sea, the Arkona Sea, the Bornholm Sea and the Bothnian Sea.

Silicate concentrations in the Baltic Sea Area have recently been decreasing, on average, in the surface water layer. Reasons discussed in this connection are intensified diatom blooms favoured by eutrophication and the subsequent sedimentation of these algae.

4. PELAGIC BIOLOGY

Signs of eutrophication are evident in the pelagic ecosystem of the Baltic Sea, although no drastic changes either on the quantitative level or in the species composition have occurred in the open pelagic system since the preparation of the First Periodic Assessment.

When comparing the periods 1979-1983 and 1984-1988, primary production showed increasing trends in most areas. In the Arkona Sea and the Gulf of Finland, the summer primary production decreased, while in the Bothnian Sea it remained at the same level. Chlorophyll-a values also showed an increasing trend in most areas, except in the Arkona Sea and the Bornholm Sea.

In general, no clear changes in the phytoplankton species composition have been detected. Several exceptional, and in some cases toxic, phytoplankton blooms have been reported. Blooms of dinoflagellates, chrysophyceans and prymnesiophyceans have been more frequent in the Kattegat-Belt Sea region than in the Baltic Sea, where in most cases the blooms were caused by cyanobacteria (blue-green algae). Several potentially toxin-producing species of cyanobacteria, dinoflagellates, chrysophyceans and diatoms are found in the Baltic Sea Area and present a risk of noxious blooms. In the Kattegat and the Belt Sea areas a tendency of increase of flagellates has been observed.

The zooplankton abundance values in 1979-1988 revealed large inter-annual fluctuations, but no trend. The only exception is the Arkona Sea, with a significantly increasing trend in summer.

The assessment period 1979-1988 is still too short for a proper trend analysis. It has revealed large inter-annual variations in the plankton communities which can partly be related to large climatic fluctuations. The plankton community is controlled by various factors which result in different temporal and spatial scales for the response to environmental changes. These variations can serve to dampen the effects of, e.g., the still large input of nutrients. The anthropogenic disturbances increase the variability of the system as well. The few long-time series available on plankton reveal clear signs of eutrophication. During the last 30 years, the phytoplankton primary production has almost doubled from the Kattegat to the Baltic Sea Proper. The phytoplankton biomass expressed as chlorophyll-a increased by nearly the same order of magnitude. Due to the development in methods and to the increasing knowledge of systematics, long comparable time series on phytoplankton are not available. The phytoplankton composition has not changed drastically, but there is a tendency towards more frequent, and sometimes toxic, blooms. Long-term investigations in the Bornholm and Gotland Seas show a significant increase in the zooplankton abundance from the 1950s to the end of the 1970s.

The increase in the production of organic matter and its subsequent sedimentation and decomposition in the benthic system has decreased the oxygen content of the deep water. The decrease is no longer restricted to the deep basins of the Baltic Sea, but increasingly affects the shallower parts and has resulted in drastic changes in the benthic communities below the halocline. The oxygen deficiency has also affected the food resources of fish and their spawning areas.

The present state of the pelagic system is determined by the on-going eutrophication process. In general, this is more pronounced in the coastal areas compared with the open waters of the Baltic Sea. Direct nutrient inputs of anthropogenic origin and remobilized phosphorus from the sediments are the main sources for enhancement of the biological production.

5. ZOOBENTHOS

In the northern part of the Kattegat, the zoobenthos biomass has increased as a result of the increased deposit of biogenic organic material to the bottom.

In the southern part of the Kattegat just below the halocline, as well as in the deeper areas of the Belt Sea, a situation of reduced zoobenthos biomass and even macrofauna death, reported for the period 1979-1983, has continued during the period 1984-1988. This reduction is coupled to a more frequent occurrence of seasonal oxygen deficiency and, in some places, even the occurrence of hydrogen sulphide during the 1980s.

In the deeper parts of the Arkona Basin, a deterioration of the fauna has taken place during the 1980s. At station BY1 (K7), macrofauna death was recorded for the first time in June 1989. This decline is associated with the increased frequency of low oxygen values in the 1980s.

Below the halocline in the Bornholm Basin, the permanent bottom fauna disappeared in the 1970s. Although inflows of saline water occurred during the period 1979-1988, the periods with favourable oxygen conditions have been short and only the occasional presence of bottom fauna has been recorded. In the Gdansk Deep, a strong deterioration of the macrofauna has taken place since 1978, and the area devoid of macrofauna has increased since 1979. In the Eastern Gotland Basin, no renewal of the bottom water has occurred during the last 13 years, and the area below about 130 m has been devoid of macrofauna during the period 1979-1988.

In the Eastern Gotland Basin from the halocline (ca. 80 m) down to about 130 m there has been a clear decrease in both the abundance and biomass of macrozoobenthos during the last 25 years. In the Northern Central Basin, the entrance to the Gulf of Finland and the Western Gotland Basin, the development at this depth interval has been different. Firstly, a recovery has been recorded in areas with an impoverished fauna; secondly, bottoms formerly devoid of macrofauna have been recolonized. These changes can be explained by an improvement in the oxygen conditions.

In the middle part of the Gulf of Finland, where the fauna of the deep areas deteriorated in the 1970s, a normal macrofauna community has been re-established in the period 1986-1989.

In the areas above the halocline in the Baltic Proper, the Gulf of Riga, the Gulf of Finland and the Archipelago Sea, an increase in the zoobenthos biomass values has mainly been reported, interpreted as a response to the general eutrophication of the Baltic Sea.

In the entrance area to the Gulf of Bothnia, i.e., the Åland Sea, a decrease in both the abundance and biomass of the zoobenthos has been recorded in the deepest part of the area. In shallower areas, there is no evidence of a change.

In the open area of the Bothnian Sea, no trend has been observed during the last 20 years, but the zoobenthos values are significantly higher than those reported in the 1920s. In the open areas of the Bothnian Bay, an increase in both the abundance and biomass has been reported since 1965.

Locally polluted areas along the coast of the Gulf of Bothnia have shown a general improvement during the last 20 years, although there are some exceptions. This improvement must be seen as the result of changes in industrial processes, sewage treatment and stricter regulations. From the other regions of the Baltic Sea, the information about locally polluted areas is too scarce to draw conclusions.

6. BALTIC FISH STOCKS

A number of factors influence the size of commercial fish stocks in the Baltic Sea Area, ranging from the influence of natural conditions to the level of catch in the fishery. While information is lacking on the influence of environmental conditions on the pelagic stocks in the Baltic Sea Area, environmental influences on the demersal, i.e., bottom or near-bottom living, species of fish and shellfish can clearly be seen in certain areas.

In the southern Kattegat, an increasing frequency of periods with oxygen deficit in the summer and autumn has particularly affected the stock of Norway lobsters. This has caused a northward movement of the fishery, so that in 1988 and 1989 there was no commercial fishing for Norway lobster in the southern Kattegat. The stress caused by the oxygen deficit in this area is also believed to be linked to an increased prevalence of certain viral diseases in the dab population. As low oxygen values are not found in the spring during the time of the pelagic phase of the eggs and larvae of cod, plaice, dab, and sole, and certainly not at the depths of O-15 m where the eggs and larvae are found, oxygen depletion has had no effects on the survival of the eggs and larvae of these species in this area.

Similarly, in the Belt Sea and Arkona Sea, the low oxygen concentrations near the bottom *in* the summer and autumn have restricted the commercial fishery on demersal species to the period December-April. However, as the spawning time for cod, plaice, and flounder in this area is between February and April, when there is no oxygen deficit, this does not affect the survival of the eggs and larvae of these species.

In the cod spawning areas in the Bornholm Sea, the Gotland Deep, and the Gdansk Deep, there is a growing problem owing to the gradually decreasing salinity of the Baltic Sea and the low oxygen concentrations in the bottom waters. Cod eggs require a salinity of 11 psu or more to keep afloat and an oxygen concentration of at least 2.0 ml/l to survive; thus, the northern border for successful reproduction is found in the Gotland Deep. Successful spawning seems to be positively correlated with the inflow of saline water from the North Sea, which increases the salinity in the bottom layer and improves the oxygen conditions below the halocline. The increasing salinity enables the cod eggs to float higher in the water column, where improved oxygen conditions result in improved survival of the cod eggs.

7. **MICRO-ORGANISMS**

Only some parts of the Baltic Sea have been covered by the routine microbiological monitoring programme, thus, the duration of these studies is too short to permit a trend analysis.

Surveys performed during late summer, when microbial activity plays an important role in the cycling of matter, along a transect through the middle of the Baltic Sea showed a remarkable uniformity of total bacterial number and activity in the mixed surface layer. This uniformity was obvious with regard to the regional distribution within each survey (with the exception of the Skagerrak and Kattegat) and the temporal changes between the surveys during the different years of investigation.

In the Kiel Bight, the number of colony-forming bacteria showed large inter-annual variations between 1986 and 1989. At two stations in this region, a decrease in the number of these bacteria was noted, which, however, was not found at the third station. Due to the limited number of data and the short time series of the study, no conclusions concerning a trend can be drawn yet.

Taxonomic investigations performed in the northern and central Baltic did not reveal a change in the species composition of the microbiota during the recent years.

Concerning the indicatory groups of bacteria, a clear relationship between the character of marine contamination and the physiological properties of the microbial populations could be demonstrated. Due to the contamination of some sea areas by petroleum and chlorinated hydrocarbons, it appears that mass bacterial populations may adapt themselves to low concentrations of toxicants and acquired the ability to decompose organic compounds, such as **PCBs** and certain polynuclear aromatic hydrocarbons **(PAHs).** The increase in the number of indicatory micro-organisms observed during the past few years is indicative of the growing influence of anthropogenic factors.

8. TRACE **ELEMENTS**

In relation to previous assessment periods, the trace element data base is still rather limited and allows only very preliminary conclusions to be drawn on trends.

It is still very difficult to compare data on particle-associated trace metals from different laboratories, owing to methodological uncertainties. There is an urgent need for intercomparison and standardization of the various procedural steps in obtaining data on particle-associated trace metal concentrations, particularly with regard to sampling methods and pre-treatment of the sample.

In view of the high variability in the Baltic Sea ecosystem, there is an inadequate pool of data to be able to provide information (1) on the particle-associated concentrations of trace metals in different water masses and at different seasons, (2) on the metal content of suspended particulate matter, and (3) on the nature of the particulate matter in terms of origin and mineralogical and grain-size composition.

Gradients and differences observed in (a) the concentrations of particle-associated trace metals, (b) the concentrations of the suspended particulate matter, and (c) the distribution patterns in the metal contents of the different types of particle may reflect both anthropogenic influences and natural processes that cause redistribution and generation of suspended particulate matter of different composition and properties.

Lead

Biota collected from sampling locations in the Kattegat, the Sound and the Great Belt showed tendencies for decreasing lead concentrations. These findings are supported by tendencies of decreasing dissolved lead concentrations in Baltic waters. Both observations coincide with the reduced use of lead additives to gasoline in western Europe.

Copper and zinc

For copper and zinc concentrations in fish, no significant differences in comparison with the North Sea were observed.

Cadmium

An upward trend of cadmium concentration in fish was realized in the far north of the Bothnian Bay. In addition, a general tendency of increasing cadmium concentrations in biota when going in northerly direction in the Baltic could be identified.

The prime factor behind the fact that higher cadmium concentrations were found the further north in the Baltic Sea samples were taken is obviously an inverse relationship between salinity and cadmium uptake. The salinity in the Baltic varies from about 5-7 psu*) in the Bothnian Bay to more than 20 psu in the Kattegat. These changes in salinity are accompanied by changes in total cadmium concentrations, and in the chemical speciation and bioavailability of cadmium. Observations that cadmium concentrations have increased in biota during recent years may possibly be attributed, at least to a certain extent, to the decreasing salinity in the Baltic Sea between 1979 and 1988.

Mercury

The monitoring data submitted by the Contracting Parties reflected in most instances approximately present background levels. Elevated concentration levels were observed in fish collected from the Øresund and from the southern Bothnian Sea.

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*) psu = practical salinity unit ≈ 10^{-3} ≈ °/₀₀

Organotin compounds

Because of the initial adverse effects (shell deformations) observed in blue mussels from the Swedish coast, there should be growing concern about the presence of organotin compounds in the marine environment. Serious problems occur through the use of tributyltin (TBT) as an anti-fouling agent in paints. In areas of restricted water circulation and intensive recreational boating, leaching of TBT from treated surfaces has caused adverse effects on marine life. It is recognized that water concentrations even at the ng/l concentration level can have lethal and sub-lethal effects on a wide variety of marine organisms, particularly on the sensitive forms of the early life stages of fish and shellfish.

9. ORGANIC CONTAMINANTS

General

Many anthropogenic organic compounds are found in the water, sediments and biota of the Baltic Sea. This load is the sum of several sources: riverine input, direct discharges and airborne transport from sources mainly in the northern hemisphere.

The contribution of organic contaminants to the Baltic Sea from rivers and direct discharges can be influenced directly by the Baltic Sea countries, while the input from long-range air transport can only be reduced by global agreements.

In general, biota in the Baltic Sea are under a stronger influence of anthropogenic contaminants than in the North Sea or the North Atlantic, partly due to the poor water exchange and Baltic Sea topography as an inland sea.

Emission controls applied for some of the well-known contaminants have reduced their levels in the environment.

Because of the great analytical difficulties of measuring many of the organic pollutants in water, sediments and biota and due to the limited knowledge of biological and ecological effects caused by persistent, bioaccumulating and toxic compounds, it is not possible to perform a hazard assessment of the present total load of organic contaminants on the Baltic Sea fauna and flora.

Petroleum hydrocarbons

There is an evenly distributed background contamination of petroleum hydrocarbons in the Baltic Sea, which can mainly be the result of atmospheric deposition. Concentration levels of specific petroleum

hydrocarbons in sea water are in the range of a few ng/l or less. From the comparable data available at present (after 1982), however, it is not clear whether any trend can be established. Contamination by saturated and aromatic petroleum hydrocarbons is higher in coastal waters and particularly close to urbanized areas, with a steep decline moving to open waters.

Adsorption on to settling particulate matter leads to high concentrations of petroleum hydrocarbons in sediments in accumulation areas under urban influence. The ecological effects of this chronic exposure on marine organisms are largely unknown.

Evaluation of analytical results obtained using the UV-F method, which is only group specific, must be done carefully because of very large qualitative differences in petroleum hydrocarbons from different sources. The W-F method used for screening, and thus useful for large numbers of samples, must be supplemented by specific analyses on selected samples in all cases. To determine the specific petroleum hydrocarbon compounds in marine samples, measurement by gas chromatography/mass spectroscopy (GC/MS) should be applied.

To obtain reliable information on the input and fate of petroleum hydrocarbons in the Baltic Sea, compound specific investigations are necessary.

Pesticides

There is a clear downward trend for DDT concentrations in the Baltic Sea from the 1970s to the 1980s; however, the environmental levels, as mirrored by comparable data from herring, are still higher than in the Skagerrak area. A small temporary increase in DDT concentrations in water and biota in the southern Baltic Proper from 1983 to 1985 was evidently a result of a temporary use of DDT for forest pest control.

There is some concern about polychlorinated camphenes (PCC) still in use as a pesticide. The slow rate of degradation and the bioaccumulative properties lead to PCC levels in the marine environment which are not possible to determine adequately due to the complex composition of the product. As a result, it is not possible to make a reasonable hazard assessment on the present use of PCCs.

Due to the ban on technical hexachlorocyclohexanes (HCHs), the Baltic Sea water concentrations of a -HCH, the main component, have dropped considerably.

PCBs and "New contaminants"

For PCBs there was also a clear downward trend in concentrations in biota from the 1970s to the 1980s and concentrations now seem to have stabilized at a lower level. The downward trend is most clearly observed in the Baltic Proper. Comparable data on herring, however, indicate that the PCB levels are still higher in the Baltic Sea than in the Skagerrak area.

Data on contaminants other than PCBs are generally few and scattered and produced with different, non-standardized analytical methods. This implies that it is not possible to evaluate distribution patterns or temporal trends in the environmental levels of these contaminants.

Among the new contaminants there is an increasing list of identified compounds that could pose a threat to the environment according to their analogies with known pollutants. Examples of these are brominated biphenyls, brominated diphenylethers and chlorinated thiophenes.

ACTION REQUIRED

Environment

In order to reduce the oxygen consumption in the Baltic Sea the efforts to minimize the discharge of organic matter and nutrients in sewage and industrial wastewater should be continued. Efforts to restrict the use of fertilizers in agriculture to levels where excess nitrate is not transported to the sea should be continued.

Though the present knowledge of the nutrient budget of the Baltic Sea is still insufficient, especially regarding the input from the North Sea, geochemical phosphorus fluxes, rates of denitrification and nitrogen fixation, there is good reason to assume a significant effect of anthropogenic inputs on the increase of phosphate and nitrate in surface water.

Therefore, inputs of nitrogen and phosphorus compounds should be further reduced. The group welcomes the Ministerial Declaration to reduce land-based and airborne inputs by 50 % by 1995, even if at present it cannot be calculated what the effect of such a reduction will be regarding primary production and harmful algal blooms.

Efforts to reduce nitrogen input to the sea from the atmosphere should also be continued.

The reduction of inputs of lead seems to have already been successful with regard to concentrations in fish and shellfish in the Kattegat. Further reduction should be achieved by the use of unleaded gasoline.

Though little is known on the concentration and distribution of Tributyltin in Baltic water and some questions on its long-term persistence in the marine environment are still open, present evidence from research in other areas provides an argument to reduce its use in antifouling paint.

In view of the special sensitivity of the Baltic Sea, because of its character as an almost enclosed water body, the Baltic Sea States should make atrong efforts to further reduce the input of persistent organic compounds and heavy metals to prevent their accumulation in the ecosystems.

To reduce long-range atmospheric inputs of contaminants, agreements in the global frame are necessary. Accordingly, the Helsinki Commission is encouraged to continue and further strengthen the relevant international work in this field.

The further use of polychlorinated camphenes (Toxaphene, Strobane, Melipax, Phenacide) as pesticides should be reduced as they can be replaced by substances which are more readily degradable.

In order to reduce the contamination of the Baltic Sea and to reduce the risk of future "surprises", it is necessary to promote the use of the present knowledge and experience on prognostic hazard assessment of effluents and chemicals, based on ecotoxicological testing, as a basis for the control of discharges and of the use of new and existing chemicals.

Research

The Baltic Monitoring Programme mainly provides data on concentrations and is meant to allow trend analyses of concentrations over time. These data alone are not sufficient to explain tendencies observed and to indicate cause and effect. In the future, more weight should be given to process- and effect- oriented research.

Investigations on the water exchange processes between the North Sea and the Baltic Sea should be intensified (including modelling activities), in particular, investigations on the causes and conditions of major inflows of highly saline water into the Baltic Sea. Also, further investigations are necessary on the stagnation and renewal processes in the different Baltic deep basins and the water exchange between them. Attention should be given to studies on the exchange processes across the permanent halocline.

The causes of increasing pH in the Baltic Sea should be investigated and the effects of acid rain on the environmental conditions in the Baltic Sea Area should be studied.

Mass balances and transport mechanisms in nutrient trends should be studied in order to differentiate between anthropogenic and natural contributions.

Data should be collected on the identification and quantitative analysis of organic nitrogen compounds (urea, humic acids, proteins, amino acids) in sea water in order to understand their significance for biological productivity.

Detailed studies on the biogeochemical nutrient cycle under the special conditions of the Baltic Sea are necessary.

To properly understand and better assess the functions and fluctuations of the components of the Baltic ecosystem, more information should be obtained about the rates of biological production and decomposition. Therefore, it is highly recommended that basic research be combined on rate measurements on microbiology, microzooplankton, mesozooplankton, macrozoobenthos, and fish, as well as measurements of total community respiration/biological oxygen demand and particle flux, and relate them to each other.

Changes in zoobenthos biomass do not necessarily reflect changes in production. To obtain figures more suitable for correlations with pelagic production and fish stock assessments, production estimations should be done, using turnover ratios.

Future assessment activities should promote the evaluation of possible relationships between fish stock fluctuations and fluctuations in the biomass of zooplankton and zoobenthos.

Microbiological studies should form an integral part of investigations which at least should include studies on pelagic biology and chemistry.

Research should be promoted (by a request to ICES) on the effects of environmental conditions on the early life stages of fish, and on the relationships between the biomass of fish and that of zooplankton.

For an improved approach to estimate the mass balance of trace elements in the Baltic Sea, the following subjects need to be considered:

concentrations in water, sediments, suspended particulate matter and biota,

origin and quantity of material entering the Baltic Sea from natural and anthropogenic sources,

the magnitude of sinks and their location or distribution, and

the role of transfer processes.

Interdisciplinary research (e.g., on microbiological and photochemical degradation/transformation, the significance of speciation, etc.) should be stimulated to better understand the fate and effects of persistent organic contaminants released into the environment. An increased knowledge on the long-term ecological response to environmental pollutants is urgently needed.

The magnitude of the input of organic contaminants and the relative contribution from fallout, rivers and direct discharges into the Baltic Sea should be evaluated in order to assess their relative significance and to make possible appropriate countermeasures.

Monitoring

One of the scientific bases for research on processes in the sea is the knowledge of parameters and their variability in space and time, many of them already included in the Baltic Monitoring Programme. This monitoring programme should be continued and improved. Suggestions including data collection in fields not covered by the Programme are:

to adjust the frequency of measurements of Baltic monitoring stations to an optimum to follow the seasonal development of the phytoplankton;

in order to be able to follow the development of the zoobenthos in the vicinity of the halocline in the central and northern Baltic Proper, a few more regular monitoring stations are needed;

since increased biomass, probably caused by eutrophication, has been reported for shallow areas, the number of shallow water benthos stations should be increased, and the countries should be encouraged to deliver more national zoobenthos data for a better coverage of the area:

include analysis of fat content in fish liver also for the investigation of trace elements. Trace elements (in particular trace metals) in the liver are connected to specific sites in the protein fraction, which varies in accordance with the liver's lipid content. In order to allow calculations of trace element concentrations in relation to the protein fraction, knowledge of the fat content is necessary;

follow exactly the sampling strategies described in the Guidelines for the BMP for trace metals and organic contaminants in fish in order to analyse material comparable in age, size, reproductive and nutritive condition year by year;

the Helsinki Commission should ensure that certified reference materials are made available for laboratories involved in the Baltic Monitoring Programme in order to improve the quality and the quality control of the data. Further elaboration of methods agreed upon and participation in intercalibration exercises is necessary;

the supply of adequate technical equipment and trained personnel for sampling and analytical work is the responsibility of the Contracting Parties;

in terms of new contaminants further develop and carry out chemical and biological screening in order to discover new contaminants which have slipped through the first defence net and also to check the effects of countermeasures taken against pollution in general and against specific products. This is also the only way to be able to identify effects on the Baltic Sea Area from the international use of chemicals which are globally distributed by long-range airborne transport; and

in order to get compound-specific results for petroleum hydrocarbons the UV-F method, mainly used until now in the Baltic Monitoring Programme, should be supplemented by GC/MS investigations.

To obtain more benefit from the effort expended in the frame of the BMP, the programme of the monitoring cruises should be more efficiently pooled according to the defined goals of the various "fields". By this means, a better coverage could be reached and further use of the data improved.

Assessment

For the Second Periodic Assessment the HELCOM Data Base was successfully used for the first time. The uncertainties found in the use of the bank were mainly due to incorrect or missing data reporting as well as difficulties in quality control by the users. The gaps in the data reporting of some countries has caused difficulties to process data from some sub-areas.

In the next assessment, information should be included on the health status in the Baltic Sea organism populations (diseases, physiological and morphological anomalies, etc.).

In every case, the reporting and control system must be improved. It is expected that all countries really report the analyzed data to the HELCOM data base according to the recommended standards. HELCOM is asked to develop a necessary control system.

For the Third Periodic Assessment, a more realistic period for work should be given between the time when all data are available to the experts and the time when the manuscripts should be finalised. More time than was now, in practice, given is needed when one expects well-founded estimates regarding causes and effects for trends observed. More attention should also be paid to interdisciplinary review of information and the development of associations between various components of the Baltic ecosystem.

MAP OF THE MONITORING STATIONS IN THE BALTIC AREA