EIGHTH ICES DIALOGUE MEETING

"HOW TO USE THE SEA: MANAGEMENT INTERACTIONS WITH SPECIAL REFERENCE TO THE BALTIC AND ITS FISHERIES"

International Council for the Exploration of the Sea
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OPENING BY THE CHAIRMAN, MR JAKOB JAKOBSSON, PRESIDENT OF ICES

Ladies and Gentlemen,

It is with great pleasure that I open the Eighth ICES Dialogue Meeting which has as its title "How to Use the Sea: Management Interactions with Special Reference to the Baltic and its Fisheries". Previous Dialogue Meetings have proved to be lively fora where fishery scientists, fishery managers and fishing industry representatives discussed matters relating to fisheries management and the advice upon which it is based. The aim of the discussions was to improve understanding and communication amongst these three groups. The last such Dialogue Meeting was held in 1989 prior to the NEAFC (North-East Atlantic Fisheries Commission) Meeting in London.

This, the Eighth Dialogue Meeting, is of a new kind as it incorporates for the first time consideration of environmental matters. This is entirely appropriate at present because marine scientists are increasingly trying to understand the environmental effects on fish stocks and the effects of fisheries on ecosystems. ICES embraces both the fisheries and environmental fields of research and advisory functions and so is in an ideal position to organise such a meeting. The Baltic offers an ideal focal point for such interdisciplinary discussions.

Poland's offer to host the meeting in Gdynia, as part of the celebrations marking the 70th anniversary of the Sea Fisheries Institute, was enthusiastically accepted. Dr Karnicki, the Director of the Institute, has overseen the local arrangements most efficiently. I thank the co-sponsors, the Baltic Marine Environment Protection Commission (HELCOM) and the International Baltic Sea Fishery Commission (IBSFC), for their support and cooperation, and the Commission of the EC for funding the simultaneous interpretation which is available in English, German, Polish and Swedish.

I am personally very happy to be back in Poland after a twelve-year absence, although I was in another Baltic country earlier this year for an ICES Symposium.

I now call upon the Chairmen of HELCOM and IBSFC to make their welcoming remarks.

STATEMENT BY MR FLEMING OTZEN, EXECUTIVE SECRETARY OF HELCOM

Mr President,

Allow me first of all to thank and congratulate ICES for having taken the initiative to organise the Eighth Dialogue Meeting, which will be the first of these meetings to focus on fisheries as well as on the protection of the marine environment. ICES is working in both camps and I, therefore, feel it quite natural for ICES to have been the initiator of this meeting.

I also take this initiative as a clear indication of the increasing involvement of ICES in the environment field which the Helsinki Commission appreciates very much.

Both IBSFC and HELCOM are co-sponsoring this Dialogue Meeting and it is my hope that the results from the meeting will facilitate a more concrete co-operation between these two Commissions than merely sending observers to each others' meetings.

A first step in this direction has already been taken when IBSFC joined the HELCOM ad hoc High Level Task Force in May this year as an observer and the Task Force has already received constructive inputs to that part of the Joint Comprehensive Programme which addresses fisheries.

The HELCOM Task Force also expects that the results from the Dialogue Meeting will further contribute to the programme regarding the interrelation between natural factors in the marine environment, fish catch, and pollution.

The Helsinki Commission is looking forward to the conclusions from a constructive dialogue during the meeting, and it is our hope that discussions today and tomorrow will ascertain the start of a continued dialogue.
between representatives from science, management, and industry from both the fisheries and marine environmental disciplines in the Baltic Sea area.

It is my hope that the initiative taken by ICES will be an appetizer to take similar initiatives in other geographical areas within the ICES region.

I wish you the best of success in your coming deliberations.

STATEMENT BY MR PEKKA NISKANEN, CHAIRMAN OF IBSFC

Mr Chairman, Mr Director, Distinguished Participants, Ladies and Gentlemen,

As the Chairman of the IBSFC I am very pleased, on behalf of our Commission, that the subject of the Eighth Dialogue Meeting is related to the problems we are facing in the Baltic Sea. So we are happy to be co-sponsors of this meeting. I also want to thank the organizers for arranging this meeting here in Gdynia, which is a well-known site of fishery and marine research.

The situation in the Baltic Sea is very serious with regard to environmental conditions as well as to fishery resources. It is common knowledge that water quality has continuously deteriorated despite the efforts made by surrounding countries. The High Level Task Force was established within HELCOM to prepare a Joint Comprehensive Programme in order to restore a sound ecological balance. An interim report of this work has already been circulated. Our Commission welcomes this new step and, for its part, is prepared to cooperate as far as possible.

The discharge of pollutants is not alone to blame for the present situation. The lack of inflow of saline and oxygen-rich ocean water to the Baltic has made it even more difficult. As a consequence, the absence of such water together with pollution have rapidly deteriorated conditions for living resources. The most serious example is cod. The major spawning areas of cod suffer from an oxygen deficit in deep waters which prevents reproduction. Consequently, cod stocks are depleted to almost a critical level. Heavy metals and other toxic substances might mean that fish as food could pose a threat to human health, and this would have serious implications for the commercial fishery. If environmental conditions become much worse, there will be little need for management of the fish resources. Therefore, it is clear that the IBSFC welcomes all efforts which aim at reducing pollution and improving the marine environment.

This situation calls for effective and rapid action. Cooperation among all states and organizations is essential and a reduction of discharges of harmful substances from states surrounding the Baltic Sea is, of course, a key factor. The Joint Comprehensive Programme under preparation should, therefore, be implemented with great urgency.

Mr Chairman, the discussions we are about to begin will certainly bring out a lot of information with regard to the marine environment, fisheries, and how to manage them. In the present situation, it is most important that this information is available to all who are engaged in the conservation of living resources and the restoration of environmental conditions as well as others using this unique sea in their activities. I am convinced that administrators, scientists, representatives of different industries, and finally decision makers will benefit from the outcome of this meeting. As I have pointed out in many connections, the basis for proper management of fish stocks is indelibly bound to maintaining suitable environmental conditions. Unfortunately, the present state of the Baltic Sea does not fulfil all requirements in this respect. However, these requirements can be met if all the states concerned put into effect all those recommendations which aim for sound environmental conditions.

Mr Chairman, I can assure you that the IBSFC welcomes this meeting and will as soon as next week at its Seventeenth Session have a preliminary review of its outcome. Once again, on behalf of my Commission, I would like to thank all those who have arranged this meeting and, in advance, those who will present their important and interesting papers.

Thank you, Mr Chairman.
ENVIROMENTAL REVIEW FOR THE BALTIC SEA

L. Brügmann
Institute of Baltic Sea Research
Rostock-Warnemünde

1 INTRODUCTION

At the end of the twentieth century when Man has, for decades, been a major environmental and climatic influence on the earth on a global or at least regional scale, one cannot assume that a sea surrounded by nine highly industrialized countries with an intensive agriculture could as a whole - still be in a 'natural state'. In part, the anthropogenic influences have 'only' accelerated (or slowed down) natural processes, for example, eutrophication, erosion/abrasion and weathering, by mainly physical and chemical disturbances (loading of nutrients and heavy metals, shipping, fishing, especially bottom trawling, mining). However, in addition, xenobiotics and radionuclides contribute to new threats for the ecosystem, its compartments or even for Man as a consumer of sea-derived food.

To characterize the 'present situation' of the Baltic Sea, a use-related approach seems to be justified. The 'state' of the Baltic Sea could, for instance, be discussed regarding its use as a means for transportation/navigation, for exploiting non-living resources (e.g., oil, minerals, sand, gravel, water and substances dissolved or suspended therein), for utilizing the ability of the ecosystem to detoxify, deposit or totally 'assimilate' contaminants released via land runoff and the atmosphere, for fishing, and for recreation. However, such a very pragmatic approach would exclude the 'nature conservation' aspect, and would not consider the ecosystem as a whole, as an entity to be protected in its own right.

Therefore, in the following sections an extract has been made from the outcome of the HELCOM/GESPA assessment work (HELCOM, 1990) and from other recently published papers, mainly Swedish.

2 DESCRIPTION OF THE PRESENT SITUATION

2.1 Hydrography/Water Exchange/Oxygen Conditions

The Baltic Sea, often called an "Intra-continental European Mediterranean Sea" and being marginal to the Northeast Atlantic, extends from the Kattegat (line Skaw-Marstrad) through the Bothnian Sea. The Baltic Proper covers the central area from the line Gåsper Rev-Darsser Ort to the entrances of the three Gulfs. The present Baltic is a relatively shallow (mean depth 56 m) and 'young' (ca. 12,000 years) post-glacial sea which is the world's largest brackish water body (415,266 km²; 21,721 km³; generalized coastline ca. 7,000 km; entire coastline ca. 22,000 km) (see Figure 1).

The exchange of water between the Baltic Sea and the North Sea is controlled by sills with threshold depths of 22-25 m (Great Belt, minimum width ca. 18 km, 64% of water exchange), 18 m (Darss Sill) and 8 m (Drodgen Sill/Sound, width 6 km, 27%), respectively (see Figure 2). Through the Little Belt (width 1 km) about 9% of the water exchange with the North Sea occurs. In the Baltic Proper, there are basins and 'deeps' with maximum water depths of about 250 m (Eastern Gotland Basin) or even 459 m (Landsort Deep). The freshwater input (mean 472 km³/year) drains over an area of more than 1.67 x 10⁶ km² in which about 80 million people live and have built up intensive agriculture and environmentally relevant industries, including metal, and pulp and paper production. The freshwater excess leaves the Baltic Sea in a "Baltic Current", which may still be noticed in the western part of the Skagerrak due to its lower salinity.

The Baltic Sea would be a freshwater lake if it were not for the permanent, as well as episodically very large, amounts of saline water flowing in from the Skagerrak/North Sea via the transition zone, and extending to the bottom layers of the Baltic Proper. This inflow fills up the more shallow basins of the Belt Sea first (see Figure 3). After passing the Darss Sill, the Baltic Proper is reached and the inflowing water masses may have relevance for greater parts of the ecosystem. Successively, depending on the amount of the inflowing water and its salinity, the Bornholm Basin (105 m), the Gdansk Deep (110 m) and the Eastern Gotland Basin are passed. It may take years until the 'old' and mainly anoxic bottom water of the Gotland Basin has been replaced by the inflowing and still somewhat oxygen-containing water. The further track of the inflow may be traced via the northern Baltic Proper and anti-clockwise around the island of Gotland into the western basin. The Gulfs are not influenced by inflow events. The salinity of the inflowing water decreases from about 30-34 PSU to only about 10 PSU in the Western Gotland Basin. Only one-third of the inflowing water is really Kattegat water (originally up to 35 PSU). The other two-thirds is represented by Baltic surface water which is mixed in the Danish Sounds with the inflowing bottom water. Since the turn of this century, about 90 inflow events have been registered. They may be divided into 12 groups. In 1913, 1921, 1951 and 1976, the volume of the inflowing water significantly exceeded 50 km³. The maximum was noted in November/December 1951, when about 200 km³ of water with ca. 22 PSU passed the Darss Sill over a period of three weeks.
The residence time of the Baltic Sea water (25-40 years) favours the accumulation of contaminants therein. Only about 2-3% of the input of a conservative contaminant would leave the Baltic Sea annually. Due to its special hydrology, the Baltic Sea exhibits strong vertical and horizontal salinity gradients. At the surface, the salinity decreases from about 20 PSU (northern Kattegat) to less than 3 PSU in the Bothnian Bay. The difference in salinities between the surface and bottom water slows down the vertical exchange. A discontinuity layer at 60 to 80 m depth divides the water of the Baltic Proper into a low salinity surface layer with a partly high organic production and higher salinity bottom water with oxygen deficiencies. The last significant salt water inflow event dates back to the autumn of 1976. Thereafter, in spring 1980, winter 1982/83, spring 1986 and autumn 1988, there have been other inflow episodes, which, however, did not appreciably improve the present 'unusual' situation, the on-going freshening of the Baltic Sea. In the stagnant bottom water of the deeps, the oxygen has decreased further and hydrogen sulphide and phosphate concentrations have increased. However, the accompanying lower salinity and temperature have weakened and lowered the discontinuity (density) layer. This has improved the vertical water exchange and the input of oxygen into medium depths. Consequently, between 1983 and 1987 the bottom area in the Baltic Sea containing hydrogen sulphide increased, whereas the area with oxygen concentrations below 2 ml/l decreased (see Figure 4).
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In the Belt Sea (maximum depths between 30 and 35 m), salinity discontinuity layers also exist. However, they are not permanently present and may occur at very different depths. During summer, with low mixing and intensive heating, a stable temperature layering takes place which favours the stagnation of the bottom water and excessive oxygen consumption. This has resulted repeatedly, since the beginning of the 1980s, especially in 1981 and 1983, in the dying-off of benthic organisms and bottom-living fish in late summer and early autumn owing to oxygen concentrations below 1 ml/l and even anoxic conditions (see Figure 5).

During this century, in the Kiel Bight similar events with die-offs of the bottom fauna have also occurred in 1913, 1926, 1961, 1964, 1967, 1972 and 1975. However, never before have such large areas been affected as in 1981.

In the 1980s, for the first time in the Arkona Basin drastic changes were also recorded in the deeper parts. Following significant eutrophication effects, indicated by an increase in the zoobenthos biomass, in parallel and subsequently the species number decreased and opportunistic species were favoured. In 1989, at the monitoring station "BY1" a dying-off of the macrofauna was observed for the first time. This was accompanied by the occurrence of sulphur bacteria (Beggiatoa), which can only exist at the contact zone between H2S-containing mud and a bottom water that still contains at least some oxygen. If the macrofauna, mainly molluscs, is absent in greater parts of the Arkona Basin, the food basis for some fish species will be significantly diminished.

Investigations performed in the Landsort Deep (300 m) which started about 100 years before present impressively reflect both the increasing nutrient load of the Baltic Sea and the decreasing oxygen concentrations (see Figure 6) correlated with this:

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<tr>
<td>Salinity (PSU)</td>
<td>10 - 10.5</td>
<td>11</td>
<td>10 - 10.5</td>
</tr>
<tr>
<td>Oxygen (ml/l)</td>
<td>2.75</td>
<td>1.50</td>
<td>0.25</td>
</tr>
<tr>
<td>N-input (10^3 t/yr)</td>
<td>240</td>
<td>440</td>
<td>960</td>
</tr>
<tr>
<td>P-input (10^3 t/yr)</td>
<td>7.7</td>
<td>15.6</td>
<td>59.0</td>
</tr>
</tbody>
</table>
A similar development in the oxygen concentrations is visible from the results of measurements carried out in the Gotland Deep (200 m) during the period 1893-1987.

Stagnation periods which result in decreasing oxygen concentrations in deep waters are a phenomenon known to the Baltic Sea for a very long time. The trend of decreasing salinity in the Gotland Deep below 200 m from 14 PSU (1952) to about 11.7 PSU (1990) indicates natural hydrographical changes. 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 extreme changes in the deep layers that have never been observed since the initiation of oceanographic observations in the Baltic Sea. The salinity in Baltic waters has decreased since 1977 by 0.05 PSU to present measurements of 0.4 PSU/yr.

Figure 5 Hydrogen sulphide in the Belt Sea, on 15-17 September 1981 (Ehrhardt and Wenck, 1984; from Gerlach, 1990).

2.2 Nutrient Load/Eutrophication

One of the most important factors influencing the oxygen regime is eutrophication, i.e., the increasing organic production due to increasing nutrient input. Since the start of relatively reliable measurements of inorganic phosphorus (P) and nitrogen (N) compounds in the Baltic Sea (ca. 1958), a threefold increase of the winter concentrations has been recorded. Extraordinarily large increases were observed in the 1960s and 1970s. Since about 1978, the already rather high winter concentrations of both nutrients have not increased further, except in the Kattegat and the Gulf of Riga. For nitrate, in the Gdansk Bight and the Gulfs of Bothnia and Finland, a continued increase has been observed. For 1990, the annual nutrient input via runoff from the land and atmospheric precipitation was estimated at 979,400 t of nitrogen and 50,000 t of phosphorus.

According to EMEP estimates, many countries bordering the Baltic Sea or outside this area contribute to the atmospheric load of nitrogen compounds, as follows (rounded values): Germany (38%), Poland (14%), USSR (13%), Denmark and Great Britain (7% each), France and Sweden (5% each), the Netherlands (4%), CSFR and Finland (3% each), Belgium (2%), Norway, Hungary, Austria, and Rumania (up to 1% each).

Generally, the development of plankton in the Baltic Sea is limited by the presence of nitrogen compounds, except in the Bothnian Bay where phosphorus limits the organic production. This over-simplification has practical consequences for any restoration measures. In the Baltic Proper, the molar N/P-ratio decreased between the mid-1950s and 1990 from about 50:1 to values dipping below the optimum for plankton development (16:1). A further reduction of the nitrogen input via inflows and atmospheric deposition is possible by taking appropriate measures primarily in agriculture, as well as in the production of energy, and in transportation.

In the last few years, a decrease in silicate concentrations in Baltic surface waters has been observed. This has been diversely explained:
a) By an increased production of diatoms, including their longer spring blooms, increasing the amounts of silicates that are extracted from the water column and buried in the sediments; and/or

b) That the natural input of silicates via runoff from the continent has decreased because it is already strongly consumed by the plankton production inside the rivers.

Up to now, these processes have not significantly affected the species spectra of phytoplankton in offshore regions of the Baltic Proper. However, following the spring bloom of mainly diatoms, the species composition differs due to changes in the nutrient availability. Nitrogen (N$_2$) fixation by cyanobacteria, the so-called "blue-green algae", and the increase of dinoflagellates during the summer blooms are typical features of the Baltic Sea.

The primary production in the central parts of the Baltic Sea has been estimated by many authors to be around 100 g C/m$^2$/year. Due to winter ice coverage and P-limitation, the primary production in the Bothnian Bay is only about one-fifth of this value. There are several indications of an increased phytoplankton production in the Baltic Sea due to the increased nutrient input, especially for the Kattegat and the Belt Sea. For the Baltic Proper and other areas, the correlation between increasing nutrient load and production is not so clearly visible. During the 1970s, changes in the primary production up to two-fold higher values have been found. In addition, a shift in phytoplankton composition to, inter alia, species causing foam, fish mortalities, or mussel poisoning has occurred in coastal areas and bays. A good indicator of an increased primary production is the zooplankton biomass, which shows an increasing tendency.

The increasing deposition of organic matter has resulted in a significant increase in the zoobenthos biomass in the northern Kattegat, the Archipelago Sea and the Gulfs of Finland and Riga. This biomass (100-400 g/m$^2$) is represented mainly by the mussels *Mytilus edulis* and *Macoma balthica*, by the amphipods *Pontoporeia affinis* and *Pontoporeia femorata*, and by the isopod *Mesidotea entomon*, and in the Belt Sea and the Kattegat by the...
2.3 Heavy Metals

During the last decades, in the deeper parts of the southern Kattegat and the Belt Sea and in the Baltic Proper below the salinity discontinuity layer, the macrofauna has decreased fairly significantly. No or only very slow re-colonization has taken place. For the past 25 years in the eastern Gotland Basin in the depth range 80-130 m, a significant decrease in the number as well as the biomass of macrozoobenthos has been recorded.

Summarizing, it may be stated that in the central parts of the Baltic Sea above the halocline, the bottom macrofauna has increased. However, below the halocline it has decreased. Presently, in relation to the 1920s, down to 70 m depth four to five times more individuals with about a three times higher biomass are recorded. (Up to now, it is not clear whether and in which way grazing by bottom fish could have influenced this trend.) For the more shallow areas of the southwestern Baltic Sea, the same trends are seen, i.e., increases in the numbers of individuals and the biomasses for the marginal regions and frequently totally devastated areas in the centres of the basins.

The peculiar hydrographic conditions, including several extreme gradients (e.g., in salinity, temperature, gas content, turbidity) exclude many marine species entirely from the Baltic Sea, and most of the other species can only penetrate to certain zones. Because the ecosystems in the Baltic Sea are simple, with few species and few links between them, even a relatively small environmental change may cause severe imbalance in the entire ecosystem. No doubt additional stress by contaminants is of great importance in such an environment.

The area of the sea floor of the Baltic Sea unable to sustain benthic life is presently estimated at approximately one quarter of the total Baltic Sea bottom area, i.e., nearly 100,000 km².

2.3 Heavy Metals

The concentrations of trace metals in Baltic waters are governed both by external atmospheric and land-based inputs, and by biogeochemical processes within the water body and at its interfaces. This requires a careful wording when speaking about this type of contaminant. Generalized statements, such as "metal concentrations in Baltic waters are always higher than in the Atlantic or North Sea", are not true. For instance, it is well known that metals such as molybdenum, uranium and vanadium show lower concentrations in brackish or fresh waters than in true sea water. In addition, the concentrations of several metals, such as copper, cadmium and lead, are strongly diminished in stagnant, i.e., permanently or frequently anoxic, deep waters. Otherwise, in the surface water layer, very often the relatively high anthropogenic load is reflected especially for cadmium, copper, nickel and zinc by up to ten times higher concentrations than in the ocean. The residence time of the metals introduced is short, i.e., in the range of less than one year up to six years. This enables a fast 'reaction' of the system to reduced inputs and should exclude the accumulation of extremely high levels in the water column. It favours, however, the occurrence of high concentrations in the sediments.

Estimates have revealed that the fraction of metals introduced via the atmosphere may dominate (for nickel, lead, chromium: 95-98%), or be very significant (copper: 36%; cadmium: 48%; mercury: 50%; zinc: 56%). In some areas, the relation between land-related and atmospheric inputs may change. This is true, e.g., for the Bothnian Bay where, due to the direct input of wastes into the water from the Rönnskar metal works (copper smelter), the atmospheric fraction of the arsenic input was estimated at only 31%. (The 'arsenic problem' in the Gulf of Bothnia is also reflected by arsenic concentrations in zooplankton. Whereas for the Baltic Proper, the arsenic concentration in zooplankton was only 10 µg/g, for the Bothnian Bay it was 15 µg/g, for the Bothnian Sea, 20 µg/g, and for the Swedish coast, 40 µg/g has been found.)

In relation to natural background data on the input of metals to the Baltic Sea, the present values are 7 (cadmium, lead), 5 (mercury), and 2 to 3 times (copper, zinc) higher. The input of elements such as cobalt, nickel, chromium, and arsenic has increased only in the order of 10 to 40%. Such very rough estimates are based mainly on investigations of the enrichment of metals in aerosols and in dated sediment cores.

Estimates of the inputs of metals from land should be used with care due to gaps in available data sets and due to uncertainties regarding the net input into the open sea of substances discharged by rivers and other influxes. In 1987, the HELCOM (1987b) published a compilation which is the first 'official' data set used at the administrative level (in t/yr): chromium >0.2; mercury >5; cadmium 60; nickel 110; arsenic 180; lead 300; copper 4200; zinc 9000. (A Second Pollution Load Compilation, which is based on at least monthly measurements in 1990 on all important influxes and which will hopefully reflect a more realistic view of the situation, is expected to be completed in autumn 1991.)

The input of metals in 1986 via atmospheric deposition was estimated as follows (in t/yr):
This demonstrates that the fraction of metals introduced via wet deposition clearly dominates.

Typical concentrations of dissolved (<0.4 µm) trace metals in the mixed surface water layer of the Baltic Sea may be found within the following limits (in ng/l):

<table>
<thead>
<tr>
<th>Metal</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Median Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>arsenic</td>
<td>600 - 1300</td>
<td>mercury</td>
<td>1 - 10</td>
</tr>
<tr>
<td>cadmium</td>
<td>20 - 70</td>
<td>manganese</td>
<td>150 - 1500</td>
</tr>
<tr>
<td>cobalt</td>
<td>6 - 12</td>
<td>nickel</td>
<td>700 - 850</td>
</tr>
<tr>
<td>chromium</td>
<td>100 - 200</td>
<td>lead</td>
<td>25 - 80</td>
</tr>
<tr>
<td>copper</td>
<td>500 - 800</td>
<td>zinc</td>
<td>700 - 1400</td>
</tr>
<tr>
<td>iron</td>
<td>300 - 1500</td>
<td></td>
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</table>

In anoxic deep basins, some metals are excessively enriched (e.g., iron, manganese, cobalt) or diminished (e.g., copper, cadmium, lead, zinc). In the surface microlayer, up to 10 times higher concentrations are accumulated. Outside the coastal regions, the particulate metal fraction is mainly very low (e.g., nickel, cadmium, copper). However, at least for iron and lead, the particulate fraction may represent a very significant part of the total concentration.

Until recently, there were only a few reliable data sets on dissolved trace metal concentrations in Baltic Sea water which, however, do not adequately cover all seasons and basins. The short time span for which data exist and other uncertainties for most metals still exclude the identification of trends. A possible exception is lead. For this element, there seems to be a weak decreasing trend in the concentrations recorded in off-shore areas.

A different situation exists in relation to temporal trends of trace metal concentrations in biota from the Baltic Sea. The lead concentrations in fish from the Kattegat and Belt Sea, which are only slightly higher than those in fish from the North Sea, decreased in the last five years, probably indicating the reduction in use of leaded gasoline in Europe. For copper and zinc, which belong to the biologically 'controlled' elements, no significant differences in relation to fish from the North Sea have been found. The statistical analysis of Swedish data from 1981-1986 showed a two-fold increase in cadmium concentrations in the liver of herring from the Bothnian Bay, i.e., from about 1 to 2 µg/g dry weight. The reason for these significantly higher levels in relation to the rest of the Baltic Sea is seen in the different bioavailability of this element. Its bioavailability may be influenced by its speciation in water, which depends very much on the salinity.

The mercury concentrations in herring muscle from the Baltic Sea are close to the background values typically found in the open North Sea and other seas. However, in the Sound and in the southern Bothnian Sea, concentrations between 4 and 10 times higher were occasionally found.

### 2.4 Petroleum Hydrocarbons

With regard to oil contamination, the Baltic Sea is in a somewhat better position than the North Sea. There are only a few activities for oil exploration and exploitation. In addition, Baltic oil is not under pressure and must be pumped for exploitation. Therefore, the danger of "blow-outs" and other casualties during exploration and exploitation is much lower.

According to HELCOM estimates (HELCOM, 1987c), between 21,000 and 66,000 tonnes of oil are introduced annually into the Baltic Sea, more than 50% of which comes from the land as a kind of 'chronic oil pollution' which spreads rather evenly in the environment and can only be detected by applying sophisticated methods and equipment. Input estimates are as follows:

<table>
<thead>
<tr>
<th>Source</th>
<th>t/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rivers</td>
<td>14000 - 25000</td>
</tr>
<tr>
<td>Municipal Waste Waters</td>
<td>3000 - 9000</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>10000 - 10000</td>
</tr>
<tr>
<td>Casualties with Ships</td>
<td>200 - 9000</td>
</tr>
<tr>
<td>Navigation</td>
<td>160 - 6200</td>
</tr>
<tr>
<td>Influxes via Storm Waters</td>
<td>10000 - 5000</td>
</tr>
<tr>
<td>Oil Terminals</td>
<td>100 - 200</td>
</tr>
<tr>
<td>Industry, without Steel Mills</td>
<td>400 - 1000</td>
</tr>
<tr>
<td>Steel Mills</td>
<td>307</td>
</tr>
<tr>
<td>Refineries</td>
<td>163</td>
</tr>
<tr>
<td>Oil Platforms</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

Oil spills due to casualties of ships may dominate in the corresponding annual mass balances. Locally, this causes the well-known acutely toxic 'oiling' of marine organisms, such as sea birds, and the pollution of beaches. Up to now, the largest oil spill occurred near Klaipeda (Lithuania) where on 19 November 1981 the "Globe Asimi" went aground with 16,493 t heavy oil ("Masut"). About 8400 t of this could be recovered in the vicinity of the harbour as an oil/water mixture, whereas the remaining oil was distributed in the environment. Fortu-
nately for the Baltic Sea, a great part of this was washed onto the beaches of that area. It could be removed, at substantial cost, and only by damaging the sand beaches.

As to the possible effects of oil spills in the Baltic Sea, we know more since the tanker "Tsesis" grounded in Swedish waters in 1977 and lost about 1000 t diesel oil. Acute damage to the flora and fauna were observed. However, re-colonization, including by benthic organisms, occurred relatively quickly despite the oil residues in the sediment. The zooplankton required only some weeks to recover, the macrophytes about one year, and the crustaceans returned when the acute danger was over. The Baltic herring did not seem to avoid the impacted area. A reduced reproduction of herring in the following year could not be clearly related to the oil spill.

These observations should not be used to deny the problem of a potential threat for the Baltic marine environment due to oil pollution by tanker accidents. Several months per year many parts of the northern Baltic Sea, especially the Gulfs, the archipelago and the coastal areas, are covered with ice. Under these conditions, an oil spill would be extremely dangerous because natural processes such as evaporation or biochemical destruction act only very slowly and fighting against oil pollution is very complicated. Tankers up to about 150,000 or 200,000 t may pass the sills to the Baltic Sea. A total loss and spreading of such a load would have unforeseeable effects for the whole ecosystem.

The International Maritime Organization (IMO) has declared the Baltic Sea to be a 'sensitive area'. This implies the applicability of many restrictions regarding the input of contaminants by ships, including the total ban on tank washing operations at sea, limits for the content of oil in bilge and ballast waters, improved aircraft-supported control of illegal practices and the construction of facilities in the ports which take up (partly free of charge) oily wastes. These restrictions have resulted in the fact that the input of oil by navigation has been significantly reduced in recent years.

The amount of oil in Baltic Sea water is estimated at about 50,000 t. This figure is mainly based on measurements by UV fluorescence which show a background value around 1 µg/l for the open sea, which is relatively constant. In coastal waters, especially in the vicinity of industrial and population centres, up to ten times higher values are recorded. Only a few data are available on the concentrations of single aliphatic or aromatic compounds which may be present in the low ng/l range.

Because of a lack of information on the exact qualitative and quantitative composition, the question is still open with regard to possible chronic effects by the oil contamination presently observed in the Baltic Sea environ-

ment. Lethal effects for marine organisms are expected for adults only in the range 1-100 mg/l and for larval stages between 0.01 and 1 mg/l. However, sub-lethal effects have been described in the literature for values between 1 and 10 µg/l. (At concentrations around 1 µg/l, after 24 h exposure, a reduced rate of embryonic development has been observed in the Pacific herring (Clupea harengus pallasi).) This could be relevant in parts of the Baltic Sea, but needs, however, further confirmation.

2.5 Halogenated Hydrocarbons

As a rule, the concentrations of most halogenated hydrocarbons in compartments of the Baltic Sea ecosystem are extremely low. Water body inventories of ecologically relevant compounds (e.g., DDTs, PCBs, HCB) show contaminant masses for the whole sea in the order of only 1-100 t. Because compounds such as PCBs are still used in some Baltic countries in large amounts, exceeding this 'water inventory' by several orders of magnitude, the possibility of undetected leakages, illegal dumping or impermissible deposition at land sites close to the coast and to Baltic tributaries must be considered as permanent and serious threats to the environment. Restrictions on the use of DDT in the bordering countries resulted as early as the 1970s in a significant reduction of this pesticide in Baltic fauna. An intermediate increase in the DDT concentrations in organisms and in the water of the southern Baltic Sea around 1983-1985 was probably due to the repeated massive application of DDT formulations to fight pests in agriculture and forestry. (For instance, based on unofficial estimates, in 1983 in the former GDR on the territory of Mecklenburg-Vorpommern up to 75 t of DDT was sprayed from aircrafts for pest control.)

Due to the ban on the use of technical hexachlorocyclohexane (HCH), the concentration of α-HCH, as the main constituent of the previously applied mixture of isomers, in Baltic waters decreased. Because of its insecticidal effects, γ-HCH is still in use and will be easily washed into the sea. There it is present at concentrations between 3 and 6 ng/l without showing, as yet, a significant temporal trend (see Figure 7).

The use of another ubiquitous pesticide, the poly- chlorinated camphenes (PCCs), e.g., toxaphene, is more questionable because of its higher bioaccumulation rates, very slow decomposition, and its more lipophilic character. Risk assessments are presently not possible due to problems in identifying and quantifying the very complex mixture of PCC congeners.
Figure 7 Concentrations of HCHs in surface waters of the Baltic Sea (from Gaul and Ziebarth, 1991).
In the past two decades, the PCB concentrations in organisms from the Baltic Sea significantly decreased and now seem to approach a relatively low level. In the eggs of fish-eating sea birds, a decrease from about 300 µg PCBs/g fat to around 100 µg/g has been observed. In herring fat, the concentrations decreased from about 20 to 5-10 µg/g.

Izrael and Tsiban (1989) estimated the 'assimilative capacity' of the Baltic Sea for PCBs and benzopyrene taking into account their mass balance and biological effects threshold. They arrived at figures of around 37-150 t/yr (PCBs) and 30-91 t/yr (benzopyrene).

With regard to the presence of other halogenated hydrocarbons in the Baltic marine environment, especially in the water phase, there are only a few reliable data available. Therefore, it is impossible to find in the literature any spatial distribution patterns or temporal trends. There are several examples of compounds which have been identified qualitatively, for which, however, there are presently no conclusions regarding their potential threat for the environment. This is true, for instance, for polybrominated biphenyls (PBBs) and polybrominated diphenylethers (PBDEs) and for chlorinated thio­phenes and naphthalenes (PCNs). In the following table (published in the Swedish "Marine Pollution '90" report), the concentrations of some halogenated organic compounds measured in 1988 in herring from the Bothnian Sea, the Baltic Proper, and the Skagerrak are given (in ng/g extractable fat):

<table>
<thead>
<tr>
<th>Substance</th>
<th>Bothnian Sea</th>
<th>Baltic Proper</th>
<th>Skagerrak</th>
<th>Baltic Sea/Skagerrak</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCBs, of which</td>
<td>4700</td>
<td>6600</td>
<td>1900</td>
<td>3.5</td>
</tr>
<tr>
<td>- planar congeners</td>
<td>13</td>
<td>27</td>
<td>8</td>
<td>3.4</td>
</tr>
<tr>
<td>DDT-metabolites</td>
<td>2000</td>
<td>4300</td>
<td>570</td>
<td>7.5</td>
</tr>
<tr>
<td>PCDDs</td>
<td>2200</td>
<td>2100</td>
<td>620</td>
<td>3.4</td>
</tr>
<tr>
<td>CPs</td>
<td>1400</td>
<td>1500</td>
<td>1600</td>
<td>0.9</td>
</tr>
<tr>
<td>Chlordane</td>
<td>190</td>
<td>180</td>
<td>40</td>
<td>4.5</td>
</tr>
<tr>
<td>PBDEs</td>
<td>130</td>
<td>530</td>
<td>73</td>
<td>7.3</td>
</tr>
<tr>
<td>HCB</td>
<td>120</td>
<td>140</td>
<td>41</td>
<td>3.4</td>
</tr>
<tr>
<td>gamma-HCH</td>
<td>55</td>
<td>58</td>
<td>35</td>
<td>1.7</td>
</tr>
<tr>
<td>PCNs</td>
<td>17</td>
<td>35</td>
<td>20</td>
<td>1.8</td>
</tr>
<tr>
<td>PCDDs(^1)</td>
<td>0.15</td>
<td>0.09</td>
<td>0.02</td>
<td>4.5</td>
</tr>
</tbody>
</table>

\(^1\)in 2,3,7,8 TCDD-equivalents.

In the above table, the last column shows the ratio in concentrations found in the Baltic Sea to those found in the Skagerrak. Certainly, the representativeness of residual concentrations measured in migrating organisms is limited in terms of their use for comparative load assessments of areas. There are, however, some qualitative conclusions possible which are supported by concentration differences of the substances concerned (γ-HCH, HCB, PCBs, DDT metabolites) between herring from the Baltic Sea and those from the Skagerrak.

Additionally, these differences agree very well with terrestrial emission patterns. In general, the data seem to emphasize that the mass ratios between certain groups of substances are very similar. However, the Baltic Sea seems to be between two- and eightfold more contaminated with these compounds. In relation to the Bothnian Sea, the Baltic Proper shows somewhat higher levels, except possibly for dioxins.

Higher dioxin concentrations in herring from the Bothnian Sea may be due to the fact that there are many sites with pulp and paper industries, which are one of the major dischargers of this class of contaminants. In 1988, in the Baltic Sea area, about 15 x 10^6 t of pulp were produced, i.e., one-eighth of the world's production. Two-thirds of this amount were bleached. The industries in the major producing countries (Sweden, Finland) released annually about 2 x 10^8 t of chlorinated compounds resulting from bleaching processes into the Baltic Sea. (Other Baltic countries contribute together ca. 0.4 x 10^8 t of these substances to this type of loading.) A certain fraction of these chlorinated compounds is persistent in the marine environment and may sublethally affect the biota, especially fish. (The wastes of the pulp and paper industry contain up to 1000 different chlorinated compounds, of which only about 1/4 have been chemically identified and/or characterized regarding their toxicity. Included are potentially harmful compounds such as DDT, PCBs, PCDDs, CCI\(_4\), chlorophenols, chloroguaiacols, chlorocatechols and even 2,3,7,8-TCDD and -TCDF. In the past few years, the chlorine (Cl\(_2\)) bleaching gas has been increasingly replaced by chlorodioxide (ClO\(_2\)), from which chlorate (ClO\(_3^-\)) is produced in relatively large amounts and acts as a herbicide, destroying belts of macroalgae.)

Chlorinated wastes released from the paper and pulp industry have been found to be deposited in sediments of the Bothnian Sea and the Baltic Proper. For instance, in coastal sediments close to a paper mill at the Iggesund, up to 6 mg EOCI (extractable organic chlorine)/g organic matter were found. On a 150 km long section in a seaward direction, the concentrations of contaminants significantly decreased with distance from the coast. At about 5 km distance from the source, up to 1.5 ng TCDF/g organic matter was recorded. The occurrence of PCBs in wastewaters of this industry is due to the use of recycling paper. (At the beginning of the 1970s, self-copying paper with PCB additives was produced by many firms. This paper with the PCBs included is still recirculating.)

Seals are at the end of the marine food chain. In their up to 40-year-long life, they accumulate many contaminants, especially lipophilic compounds, to appreciable
amounts. Therefore, they may indicate the state of the sea in which they live with regard to the load of harmful substances in the water column and other compartments of the ecosystem. As was the case for the decrease in stocks of sea birds (e.g., white-tailed eagles *Haliaeetus albicilla*), the accumulation of chlorinated hydrocarbons such as PCBs and DDT metabolites was also seen as the reason for lower reproduction rates in seals. As shown by the following table, PCB levels measured in seals from the Baltic Sea are several times higher than levels in seals from other parts of the North Atlantic. For the sum of DDT metabolites, the residue concentrations in animals from the Baltic Sea are about two times higher than in those from the German Bight of the North Sea. Young animals seem to be already severely loaded with these substances (values in ng/g fat):

<table>
<thead>
<tr>
<th>Animal</th>
<th>Location</th>
<th>DDT</th>
<th>PCB</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey seal <em>Halichoerus grypus</em></td>
<td>Baltic Sea/Gulf of Finland</td>
<td>32,600</td>
<td>33,900</td>
<td>22</td>
</tr>
<tr>
<td>Grey seal <em>Halichoerus grypus</em></td>
<td>North Sea/Northeastern</td>
<td>51,600</td>
<td>65,800</td>
<td>9</td>
</tr>
<tr>
<td>Grey seal <em>Halichoerus grypus</em></td>
<td>English coast</td>
<td>4,200</td>
<td>18,000</td>
<td></td>
</tr>
<tr>
<td>Harbours seal <em>Phoca vitulina</em></td>
<td>North Sea/German Bight</td>
<td>3,200</td>
<td>79,100</td>
<td>21</td>
</tr>
<tr>
<td>Harbours seal <em>Phoca vitulina</em></td>
<td>North Sea/Northeastern</td>
<td>4,700</td>
<td>2,300</td>
<td>10</td>
</tr>
<tr>
<td>Harbours seal <em>Phoca vitulina</em></td>
<td>Arctic Sea/Spitzbergren</td>
<td>1,200</td>
<td>2,400</td>
<td>11</td>
</tr>
<tr>
<td>Harbour porpoise <em>Phocoena phocoena</em></td>
<td>Baltic Sea/Bornholm Basin</td>
<td>16,500</td>
<td>50,300</td>
<td>20</td>
</tr>
<tr>
<td>Harbour porpoise <em>Phocoena phocoena</em></td>
<td>North Sea/German Bight</td>
<td>8,700</td>
<td>55,900</td>
<td>13</td>
</tr>
</tbody>
</table>

1 Sum of metabolites or congeners, respectively.
2 Number of animals investigated.
3 Animals younger than three months old (1986-88).

### 2.6 Radionuclides

Until April 1986, the nuclear weapons tests of the 1950s and 1960s were responsible for the inventory of artificial radionuclides such as ^3^H (tritium), ^90^Sr (strontium-90), and ^137^Cs (cesium-137) in Baltic waters. By atmospheric deposition and land runoff, the budget of those radionuclides increased steadily until about 1967 (about 740 TBq each for ^137^Cs and ^90^Sr). Thereafter, despite a continued input, physical decay and export to the North Sea and to the sediments dominated. For 1983, inventories of 324 TBq (137^Cs) and 416 TBq (9^Sr), and residence times in the water body of 9 (137^Cs) and 15 years (9^Sr) were estimated.

The Chernobyl radionuclide emissions have changed part of these inventories dramatically. In September 1986, for 137^Cs an activity sum of 4620 TBq, and in August 1987 ca. 3700 TBq, were measured. This implies about a fifteen-fold increase over the previous inventory. For ^90^Sr, Chernobyl has not changed the inventory significantly. Between 1986 and 1987, more than 25% of the 137^Cs input left the water column, probably mainly lost by deposition in the marginal sedimentation areas. In 1987, the 137^Cs inventory in the sediments was estimated at 1466 TBq, with more than 60% originating from the Chernobyl accident.

Similar to the water body and the sediments, the Chernobyl loading is also reflected in organisms such as fish by 137^Cs and 134^Cs activities (in Bq/kg fresh weight):

<table>
<thead>
<tr>
<th>Date</th>
<th>^137^Cs</th>
<th>^134^Cs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>12/86</td>
<td>5.9 (4.4-9.3)</td>
</tr>
<tr>
<td></td>
<td>12/87</td>
<td>13.8 (6.5-23.8)</td>
</tr>
<tr>
<td></td>
<td>12/88</td>
<td>16.7 (7.7-20.9)</td>
</tr>
<tr>
<td>Herring</td>
<td>12/86</td>
<td>3.9 (3.5-4.3)</td>
</tr>
<tr>
<td></td>
<td>12/87</td>
<td>6.8 (3.2-8.9)</td>
</tr>
<tr>
<td></td>
<td>12/88</td>
<td>5.8 (2.4-10.8)</td>
</tr>
</tbody>
</table>

The higher activity in cod filet in relation to herring filet may be explained by the different trophic levels represented. For part of 1988 the activities of cesium radionuclides still showed an increasing tendency; however, a decreasing trend began to be evident later in that year, also.

The radioactivity taken up by man via the consumption of fish is governed by the cesium nuclides. It has been estimated that the annual dose received by consuming 7.7 kg herring and 5.8 kg of other fish has increased from 1986 to 1988 as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Dose (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>0.005</td>
</tr>
<tr>
<td>1987</td>
<td>0.008</td>
</tr>
<tr>
<td>1988</td>
<td>0.009</td>
</tr>
</tbody>
</table>

In relation to the general radioactive background load for man from other sources, the additional amount owing to fish consumption is less than 1%.

### 3 RELATION BALTIC SEA - NORTH SEA

The relationship between the Baltic Sea and the North Sea regarding environmentally important parameters may tentatively be summarized as follows:
<table>
<thead>
<tr>
<th>Property</th>
<th>Baltic Sea</th>
<th>North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (km²)</td>
<td>415,000</td>
<td>575,000</td>
</tr>
<tr>
<td>Volume (km³)</td>
<td>21,700</td>
<td>47,000</td>
</tr>
<tr>
<td>Water depth (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mean</td>
<td>56 (17% &lt; 10 m)</td>
<td>80</td>
</tr>
<tr>
<td>- maximum</td>
<td>459</td>
<td>&lt;700</td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12,000</td>
<td>180,000,000</td>
</tr>
<tr>
<td>Catchment area (km²)</td>
<td>1,670,000</td>
<td>400,000</td>
</tr>
<tr>
<td>(population)</td>
<td>ca. 80,000,000</td>
<td>&gt;100,000,000</td>
</tr>
<tr>
<td>Residence time (yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>25-40</td>
<td>0.5-3</td>
</tr>
<tr>
<td>Freshwater inflow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(km³/yr)</td>
<td>ca. 470</td>
<td>ca. 630</td>
</tr>
<tr>
<td>Salinity (surface, PSU)</td>
<td>ca. 3-20</td>
<td>ca. &gt;20-35</td>
</tr>
<tr>
<td>Fishing (t/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ca. 1,000,000</td>
<td>ca. 2,000,000</td>
</tr>
<tr>
<td>(herring + cod (+ ca. 200,000 t) = 80-90%)</td>
<td>mussles</td>
<td></td>
</tr>
<tr>
<td>Inputs (t/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>980,000</td>
<td>1,620,000</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>50,000</td>
<td>110,000</td>
</tr>
<tr>
<td>Cadmium (atmosphere)</td>
<td>35</td>
<td>45-240</td>
</tr>
<tr>
<td>Copper</td>
<td>470</td>
<td>400-1600</td>
</tr>
<tr>
<td>Lead</td>
<td>1600</td>
<td>2600-7400</td>
</tr>
<tr>
<td>Zinc</td>
<td>3400</td>
<td>4900-11000</td>
</tr>
<tr>
<td>Mercury</td>
<td>?</td>
<td>10-30</td>
</tr>
<tr>
<td>^137Cs-Inventory</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1988, 1015 Bq)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Sediment</td>
<td>0.05</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Main problems:**

<table>
<thead>
<tr>
<th>Property</th>
<th>Baltic Sea</th>
<th>North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>- stagnation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- oxygen deficiencies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- eutrophication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- unusual algal blooms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- municipal waste waters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- wastes, pulp and paper industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- halogenated substances</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- metal works</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>Baltic Sea</th>
<th>North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>- German Bight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Southern Bight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mouths of Rhine/Meuse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- some Norwegian fjords</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- mouths of some English rivers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- other coastal areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Problem areas (except inner coastal waters):**

<table>
<thead>
<tr>
<th>Property</th>
<th>Baltic Sea</th>
<th>North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Gdansk Bay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Neva mouth/St. Petersburg area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Oder mouth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- inlet areas from metal works (e.g., Rönnskar) and from pulp and paper industry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Gulf of Riga/inner part</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Because of the close link between both seas, certain properties may be exchanged between them together with the water. This is true especially for the transition area, i.e., the Skagerrak, Kattegat and Belt Sea. For the Baltic Sea, this can be considered either positively (oxygen, salt) or negatively (nutrients, Sellafield/La Hague radionuclides).

With regard to the heavy metal load via the atmosphere, there are important differences between both seas. Whereas the atmospheric input into the North Sea comes mainly from its bordering countries, for the Baltic Sea the majority of the input is provided by non-Baltic countries.

The North Sea is considered mainly 'oligotrophic' with euphotic coastal areas, bights, estuaries and river mouths. For most parts of the Baltic Sea, the term 'eutrophic' can be applied.

4 TRENDS - SUMMARIZING REMARKS

Estimates based on expected global climatic changes assume increases in the water level over the next three decades at least in the order of 0.2 m. In the northern parts of the Baltic Sea, this will be compensated by the parallel land up-lift. In the southern parts, however, the lowering of the land will add to the increasing global trend of water levels. The problems for low-level coastal areas, with rivers draining them and having only minor slopes, are obvious.

Regarding the input of most contaminants into the Baltic Sea, no or only very preliminary statements are possible. This is due to:

a) a very weak data basis,
b) uncertainties as to how much of the gross input finally arrives in the open sea,
c) the lack of reliable historical data, except possibly for some nutrients,
d) the lack of reliable data on atmospheric inputs, i.e., immissions (Available estimates are based on measurements at the coast and on models using emission figures. This results only in data which could meet the order of magnitude of true values.),
e) partly or totally missing data for many persistent trace organic chemicals, and
f) the very limited understanding of the nature and extent of the exchange of contaminants at the interfaces with the sea bottom and with the atmosphere.
In recently published papers, the following trends have been given for some environmentally relevant parameters:

**Nutrients**

a) Loads (Baltic Sea)
   - 1900 - 1980 (PO$_4$P) 8-fold increase
   - 1950 - 1980 (PO$_4$P) 4-fold increase
   - 1950 - 1980 N 2-fold increase

b) Rates (Kattegat surface water, 1964-1987)
   - PO$_4$P 0.017 µmol/l/yr
   - NO$_3$-N 0.21 µmol/l/yr

c) Concentrations (Baltic Proper winter surface water, 1970-1980)
   - PO$_4$P and NO$_3$-N 3-fold, each

**Phytoplankton biomass/primary production**

1970-1980 2-fold, each

**Transparency (Decrease of the mean value)**

Northern Baltic Sea 1969-1986 vs. 1914-1939 2.5-3 m
Swedish coast during period 1965-1988 4 m

Until the mid-1960s, the Baltic Sea was mainly oligotrophic ("poor in nutrients"), with a high water transparency, low phytoplankton biomass, and low fish production. Presently, nearly eutrophic conditions ("well supplied with nutrients"), with a lower transparency, and an increase in plankton biomass and fish production, can be noted. For some coastal waters, even hypertrophication ("over-supplied with nutrients") is observed.

Until the mid-1950s, most of the sea bottom was populated by benthic fauna. Now, the percentage of 'desert' areas has increased, accompanied by significant changes in the composition of the benthic macroflora. For instance, the brown (Fucus vesiculosus) and red (Furcellaria fastigiata) algae have been partly replaced by a different genus of brown alga (Pilayella littoralis.)

On the whole, the negative effects of an increased primary production already outweigh the positive effects, i.e., the higher potentials for macrofauna and fish production. (Compared to the Baltic Sea, the trends observed for the coastal areas of the North Sea are partly similar in their magnitude. From about 1960 to the end of the 1970s, the PO$_4$-P concentrations increased two- to three-fold. In the German Bight, the winter values increased over the last 23 years 1.5-fold (PO$_4$-P), 1.7-fold (N-tot) and 4-fold (NO$_3$-N), respectively.)

5 GAPS

Complex open questions regarding natural phenomena include, first of all:
- the natural long-term changes and their influence on environmental conditions;
- the water exchange with the North Sea, the driving forces, the general air/sea coupling and its short- and long-term trends; and
- vertical and horizontal mixing, especially regarding the importance of upwelling events, the coastal zone/open sea exchange processes, and differences in the water residence times depending on water depth and region.

Regarding the contamination of the Baltic Sea, it is urgently needed:

- to derive early warning signals from effect studies for possible changes in the ecosystem(s);
- to separate clearly the natural from the anthropogenic causes of observed changes;
- to find characteristics for identifying 'key contaminants' in the Baltic Sea;
- to develop reliable mass balances for those 'key contaminants' aimed at identifying their main sources, sinks, and possibilities for society to influence positively future loading characteristics; and
- to develop realistic criteria regarding the quality of the water, sediments and organisms of the Baltic Sea.

6 FINAL REMARKS

In practice, the Baltic Sea was divided years ago among the bordering countries regarding their exclusive rights in their territorial waters and their privilege to exploit mineral and living resources in exclusive economic and/or fishery zones.

The claims of the countries bordering the Baltic Sea regarding zones of exclusive rights (in nautical miles; Law of the Sea Bulletin No. 8, 1986) are listed in the following table:

<table>
<thead>
<tr>
<th>Country</th>
<th>Coastal Sea</th>
<th>Continental Shelf</th>
<th>Fishery Zone</th>
<th>Economic Zone</th>
<th>Percentage of Baltic Sea (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>3</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>10</td>
</tr>
<tr>
<td>Germany</td>
<td>3 (12°)</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>3</td>
</tr>
<tr>
<td>Finland</td>
<td>4</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>16</td>
</tr>
<tr>
<td>Poland</td>
<td>12</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>10</td>
</tr>
<tr>
<td>Sweden</td>
<td>12</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>37</td>
</tr>
<tr>
<td>Russia</td>
<td>12</td>
<td>yes</td>
<td>yes</td>
<td>200</td>
<td>23</td>
</tr>
</tbody>
</table>

1 Territorial waters, calculated from the baseline
2 Until the 200 m depth line or until the border of exploitability according to the Convention on the Continental Shelf from 1958; practically, however, only until the 'middle line'
3,4 Theoretically, until the 200 n.m. border; practically, however, only until the 'middle line' or until an agreed border
5 The territorial waters of the former GDR were incorporated into the unified Germany with their maximum extension of 12 n.m.

On the other hand, these rights imply proportionally certain duties to take all necessary precautionary measures to avoid drastic changes of the ecosystems. Warning signals that this could happen may be seen. However, the question is still open regarding the main reason for the changes presently observed in the Baltic Sea. If natural processes are the dominating factors, the 'degrees of freedom' for today's industrial society to counteract them are rather limited. If it should, however, appear that Man plays the dominating role, measures for the protection of the environment could bring back major parts of the Baltic Sea to the state of an oligotrophic brackish sea.

7 REFERENCES


DISCUSSION

Dr G. Topping (Chairman of the ICES Advisory Committee on Marine Pollution) stated that, on the basis of the calculations of nitrogen inputs, it appears that the present inputs cannot account for the entire increase in concentrations in the Baltic environment. He asked whether it would appear that riverine inputs are the greatest source of nitrogen and, thus, should be decreased.

Dr Brügmann replied that the data are not complete; in particular, there are inadequate data on nitrogen in the sediments and other parts of the water column, the speciation of nitrogen, and the organic compounds of ammonium. In addition, the extent of denitrification is unknown. The figures for riverine inputs are still very scattered and incomplete. Data on atmospheric inputs are mainly based on data acquired on land, and it is very difficult to extrapolate to deposition at sea. Furthermore, there is the issue of analytical uncertainty in the measurements of the inputs of nitrogen via all these routes. Accordingly, the issue of nitrogen inputs is very complicated.

Professor U. Grimås (Swedish Environmental Protection Agency) stated that, in terms of the figures on radionuclides, one should be very cautious in the use of the word 'threat', because there is no threat to humans or marine organisms from radionuclides in the Baltic. He...
stated that, in investigations in a lake, concentrations of 20,000 Bq/kg in fish showed a positive effect on reproduction and growth.

Dr Brügmann replied that we may need to wait decades to observe some types of effects; neither do we know about synergistic effects. He stated that he was not implying that radionuclides are the most important contaminants. Organohalogen compounds are clearly more important. He felt that the greatest problem at present is eutrophication, secondly, the risk of oil contamination from accidents, and, thirdly, organohalogen compounds.

Professor F. Thurow (Federal Fisheries Research Institute, Kiel, retired) asked about the use of the term 'residence time' as being 25 to 40 years, when North Sea (surface) water containing pollutants enters the Baltic Sea on a continuous basis. He also asked, in terms of the fate of substances discharged into the water, whether there has been a quantitative evaluation of what happens to, e.g., trace metals (are they sedimented?) and hydrocarbons (are they degraded?).

In response, Dr Brügmann stated that, with regard to hydrocarbons as products of combustion, there is a high background of these compounds in the Baltic Sea, although some of them may be very old. In terms of organohalogen compounds, some of them can be degraded somewhat, but there is little information on the residence times of these compounds. The best data available are for trace metals. Much of the trace metal load is associated with fine sediment particles, however, it is not known how much of the metals in the sediments is available to re-enter the system, e.g., on a change in redox conditions from anoxic to oxic. There could be a large release of trace metals from the sediments with such a change in redox conditions, or during strong storms, when sediments may be stirred up approximately 25 m in the water column. There are no figures available on the release of trace metals from the sediments under these conditions, although it was clear that managers would be interested in having this information.
ABSTRACT
The fishery in the Baltic Sea may be almost 10,000 years old. Drastic increases in catches occurred only during the last 50 years, when the annual yield grew from some 100,000 t to 1,000,000 t. Herring, sprat, and cod contribute some 80% of the total catches. Salmon and eel are of economic importance as well. The fish biomass is not likely to have changed very much during the 20th century.

The Baltic Sea, which is almost enclosed, is a highly structured area throughout which conditions differ between regions. Fish grow slowly in the inner bays. Towards the inner bays, the number of marine species decreases and that of freshwater species increases. Migrations between feeding and spawning areas may occur over wide distances. Feeding decreases or stops in winter and during spawning. Cod is a heavy predator on clupeids.

In order to give advice on the current state of exploitation, actual fishing is compared with the level giving the highest (or almost highest) sustainable catches. These analyses indicate that the stocks of cod, western herring, wild salmon, and some flatfish are overfished to various degrees, with cod and wild salmon being in danger of depletion or extinction.

The quality of assessments and advice can be enhanced in spite of the progress made in recent years. Identification of unit stocks and the degree of mixing should be more accurate. Estimation of recruitment and mortality in the previous data year can also be improved, although estimates of biomass and projected catches have been largely correct. The evaluation of the state of exploitation is likely to be without gross error.

1 INTRODUCTION
The present situation for Baltic fish is a wealth of herring-like species and ever decreasing cod, the one species which most of us want to be more plentiful. How did this come about? Two fundamental factors could have produced the present state: nature and/or man. The environment issue was dealt with in the previous paper (see Brügmann, this volume). Other clues may be found in the fishery itself, in fish biology, and/or in the advice supplied. All of these aspects will be considered in turn.

2 EXPLOITATION
Exploitation of living resources in the Baltic Sea is thought to have started 10,000 years ago at the earliest. Fish trading only became important in about the last 1000 years. Fishing became a prominent user of the sea only during the last 50 years, when the catches rose from about 100,000 t to 1,000,000 t per year.

2.1 History of the Fishery
The Baltic Sea, like the North Sea, took its present form about 10,000 years ago. Probably the earliest information on fish consumption comes from the "kitchen middens" used since the late stone age. These are piles of remnants of food, among them fish bones and even fish hooks. Important marine species identified from this offal are herring, cod, flatfish, and eel. Scratch drawings carved on Scandinavian rocks that are up to 4,000 years old show evidence of a fishery at this time.

This information relates to the transition area between the North Sea and the Baltic Sea, as does the Nydam boat (Figure 1) from the 4th century found in southern Denmark. The vessel, built by members of a teutonic tribe, has the same features as Viking vessels 500 years later, except that it is narrower, without a sail, and the planks are sewn together instead of being nailed. Wends, slavonic tribes which invaded parts of middle Europe as far north as the southern Baltic coast by about 600 A.D., had fished with hooks, traps, and beach seines.

Fish processing and trade is first known to have occurred in Viking times. In many places around the Baltic, herring was caught locally whereas cod was frequently or exclusively transported from far away.

The fishery on herring from Skåne (southern Sweden) was of paramount importance for the Hanseatic League from the end of the 13th to the end of the 15th century. The town of Lübeck alone imported 100,000 casks of cured herring, corresponding to 10,000 t, in a single year. Salting, packing, and trading took place on a small peninsula at the southern entrance to the Öresund.
At the end of the 14th century, 40,000 vessels are said to have taken part in the fishery. Up to 400 cargo vessels (example shown in Figure 2) have been reported to have anchored in front of Falsterbo. A likely main gear was the seine. Considering that herring spawn near the coast in shallow water and taking into account the amounts of this species known to have been processed, one might conclude that the total catches may have been as high as at the beginning of this century, that is, 100,000 t.

Figure 1 Nydamboat, 23 m, 4th century A.D.

Figure 2 Buise, 1690.

In 1362 and in 1368, the League fought two wars against Denmark in order to recover the privilege to fish and trade off the coast of Skåne. Towards the end of the 15th century, herring catches declined. A resumption of the fishery was possible only some time after the industrial revolution began.

Around the beginning of the 20th century, the seine was still an important gear in the Baltic herring fishery. Set nets were used and trawls were dragged by sailing vessels, but the fishery was confined to the coast (Figure 3) for technical and legal reasons. Denmark was the first country to have her vessels motorized. Other countries followed only after the First World War, when otter board trawling for flatfish started. At this stage, the fishery entered the open sea area where vessels from different countries met. This was the beginning of the period in which common property resources were exploited. It ended some 60 years later when the Sea was divided into national fishing zones.

Figure 3 Swedish (above) and German (below) fishing areas for herring (left) and cod (right) by about the year 1900 (Wollebæk, 1904; Henking et al., 1905).

2.2 The Catches in this Century

The technical revolution is not reflected in the catches reported for the beginning of this century. These amounted to some 50,000 t in 1903 and 112,000 t in 1908. The latter figure was sustained throughout the 1920s and early 1930s (Figure 4). A considerable increase began in the 1950s and the yield peaked at 1,000,000 t by 1975. Clupeids and cod contributed some 80% in terms of weight. Salmon and eel were also of great economic importance.
Figure 4  Yield of the Baltic fishery.

2.2.1 Important species

From the beginning, herring produced the highest yields, followed by flatfish, cod, and sprat. All other species played a minor role in terms of weight. At the end of the 1930s, pair trawling was introduced. Herring catches increased slowly. During the Second World War, 85 German steam trawlers started to fish the hitherto unexploited cod in the eastern Gotland Basin, resulting in an increase in the landings of cod.

After the war, all Baltic countries developed their fisheries markedly and this led to a tremendous increase in the landings which continued until the middle of the 1970s when roughly 1,000,000 t of fish were caught in the Baltic-Belt Sea area. Note that the catches increased in steps, during the 1940s, 1960s, and 1970s. Another 400,000 t were reported for the Skagerrak/Kattegat area. The main gear since then has been the mid-water trawl. After 10 years at this level, catches dropped to less than 800,000 t in 1989. This corresponds to 2 g/m²/year compared to 4.3 g/m²/year in the North Sea.

This picture of the total yield was dominated by the herring fishery which produced almost 500,000 t in 1983, but has subsequently dropped to some 430,000 t.

Cod catches reached a level of some 200,000 t by about 1950 and remained there for almost 30 years, after which an intermediate peak of roughly 400,000 t occurred. In recent years, yields have returned to their former level.

The sprat fishery became important only around the late 1950s with the introduction of the so-called flotilla fishery with motherships and fishing vessels using mid-water trawls. The bottom trawl, used prior to this, had taken catches of 1 to 5 year-old sprat. Now with mid-water trawls, very old sprat (over 10 years of age) were being exploited for the first time. The yield reached an intermediate peak of over 200,000 t in the early 1970s and recently has remained at almost 100,000 t (Figure 4).

Salmon catches (including rivers) amounted to a few hundred tonnes at the start of this century and roughly doubled by the beginning of the 1940s. Subsequently, on the introduction of the drift-line fishery, they exceeded 3,000 t. In the years thereafter, until the beginning of the 1980s, there was a decline to some 2,000 t, followed by a steep rise to over 5,000 t (ICES, 1990a). This occurred while fishing effort was steadily declining (Figure 5).

The catches of dab in the Baltic Proper rose very rapidly in the late 1920s and reached a peak by 1931. Subsequently, they decreased to very low values in 1940, and have never recovered (Figure 5). Landings from the Belt Sea also increased very rapidly in the 1920s and reached some 1,500 t in the 1930s. Since then, there was a slightly decreasing trend until the late 1970s when they rose to about 2000 t. The data are incomplete because large amounts of small dab are discarded and not reported (Temming, 1989).

Flounder are discarded during closed seasons. In addition, fishermen from some countries fishing for cod east of Bornholm throw away all flounder caught. A comparison of research vessel and commercial data suggests that flounder catches in the Baltic Proper are up to 40% higher than reported if corrected for German discarding practices: At any rate, landings were high around 1930 and declined to very low values between 1941 and 1955 (Temming, 1989). Thereafter, they may have returned to the old level (Figure 5). In the Belt Sea, a decline is indicated for the 1980s.

The fishery for plaice in the Baltic Proper shows essentially the same picture as that for dab and flounder (Temming, 1989). Landings increased rapidly in the 1920s and declined in the 1930s. The plaice fishery started to recover in the middle of the 1950s, but this

<table>
<thead>
<tr>
<th>Species</th>
<th>1932</th>
<th>1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eel</td>
<td>0.53</td>
<td>13.75</td>
</tr>
<tr>
<td>Herring</td>
<td>0.39</td>
<td>100.99</td>
</tr>
<tr>
<td>Flounder</td>
<td>0.28</td>
<td>4.45</td>
</tr>
<tr>
<td>Salmon</td>
<td>0.19</td>
<td>23.79</td>
</tr>
<tr>
<td>Plaice</td>
<td>0.17</td>
<td>0.96</td>
</tr>
<tr>
<td>Cod</td>
<td>0.16</td>
<td>262.05</td>
</tr>
<tr>
<td>Sprat</td>
<td>0.09</td>
<td>23.64</td>
</tr>
</tbody>
</table>
reversed to a decline 10 years later. Apart from a short increase at the end of the 1980s, this decline has continued (Figure 5). Plaice has always been extremely important in the Belt Sea. However, the yield there has decreased ever since the end of the 1970s to some 200 t, so that the plaice fishery in the whole Baltic is negligible at present.

![Figure 5](image)

Figure 5 Catches of flatfish and salmon in the Baltic Proper.

The reported catches for eel have fluctuated between 2,000 and 4,000 t, but are presently declining.

In addition to the species mentioned above, smelt is of some importance, with annual catches of roughly 4,000 t reported. Yields of some other species fluctuate widely:

<table>
<thead>
<tr>
<th>Species</th>
<th>Yield (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whiting</td>
<td>100 - 7,000</td>
</tr>
<tr>
<td>Stickleback</td>
<td>100 - 19,000</td>
</tr>
<tr>
<td>Eelpout</td>
<td>0 - 9,000</td>
</tr>
<tr>
<td>Horse mackerel</td>
<td>0 - 14,000</td>
</tr>
</tbody>
</table>

2.2.2 Other species

The reported catches of all "Other Species" except herring, sprat, and cod amounted to over 100,000 t in the 1970s. This constituted roughly 10% of the total. Since the beginning of the 1980s, the proportion has decreased. At the peak of the fishery in 1984, the reported catches of "Other Species" amounted to 62,000 t or 6.2% of the total. Groups of other species contributing in 1987 were:

<table>
<thead>
<tr>
<th>Species</th>
<th>Yield (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater fish</td>
<td>13,000</td>
</tr>
<tr>
<td>Migratory species</td>
<td>13,000</td>
</tr>
<tr>
<td>True marine fish</td>
<td>32,000</td>
</tr>
<tr>
<td>Blue mussel</td>
<td>7,000</td>
</tr>
<tr>
<td>Unsorted fish</td>
<td>6,000</td>
</tr>
</tbody>
</table>

However, the data on catches of these species are thought to be incomplete. First, research vessel fishing shows species which are not listed officially (rockling, butterfish, sandeel, fatherlasher, cottids, etc.). Second, flounder and eelpout make up a much greater proportion in research vessel catches than in the reported landings. Making allowance for these factors, the "Other Species" catch of marine fish would amount to some 77,000 t in 1987 rather than the reported 32,000 t.

Since the actual catch of freshwater and diadromous species will be higher than reported, Elmgren (1984) and Thurow (1978, 1984) have estimated an "Other Species" catch for the 1970s of some 165,000 t. This finding does not change the overall picture. Apart from some fluctuations, herring, sprat, and cod played the leading role throughout this century. Their proportion in the total yield, however, is likely to be 80% rather than 90%, which is what the official catch data indicate.

3 BIOLOGY

The Baltic Sea, which is almost enclosed, is a highly structured area. The physical, chemical, and biological conditions differ between regions. This has effects on the distribution and growth of marine biota. Oxygen in bottom layers has generally declined, and salinity has decreased since the 1960s (see Brügmann, this volume) and salinity has decreased since the 1960s. Nutrients, primary production, and the biomass of non-fish demersal animals above some 70 m have all increased at the same time.

3.1 Distribution

On entering the Baltic Sea, the number of marine fish species decreases, whereas that of freshwater species increases. Fish move between spawning and feeding areas over great distances. Pelagic fish exhibit marked diurnal vertical movements, but demersal fish show this only to a lesser extent.

3.1.1 Species structure

Salinity is largely responsible for the species structure of the Baltic fish community. While over 100 marine species are represented in the North Sea, this number decreases dramatically in the Baltic Sea. In the transition area of the southern Baltic some 40 species are present but only about 20 species are found in the furthest bays.

About 40 freshwater fish species are regularly found in the Baltic Sea (Lehtonen and Toivonen, 1981). They are, however, more or less confined to coastal areas and do not regularly stay in the open sea. Indications are that they migrate very little and form small, local populations.
Species which can tolerate saline as well as brackish and nearly freshwater conditions, such as herring, sandeel and eelpout, occur throughout the Baltic (Figure 6a). Others are distributed in limited areas (Muus and Dahlström, 1968) (Figures 6b and 7). Among freshwater species, some move in more haline waters. Pikeperch, bream, stickleback, and others are found outside the coastal area of the southern Baltic, whereas at times carp and eel occur exclusively in fresh water.

There are two races of herring present in the Baltic, one propagating late in the year (autumn spawners), the other early (spring spawners). The significance of the former in terms of biomass has at times been considerable, but since the late 1970s it has been almost negligible. This race spawns in areas exposed to marine conditions rather than in bays and fjords as do spring spawners.

Sprat and cod spawn over the deeper parts of the basins where the salinity is appropriate for the eggs to float. Fish feeding far away from these places (Figures 8b and 9a) have to travel long distances to reach their spawning areas.

Baltic salmon feed in all areas from the northern bays down to the Arkona Basin. They leave these grounds in April in order to make for the home rivers in the Gulf of Riga, the Gulf of Finland and the Gulf of Bothnia (Figure 9b). Salmon from the Swedish west coast migrate outside the Baltic Sea to feeding areas in the North Atlantic, such as west Greenland.

Migration is induced by feeding and spawning. Migrations to spawning areas are relatively short in the Bothnian Bay and the Bothnian Sea, where herring remain throughout the year. Hence, both areas have their own spawning stocks. Some fish in the remaining areas have to swim much further in order to propagate, e.g., from the southern central Baltic Sea to the Swedish coast north of Gotland. Likewise, Skagerrak herring move to Kiel Bay and the Arkona Basin (Figure 8a).
Freshwater fish are practically absent from the open sea (Lehtonen and Toivonen, 1981). Anadromous species (salmonids, vimba (cyprinid), and lampreys) are absent from the entire Baltic Sea during summer, autumn, and sometimes even winter, in order to spawn in freshwater. Apart from salmon and the far-migrating group of sea-trout, the anadromous species are limited to the coastal area (Lindroth, 1981).

3.1.3 Vertical distribution

Pelagic fish, such as herring and sprat, are species which live throughout the water column. They may, however, move between the surface and the bottom depending on the season and the time of day. In addition, oxygen content and/or temperature limit their movements. During daylight hours herring and sprat are confined to deeper water. With growing darkness they move to the surface layers in order to feed. Diurnal vertical migrations are intense in spring and summer.

The seasonal distribution is depicted in Figure 10. In winter they seek warmer waters in the deeper layers, but an oxygen deficit (less than 1 ml/l) may prevent them from going there. Sprat and young herring stay above the thermocline in spring, summer and autumn, although adult herring stay closer to the bottom. The thermocline moves deeper as the season proceeds and so do the fish which, in addition, migrate away from the coast. The distribution of fish is generally patchy.

Cod in the western Baltic seem to show some vertical feeding migrations following a diurnal rhythm (Thurow, 1986). East of Bornholm, at spawning time, cod stay around the halocline at a depth of some 60 m in order to avoid oxygen deficiencies in deeper layers. Juvenile cod keep to the bottom in depths of less than 70 m, as do adult fish outside the spawning season.

During the feeding season, flounder approach the coast and can even move upstream into the rivers. They are, however, also caught in salmon driftfets near the surface in areas with depths of some 100 m or more.

3.2 Food and Feeding

The feeding intensity varies much over the year. It decreases considerably in winter and during spawning, when feeding may cease.

The first food of larvae and juvenile herring-like fish consists of algae, i.e., planktonic plants, and of early developmental stages of pelagic crustaceans. They turn to the adult stages of the latter group as they grow. Sprat and many herring remain with this type of food for their whole life span. But some herring may switch over to small fish, like gobies, and the "giant herring" may even eat stickleback and sprat (Ojaveer, 1981).

Garpike feed on clupeids, sandeel, stickleback, and crustaceous animals (Muus and Dalström, 1968). Salmon is a heavy predator on sprat and, to a lesser extent, on small herring. This is why Baltic salmon flesh is paler than that of Atlantic salmon. The amount of sprat eaten by salmon was estimated at about 15,000 t per year in the 1960s, i.e., almost three times the size of the salmon stock (Thurow, 1966).

Demersal fish, such as flatfish, cod-like species, and sandeels, eat bottom-dwelling crustaceans, molluscs, and worms (Bagge, 1981). However, cod, which grows to a much larger size than the other demersal species and has
a much larger biomass, preys on clupeids. In the central Baltic it has consumed up to 40%, and in the Belt Sea up to 20%, of the clupeid biomass. However, the consumption is more related to the stock size of cod than to the clupeid biomass (Figure 11). In the Belt Sea, both are almost identical. The average annual consumption by cod in the central Baltic is equivalent to about 80% of its own biomass. Juvenile cod, i.e., those which are not sexually mature, do not prey on clupeids (ICES, 1990b).

![Figure 11](image_url)  
**Figure 11** Amount of herring-like fish (clupeids) eaten by cod.

3.3 Growth and Fishery

The annual growth increments for fish, both in length and weight, decrease moving from the North Sea deeper into the Baltic Sea (Figure 12). Population density may have an effect on growth rate as well. At age 3, plaice in the North Sea can reach a length of some 27 cm (Rauck, 1975), compared to some 30 cm in Kiel Bay where its density is probably less than in the North Sea.

The growth rates of different fish species differ very much (Figure 13). Salmon, after 5 years of life in the Baltic Sea, reach an average weight of some 12 kg. This is 6 times that of cod, 15 times that of flounder, 120 times that of herring, and 750 times that of sprat. However, the stock biomasses show an inverse pattern; salmon at age 5 account for only 10 t, sprat for 30,000 t, cod and herring 200,000 t each (ICES, 1991).

<table>
<thead>
<tr>
<th>Species</th>
<th>Sub-division</th>
<th>P</th>
<th>B</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herring</td>
<td>22-24</td>
<td>1.7</td>
<td>2.8</td>
<td>2.9</td>
</tr>
<tr>
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<td>25-27</td>
<td>1.4</td>
<td>3.8</td>
<td>4.5</td>
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<tr>
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<td>2.6</td>
</tr>
<tr>
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<td>26,28</td>
<td>0.7</td>
<td>2.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Cod</td>
<td>22-24</td>
<td>1.9</td>
<td>2.7</td>
<td>3.0</td>
</tr>
<tr>
<td>Cod</td>
<td>25-32</td>
<td>2.5</td>
<td>3.5</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Table 2 gives the age at which 50% of the total production, biomass, and yield of a year-class are achieved in about 1980. The differences between the 50% ages of yield and production show that the fishery made better use of the production capacities in the central Baltic (Sub-divisions 25-28) than in the Belt Sea (Sub-divisions 22-24). Those ages which made the greatest contribution to production were lightly exploited in the central Baltic, whereas considerable proportions were fished in the Belt Sea. This finding produces a new argument in favour of the protection of younger age groups. So far, only attainment of the age of first sexual maturity has been used (Thurow, 1984).

4 STATE OF EXPLOITATION

Estimates of the state of exploitation of fish stocks have been made by assessment working groups of ICES since about 1970. These appraisals have been conducted regularly for the three most important species, herring, sprat, and cod. A longer time series, starting in about 1960, is available for cod (Kosior, 1975). Flatfish species, flounder, plaice, and dab have been covered sporadically by working groups and individual experts (Bagge and Nielsen, 1989; Temming, 1989).

4.1 Early Development of Biomass

An analysis of the total biomass of fish in the Baltic Sea suggests that it has not changed very much (Thurow, 1991). The analysis is summarised in the following sections.

4.1.1 The main species

Herring stocks are suggested to have been at a very low level from 1920 to 1950, but increased many-fold during the following twenty years. Since catches followed the same pattern, this would indicate that the fishing effort has not changed very much between 1920 and 1970.
Catches increased because of the higher biomass. Other information, however, suggests that greater effort procured higher yield (Figure 14). Sprat biomass appears to show a pattern similar to that of herring (Figure 15).

A different development has been noted for cod. A low stock level from 1920 to 1940 was followed by a much higher, roughly constant level for almost 40 years. Around the beginning of the 1980s there was a further increase of biomass to an all-time record level. This was counterbalanced by correspondingly low levels in sprat and in herring biomass at the same time. Catch-per-effort data (Kandler, 1944; Sahlin, 1959) support the projected increase in biomass in the 1930s (Figure 16).

4.1.2 The total fish community

Assuming that other species have been fished at the same level as clupeids and cod, total biomass has been estimated and is shown in Figure 18 as indicated by broken lines. This shows essentially the same pattern for herring and sprat.

Let us look for a moment at the development of fishing mortality as indicated by yield per biomass (Y/B) for the entire fish community. Figure 17 suggests that fishing has increased rather steadily and has doubled since the 1920s. There was, however, no known open sea fishery on the three main species before the middle of the 1930s. Except for flatfish, trawling was only developed in the 1950s. Compared to the 1920s, effort has increased many-fold (Thurow, 1991).

In light of this information, it appears that some predator other than man has also participated in fishing. Seals and porpoises were very common in the early decades of this century. Elmgren (1989) estimated that they consumed some 320,000 t of fish per year at that time, and that they accounted for much more natural mortality of fish than other sources. Actually, mammals and man together took some 450,000 t of fish per year by the beginning of this century. This is about half the amount presently caught by man, whereas the marine mammals have been reduced to less than 5% of their original number. This result corresponds nicely with the doubling of mortality shown in Figure 17.

ICES (1987) and Almquist (1982) suggest that hunting was the main cause of the decline in the numbers of marine mammals, and that hunting increased in the 1930s. Seals and porpoises were a nuisance in the salmon fishery until about 1970. After that, seals were rarely seen. Assuming that populations of marine mammals were gradually reduced between 1930 and 1970, their yields have been added to those of man and the mortalities were used to estimate new biomasses as depicted in Figure 17. These are shown in Figure 18 as full lines.

It appears that the total fish biomass between 1919 and 1960 was between 3,000,000 and 4,000,000 t. The indication is that it grew to almost 6,000,000 t by 1970 and declined thereafter.
Nutrient concentrations have increased many-fold since the late 1950s. Primary production is said to have risen during the 1960s in some parts of the Baltic. Whereas the macrobenthic communities of the deeper bottoms have been wiped out, these communities increased several-fold in shallower water above the halocline (Elmgren, 1989; Wulff et al., 1990). This growth in productivity corresponds nicely with the above-mentioned gain in fish biomass.

The declining trend of total biomass since 1970 has been brought about by a corresponding reduction in stock sizes of herring-like fish, and sprat in particular.

4.2 Present States of Exploitation

A number of fish stocks in the Baltic are overfished to various degrees.

4.2.1 Definitions

In order to evaluate the state of exploitation, i.e., to see whether a stock is in danger or not, working groups first estimate actual fishing mortality (F) for the last data year. This value is comparable to the yield as a proportion of the stock. Curves of yields for different levels of exploitation are then calculated. On these curves, biological reference points of fishing mortality are marked. They indicate desirable levels and the range outside which fishing could be hazardous, as shown in, e.g., Figure 22. F_{max} is the fishing mortality at which the yield would be maximized in the long term. For some species, the yield curve has no maximum. F_{0.1} is another reference point which is somewhat lower than F_{max}. However, it gives greater security for sustainability. Finally, F_{mod} is a reference point based on the history of the stock and represents a level of fishing mortality which should be safe when sustained in the long term. Fishing up to this level of exploitation has done no harm to the stock in the past, although it may exceed the maximum yield (and the lowest costs) quite considerably.

Finally, the actual exploitation is compared with these reference points. This information enables catch projections and advice for future fisheries to be made. For these, the number of fish recruiting to the exploited stock must be known. In addition, the other losses are needed as well, i.e., mortalities from natural causes, such as predation (Figure 11).

4.2.2 Herring

The Herring Assessment Working Group formerly dealt with up to eleven management units of herring, but has recently reduced this number to four. The reason is that stocks in the Baltic Proper, the Gulf of Finland, and the Gulf of Riga mix during much of the year and cannot be separated. Figure 14 shows that the total biomass of all stocks declined in the late 1970s but recovered thereafter. Let us look at the two largest units.

In the southwestern Baltic Sea and the Kattegat, catches and spawning stock biomass have increased since 1976, although mortality remained stable since 1979, as did recruitment (Figure 19). The stock is not in danger, but is over-fished at a level four times F_{0.1}, indicating that it is not being optimally exploited.

Herring in the Baltic Proper make up some 70% of the total biomass of the species. During the period monitored, fishing has had no adverse effect on recruitment or biomass, and the spawning stock has remained stable throughout the last 10 years (Figure 20). This stock has been fished close to F_{0.1}.
4.2.3 Sprat

Three management units of sprat were dealt with until 1988, when it was decided to consider sprat in the Baltic as a single stock. Figure 15 shows the development of total stock biomass, and Figure 21 depicts that of the spawning stock biomass. Fishing mortality was very high until 1979 and total biomass was steadily and drastically reduced from the beginning of monitoring until 1980. By 1982, when fishing mortality had declined to some 60% of the former level, the stock began to recover and has done so ever since, even though fishing is less than 30% of the former level and much below $F_{0.1}$.

4.2.4 Cod

Cod in the Belt Sea and the Arkona Basin keep largely separate from those east of Bornholm. The former stock has been fished upon very heavily at a rate almost four times that required to yield $F_{\text{max}}$ (Figure 22). The yield decreased considerably after 1984, but biomass shows a declining trend since 1974, as does recruitment. This picture is even more pronounced for the Belt Sea. The stock is considered to be depleted. Given the recent poor recruitment, improvements, if any, can only be expected from a drastic reduction in fishing.

Fishing mortality on the large cod stock east of Bornholm experienced a declining trend in effort until 1979, while biomass and catches rose (Figure 23).

This increase was intensified by a series of good and very good year classes hatching from 1975 to 1981. The stock size more than tripled, and so did the resulting catches. However, when recruitment, and subsequently biomass, started to return to the former level, the fishing effort was increased so as to maintain the level of yield. This accelerated the decline in stock size. Additionally, recruitment fell below any level measured since 1960. This stock is considered to be recruitment over-fished. Not only did fishing surpass the highest catch, it additionally took so many spawners that recruitment was significantly reduced.

4.2.5 Salmon

This fishery is supplied by salmon smolts, which enter the Baltic after 1-5 years in their home rivers. Subsequently, they grow up to fishable size within a little more than a year. The smolt production is estimated to have been over 7,000,000 around 1900. This number had decreased to 2,000,000 by about 1970. To counterbalance this, Sweden (and later other countries) started to rear smolts artificially in the early 1950s. Their numbers exceeded 1,000,000 by 1961 and were approaching 6,000,000 in the 1980s, whereas the natural production remained around 1,000,000, i.e., some 15% of the total (ICES, 1990a).

Figure 24 shows that biomass has been increasing since 1982 to some 7,000 t. This is exclusively due to the rise in artificial smolt numbers. Escapement from smolt stage to spawning for wild stocks is between 0.6 and 2.6%, i.e., much too low. These natural stocks are therefore overfished and in danger of extinction.

4.2.6 Dab

Among flatfish, dab is a more euryhaline animal; it also requires a higher oxygen supply than the others, and has the slowest growth rate. In spite of this, it is at present a successful species in the Belt Sea area.
Figure 19  Herring in the Western Baltic and Kattegat: Yield, Fishing mortality (F), Spawning Stock Biomass (SSB), Recruitment (R), and State of Exploitation (ICES, 1990).

Figure 20  Herring in the Central Baltic, Gulfs of Finland and Riga: Yield, Fishing Mortality (F), Spawning Stock Biomass (SSB), Recruitment (R), and State of Exploitation (ICES, 1991).

Figure 21  Sprat in the Baltic: Yield, Fishing Mortality (F), Spawning Stock Biomass (SSB), Recruitment (R), and State of Exploitation (ICES, 1991).
Figure 22  Cod in the Belt Sea and Arkona Basin: Yield, Fishing Mortality (F), Spawning Stock Biomass (SSB), Recruitment (R), and State of Exploitation (ICES, 1991).

Figure 23  Cod in the Baltic east of Bornholm: Yield, Fishing Mortality (F), Spawning Stock Biomass (SSB), Recruitment (R), and State of Exploitation (ICES, 1991).

Figure 24  Biomass of salmon and artificial smolt production in number.

In the 1920s and 1930s, dab was largely exploited as a by-catch in the fishery directed towards plaice and flounder in the Baltic Proper. Subsequently, it was caught in the cod fishery. However, in the beginning, the species was discarded and only later were ages 3 and older marketed. Since few of the discarded fish survive, the mortality caused by fishing is much higher than the amount landed would suggest.

Catch per effort in the Baltic Proper shows that biomass has followed a trend similar to that of catches (Figures 5 and 25). Around the 1930s, the environmental conditions were such that successful spawning was possible. Dab in the Bornholm and Gdansk Basins formed a separate stock.

The limits of distribution today are in the Arkona Basin. Density increases as one moves to the northern approaches of the Belt Sea. An assessment for this area shows that the actual catches are four times greater than the reported ones (Temming, 1983, 1989). The investigation also suggests an increase in total biomass from
some 10,000 t in the 1950s to almost 20,000 t in the early 1980s (Figure 26). Fishing mortality was found to be very high (Z = 1.5).

Figure 25 Density of Flounder and Dab, Swedish landings/vessel/year (Sahlin, 1957; after Temming, 1989).

Figure 26 Spawning stock size of Dab and Plaice in the Belt Sea (Bagge and Nielsen, 1989).

4.2.7 Flounder

Flounder assessments are not very reliable because of the shortcomings in the catch statistics. Swedish density data do suggest, however, that the decline in the catches during the 1930s was accompanied by a decrease in stock size and that the stock remained low until 1955 (Figure 25) (Sahlin, 1959). Working Group appraisals for the years since 1970 gave biomasses of between 60,000 t and 100,000 t for the entire Baltic. Most stocks are lightly fished, but southeast of Gotland fishing mortality exceeds F_{max} as does the fishery in the Belt Sea.

4.2.8 Plaice

Plaice has no current importance in the Baltic Proper. An analysis in the 1970s suggested over-fishing but no reliable assessment was made. Recruitment has declined (as it has in the Belt Sea) since the end of the 1970s, and so has biomass (Figure 26). This assessment is based on data which includes the years up to 1986 (Bagge and Nielsen, 1989). Subsequently, catches have declined further to less than 200 t in 1989. Since plaice is being exploited as a by-catch in the cod fishery, it is likely that biomass has decreased in the same way as catch.

Bagge et al. (1990) have shown that recruitment and the biomass of cod, flounder, and plaice in the Kattegat were reduced in the same way as in the Belt Sea, but that dab and sole increased there. They suggested that the decline might be associated with a change in the composition of phytoplankton species to the disadvantage of plaice and cod larvae and to the benefit of dab.

4.3 Summary

Total fish biomass between 1920 and 1960 is estimated to have been in the range of 3-4 million t. A steep rise to some 5,500,000 t occurred in the 1960s when general productivity increased as well. Since 1970, a declining trend has been observed.

It can be stated that the herring stock between the Kattegat and the Arkona Basin is over-fished, i.e., not at a rate giving highest yield and stability, although it is in no danger. All other herring units and the sprat stock are under-fished or optimally exploited.

Both cod stocks are overfished, the Belt Sea stock being depleted, the Baltic Proper stock being recruitment overfished. Both of them are in severe danger.

Among the other species mentioned, wild salmon and some flounder stocks are heavily over-fished in the Baltic Proper. Dab and plaice have practically disappeared there. In the Belt Sea, the dab stock is in good condition whereas flounder and plaice are decreasing (Table 3).

5 INSIDE THE ASSESSMENTS

Estimates of biomasses and future catches can still be improved, but the evaluation of the state of exploitation is likely to be correct.

5.1 Procedure

Data collection has to take place regularly over several years before assessments can be considered reliable.

The basis for assessments is the catch in numbers distributed by age groups. This requires length and weight measurements and age readings from market sampling. Statistics are completed by analysing by-catches and the landings of other fish compared to the amounts of the target species. Discard evaluation is of great importance for some stocks.
Table 3  

<table>
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<tr>
<th>Stock</th>
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<th>$F_{0.1}$</th>
<th>$F_{\text{max}}$</th>
<th>$F_{87-90}$</th>
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<tr>
<td>Herring</td>
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</tr>
<tr>
<td></td>
<td>25-29, 32</td>
<td>0.19</td>
<td></td>
<td>0.21</td>
<td>Well-fished</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>0.26</td>
<td></td>
<td>0.09</td>
<td>Under-fished</td>
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<td>0.22</td>
<td></td>
<td>0.07</td>
<td>Under-fished</td>
</tr>
<tr>
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<td>0.17</td>
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<td>Cod</td>
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<tr>
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<td>0.96</td>
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<tr>
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<td>&gt;2</td>
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<tr>
<td>Dab</td>
<td>22</td>
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<td></td>
<td>1.5</td>
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</tr>
<tr>
<td>Flounder</td>
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<tr>
<td></td>
<td>24,25</td>
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<td></td>
<td>0.36</td>
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</tr>
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<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td>29,30</td>
<td>0.37</td>
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<td>0.21</td>
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</tr>
<tr>
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<td>32</td>
<td>0.34</td>
<td></td>
<td>0.20</td>
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<td>Plaice</td>
<td>22</td>
<td></td>
<td></td>
<td>0.62</td>
<td>Over-fished?</td>
</tr>
</tbody>
</table>

The conduct of young fish surveys for data on recruit numbers and the collection of commercial effort and catch per unit effort information are the other cornerstones of the assessment. Effort time series from all countries are calibrated against the corresponding fishing mortalities. Hence, fishing mortality for the last data year can be found from the effort exerted for that year.

The assessments are conducted by the assessment Working Groups and the results are then reviewed by the Advisory Committee on Fishery Management (ACFM), which formulates the advice on behalf of ICES for the IBSFC and other fishery commissions.

5.2 Interpretation of Results

Man is not the only disturbing factor in the environment of fish. If one sees that a stock shows a declining trend, possibly along with increasing fishing effort, one is inclined to conclude that this is an effect of over-fishing. But there are predators in addition to man, such as marine mammals, and there are other conditions affecting stocks. The latter are not sufficiently understood although they may lead to stock decline (e.g., Baltic cod and sprat) or even permanent extinction.

The fish eaten by cod (Figure 11) consist mainly of clupeids. Considering the large amounts eaten, one may expect that cod has caused, or contributed to, the decline in the sprat biomass prior to around 1980. Does this allow the conclusion that the fishery manager does not have to care about the state of a stock, once a powerful competitor is at work?

Clearly, this is not so. On the perception of the drastically declining stock of sprat at the end of the 1970s, fishing should have been reduced. The rapid recovery resulting from the extremely strong 1982 year-class was a fortunate situation which can not always be relied upon.

The cod stock east of Bornholm experienced a similar development in the opposite direction. In spite of sustained fishing pressure, biomass more than tripled around 1980 (Figure 23) and has now returned to the former level. This is an example of natural population fluctuations. Fish stocks, like other populations, can exhibit cycles. Man cannot prevent natural decreases of stocks or extinctions. Fisheries can, however, be adjusted to the existing stock size so as to make the best use of the resource.

The size of the stock of cod in the Belt Sea has decreased since 1974, most rapidly since 1985. Recruitment shows a declining trend from 1976 onward (Figure 22). It is still an open question as to whether the fishery and natural events together, or one of them alone, has caused this decline.
Again it must be stressed that, no matter what the influence of nature is, the fishery should be adjusted so that it does not put stock sustainability at greater risk.

5.3 Quality of Assessment and Advice

It has been stated above that estimates of the fishing mortalities by age for the last data year and of the strengths of recent recruitments are needed as inputs to the assessments. In addition, losses to the stock other than those resulting from fishing must be known. The reliability of the advice largely depends on the quality of these inputs to the analysis. Sjöstrand (1989) and Weber (1989) have evaluated the effects which the input parameters had on the assessments up to 1985. Their results showed large differences between original and final estimates of recruitment and fishing mortality.

Much of the discrepancy can be attributed to the inadequate data during the early years of assessments. The advice was often based on the assumption of averagerecruitment and mortality.

As an example of the present situation, the quality of estimates for the cod stock east of Bornholm is shown in Figure 27. Original and final (1990) estimates are compared. There is still a high deviation. For example, the fishing mortality evaluated in 1984 for the year 1983 was about 0.8. Seven years later, the mortality for 1983 was estimated at 0.55, i.e., 30% lower. More importantly, the agreement between the two evaluations as compared to earlier years has improved and the trends are the same in both of them.

The species biomasses as evaluated in 1987 and 1990 are given in Figure 28. Differences of about 1,000,000 t are obvious for herring. These are due to the new definition of the large unit stock in the central Baltic. The differences in cod are smaller but still considerable, and these can be attributed to the change of the assumed natural mortality from 0.3 to 0.2 in the central Baltic. Small differences are found for sprat.

Figure 28 Total biomass of species in the Baltic, estimated 1987 and 1990 by assessment working groups.

Overall, working groups cannot be content with the present assessments. Identification of unit stocks of herring should be improved and their mixing analysed. There is also room for a better appraisal of recruitment and fishing mortality for the last data year. Figures 27 and 28 give information on past errors in assessment. Currently, there is no way to estimate how good the most recent approximations are. The Working Group on Multispecies Assessments of Baltic Fish, however, has been able to make firmer estimates of natural mortality for herring and sprat in the Baltic Proper. All countries are now participating in young fish surveys and new sub-divisions are being monitored. The general feeling, therefore, is that improvements toward more accurate assessments are steadily being made.

Natural mortality and weight at age data are needed as input for yield per recruit analysis. Since this information is at hand, the appraisal of the state of exploitation is less susceptible to errors than that for biomass. This part of the analyses is likely to be without major error.

Assessments have clearly been erroneous with regard to biomasses and projected catches. There has been no substantial error in the estimates of trends of biomasses and catches. More importantly, the appraisals of the states of exploitation have been correct.
6 REASONS FOR CHANGES IN STOCKS AND FISHERIES

Let us see whether the results presented here can explain the changes in the stocks and fisheries.

Salinity in bottom waters has shown an increasing trend during the first half of this century and a decreasing trend thereafter. Oxygen content in bottom layers has exhibited a declining trend since about 1900. Both features may have reduced the potential egg survival of sprat and/or cod, and hence influenced their recruitment. The abundance of offspring of cod actually shows declining trends since the 1970s (Figures 22 and 23). This is, however, not obvious for sprat (Figure 21). Also, the minimum volume of suitable water permitting maximum recruitment is not known. We, therefore, have no clear-cut evidence for a measurable effect of changes in salinity and oxygen on biomass.

Nutrients, phytoplankton production, and non-fish bottom-living biomass increased in the 1960s and early 1970s. This rise nicely parallels the growth of fish biomass at the same time.

Predation by marine mammals affected fish biomass until about the middle of the century (Thurow, 1991). Cod may have contributed to changes in the biomass of herring-like fish.

Trends of total biomass until about 1960 (Figure 18) are uncertain because of the wide confidence limits for the estimates (Figures 14-16). The increasing trend during the 1960s is thought to be better documented. Analytical assessment started for the year 1970, and the declining trend thereafter is found to be reliable.

How did all of this affect the catches? The first rapid growth in yield prior to 1957 (cod and herring, Figure 4) is likely to have been brought about by more fishing activity. The following sharp rise (herring-like fish, 1965-1968) may be attributed to increasing biomass. The further increase in 1970-1975, and the largely unchanged level until 1984, would also have been due to increases in effort.

The long-term variation in catches can thus simply be explained by changes in biomass and fishing effort. The question is, did fishing affect biomass as well? This issue was treated in Section 4.2 on the states of exploitation. There is no doubt that fishing has contributed to, or exclusively caused, the collapse of the cod stocks. It has also been instrumental in the decline of wild salmon and the sharp decline of sprat in the 1970s.

It may be concluded, therefore, that fishing has done more harm to itself than any other agent.

REFERENCES


DISCUSSION

Professor Draganik (Sea Fisheries Institute, Gdynia) agreed with Professor Thurow that the wild salmon stocks are being heavily exploited in the Baltic, but he questioned whether they were being over-fished given that it appears that recruitment is not declining.

Professor Thurow replied that he had stated that these stocks are over-fished, but did not mean to imply that they were necessarily recruitment over-fished.

Dr Karnicki congratulated Professor Thurow on an excellent presentation. He asked whether the depleted Baltic cod stocks could be enhanced by the release of artificially reared fish such as had been done successfully in some Norwegian coastal areas.

Mr N.A. Nielsen (Danish Institute for Fisheries and Marine Research) pointed out that experimental releases of young cod on the west coast of Denmark had demonstrated that such an exercise is biologically possible, but that it is probably not economically feasible. There was a very high (80%) mortality rate due to predation of 0-group fish and, although this would probably be less in the Baltic, it is doubtful if such an enhancement project would be viable.

Dr Horbowy (Sea Fisheries Institute, Gdynia) said that predation mortality in the Baltic is also high and not much lower than in the North Sea; it has been calculated to be about 75% for the first two years of life.

Dr B.-I. Dybern (Institute of Marine Research, Lysekil) noted that some similar experimental work had been done in Sweden. It had proved necessary to rear the cod in higher salinity water from the west coast of Sweden, which meant that the fish would have to adapt to the lower salinity Baltic water for the releases to be successful. For any such enhancement exercise to have an impact on the stocks, it would have to be on a very large scale, hence international cooperation would be essential.

Mr P. Tørring (Denmark) could not envisage cod stock enhancement becoming a practical proposition because the early life stages are too expensive to rear.

Dr F. Serchuk (Chairman of the ICES Advisory Committee on Fishery Management) informed the meeting that enhancement experiments undertaken at the Woods Hole Laboratory in the USA in the 1870s had proved unsuccessful, but it may be that the techniques used have improved since then, particularly with regard to selecting the time and place of release. He also made the point that it is often argued that because the quantity of fish taken by predators is greater than the catch, it is not justified to control fishing; this argument is flawed, however, because it does not take into account the large differences in the size spectra of fish taken by predators and by fishing.

Professor Thurow agreed emphatically with the latter point. Predation is highest on age groups 0 and 1, and it is essential to manage what is left after the predation phase; in most species there is still a considerable potential for growth in the older age groups. Fishing activity should be adjusted depending on the state of the stock.

Mr E. Aro (Ministry of Agriculture and Forestry, Finland) said that the migration patterns for cod described by Professor Thurow had not applied in recent years. Cod are no longer found in the Gulf of Finland, for example. Also the vertical distribution patterns of herring have changed, probably because haloclines are not so marked as before and this has affected the distribution of prey species.

Dr J. Netzel (Sea Fisheries Institute, Gdynia) made the point that the cod distribution had changed before and it seemed to be related to stock size. Historically there have been periods of good cod fishing, generally about 50 years apart. Strong year classes have only been observed when larval conditions were good in the eastern Baltic.

Dr W. Weber (Federal Research Board for Fisheries, Kiel) questioned whether Dr Brügmann should consider high nutrient inputs a "problem" in the Baltic if, as suggested, they lead to greater productivity from fish stocks.

Dr Brügmann conceded that the beneficial effects of eutrophication may outweigh the negative ones but the problem is that the effects are not properly understood and so cannot be evaluated. To consider this properly it is necessary to take in to account all factors, for example, the effects of trawling on the sediments.

Dr Ferm asked Professor Thurow how sure he was that fishing has done more harm to itself than any other factor.

Professor Thurow said he believed this to be the case and he was certain of it for recent years, especially 1990. Even if there is a decline in nutrient inputs, fishing cod at the optimum level would, in his view, produce higher yields than if the present level of fishing is maintained. He commended Poland for consistently arguing for lower total allowable catch levels than other countries during management negotiations.

Dr P. Tulkki (Institute of Marine Research, Helsinki) asked what effect oxygen depletion in the Kattegat had on fish stocks and fishing.

Professor Thurow referred to a study by Bagge and Nielsen which showed that reduced oxygen levels and an associated spread of algal growth on the bottom had a marked effect on plaice and other fauna.
ABSTRACT

The conditions for decision making influence the type of decisions that are made and the difficulty of the decisions. When conditions are complex, a large amount of detailed knowledge is needed, but the difficulty is that a fragmented overall picture may arise. The collective decision-making processes which have emerged for the management of the sea may not be able to use the available information efficiently. The challenge to fisheries science is to provide a coherent assessment of the state of the resources and the fisheries. These assessments should be integrated with similar information from other disciplines in order to arrive at a synthesis which can provide a platform for sustainable use of the sea.

1 INTRODUCTION

Fishing, administrating fisheries and the environment, and using the sea for various purposes all boil down to making decisions. Fishermen consider the alternatives of investing in a new fishing boat or finding another source of income. Fisheries administrators and politicians negotiate national quotas and decide on regulatory measures to keep fishing from overshooting the quota. Similar problems are faced by environmental administrators: should an industry be allowed to discharge waste, and if so, how much? An industry or a municipal waste water plant has to make choices between different techniques of production and different locations. The role of applied science is to give guidance to all these decision makers.

Any decision can be evaluated as right or wrong in relation to the objectives and values of a single decision maker. The sea is, however, not used or managed by a single decision maker and the classification of decisions into right and wrong is therefore not easy. A simple example is a ban on offshore fishing for salmon. To the offshore commercial fishermen this is fundamentally wrong, whereas recreational fishermen will support the decision.

Despite the conflicts in the objectives and values between different users of the sea, there is a need to find a common denominator. In several international agreements, the concept of sustainability has been accepted as a starting point. The problem with this decision is that sustainability is perceived differently by different actors and therefore it can be very difficult to agree on an overall sustainable strategy for the use of the sea. Conflicting objectives and values, and different conditions for making decisions, cause difficulties in the formulation of international agreements. This paper considers two important factors involved in international decision making. First, I examine the background of the decisions to be made in exploiting the fish resources of the sea. Thereafter, I turn to the role of fisheries science and the possibilities it has to provide guidance for a sustainable strategy.

2 CONDITIONS FOR DECISION MAKING

In the simplest case the conditions on which the decision is based change randomly from one occasion to the next. The randomness dominates so that today is a poor predictor for tomorrow. An inexperienced fisherman who knows little about the area in which he is fishing can experience catches as random events. Under such conditions there is little point in having long-term strategies and, in this case, a concept of sustainability becomes almost meaningless. It is simply a question of making the best of a situation as it arises.

Hardly anything changes completely randomly. In most cases it is possible to identify some long-term tendencies or functional relationships. Even the amateur fisherman knows that catchabilities increase during the spawning time. Such knowledge can be taken into account in strategic decisions on when and where to fish. The better the knowledge of the long-term changes and their causes, the better the strategy that can be established, and the easier it is to formulate a sustainable strategy.

Despite knowledge of long-term changes in the environment, a strategy may lose significance if another decision-maker interferes with an alternative strategy. Catches along a migratory route may suddenly drop if an intensive fishery develops downstream or if the flow of water is affected by water regulation upstream. This results in an interplay between the environment and several strategies with different objectives or underlying
values. A combination of individual sustainable strategies does not necessarily result in overall sustainability.

A complex situation arises when both the environment and the strategies of decision makers change. From the point of view of a single decision maker, the rules of the game appear to change and what was previously useful information turns out to be of limited value. The conditions for decision making are thus turbulent. A sustainable strategy cannot be fixed once and for all, because what appears sustainable today may not be sustainable in the future. The strategy will have to be flexible and able to adapt to new conditions. If, for example, conditions change so that the survival of juvenile fish deteriorates, a quota based on a fixed proportion of the stock may turn out to be too high. The new environmental conditions must be taken into account and the strategy must be adapted accordingly.

These examples are, of course, caricatures, but they provide a useful background when we look at the decisions of the fishing industry, individual fishermen and fisheries administrators. This will give us a starting point for a discussion of the role of fisheries science and the demands on fisheries science, which is the main objective of this paper.

3 DECISIONS IN THE FISHING INDUSTRY

A coastal small-scale fisherman is fairly confident that the basis for his fishing, the fish stocks, the possibilities to fish and the consumers of fish will exist in the foreseeable future. He is, however, willing to accept considerable fluctuations in catches and earnings from day to day and year to year. The underlying assumption is that, on the average, things will cancel out. Such a strategy is possible when the turnover is modest and the amount of capital and loans small. Previous experience gives enough information for investment decisions and decisions on whether to fish or not under particular weather conditions.

Small-scale fishing can only support small-scale marketing or processing. With increasing urbanization, the demand for mass-produced fish has increased. In addition, many coastal fishermen have lost in the competition with other users of coastal waters, such as dischargers of waste, sea shore developers and recreational users. These conditions have contributed to the rise of industrial fishing.

The decisions of an industrial fishing enterprise are more difficult than those of an individual coastal fisherman in the sense that the assumption of constant average conditions is no longer valid. In large-scale fishing, investments are considerable and debts have to be paid off within a fixed time span, demanding a fairly constant income. The competition for fish increases and stocks may be depleted as a result. National governments control fishing by national management measures or subsidies. International agreements may have a considerable impact on fishing possibilities. The fisherman no longer has complete control over his fishing, and his personal experience of fish stocks and fishing conditions is not sufficient for reaching the best long-term decisions. The "rules" which every fisherman has had to accept, that is, that the fortunes of fishing are largely determined by recruitment variability and weather conditions, are only partly valid. New "rules" which do not relate to fishing per se become increasingly important. The outcome of international negotiations, changes in policies of loans, subsidies or taxes, and the scientists' perception of the state of the stocks may boost or end the career of a fisherman. It is thus natural that many fishermen feel that the rules of the game change continuously and that decision-making conditions are turbulent. This is one of the reasons behind the desire for stability expressed by the fishing industry during the previous Dialogue Meeting (Goodlad, 1990).

4 DECISIONS IN FISHERIES MANAGEMENT

National administrations have a long history of interest in fisheries. For example, a general law on fishing was declared in Sweden in the 18th century, and local regulations are much older. For the national government, the motives of fishing regulations have been primarily economic, but a concern for the well-being of fish stocks can also be found in early documents. Local fisheries management has been practised in many areas with particular emphasis on the protection of stocks. Fishing communities have limited fishing to certain times, set aside certain areas for the protection of spawning and limited the efficiency of certain gears.

Early management decisions were based on concrete information - the time and place of spawning, the existence of particularly valuable resources which the crown wanted to obtain, etc. Fluctuations were unavoidable, but there was confidence in the average conditions. Thus, decisions could be made assuming some stability which justified a constant and fairly simple long-term strategy. When special problems arose, ad hoc committees with experts and data on the particular problem could be expected to solve them, because it was only a question of re-establishing average conditions.

Recent developments in fishing have changed this. At the time when most salmon were caught at the river mouths or in the river, each river could be managed individually as a unit. A rule which forbade damming of the migratory route was acceptable and sufficient to ensure sustainability. With offshore and extensive coastal fishing, this is no longer possible. Today fisheries managers
must deal with a large number of different groups of fishermen whose varying strategies influence the managers’ possibilities for action. In addition, new actors have entered the scene: politicians who wish to influence details of the management, consumers’ groups, environmentalists, recreational users, and a large number of users for which the sea is not at all a source of fish but a waste disposal area. So far these new actors have mainly participated at the national level, but they will no doubt enter the international scene in the near future. The ban on drift netting is one example where considerations outside ordinary fisheries management have affected decisions.

The changes in the fisheries have made the fisheries managers’ decision-making conditions turbulent. Simple long-term strategies cannot be used, because the rules on which they are based rapidly lose significance. Furthermore, seemingly small decisions of little immediate significance turn out to be traps and the fisheries are compelled to move in unwanted directions driven by the "tyranny of small decisions". Subsidies provide ample evidence of this. For example, a small subsidy to assist the marketing of surplus herring during spawning time ultimately aggravated the marketing situation because it provided an incentive to increase fishing during spawning time (Hilden and Mickwitz, 1990).

The decision-making conditions of managers have been complicated by fisheries scientists who suggest that the concept of managing single species in isolation is no longer valid. It is no wonder that many managers feel that they have entered a painting of Hieronymus Bosch (M. Holden at the ICES Multispecies Conference in The Hague, 1989) instead of a classic orderly landscape painting with benevolent and happy fishermen.

5 THE ROLE OF FISHERIES SCIENCE

Although the concept of sustainable use of resources has been widely accepted, experience has demonstrated that the route from theory to realization is long and difficult. Scientists have been expected to be able to tell what to do in order to achieve sustainability, and suggestions for how to optimize the use of resources are abundant in theoretical literature. Optimality implies something which is better than all other conceivable alternatives. Looking for a single global optimum is, however, comparable to chasing the wind. It is difficult to reach an agreement on what to optimize and in most cases so many varied and conflicting constraints are raised that the problems become intractable.

Given the turbulent decision-making conditions of both the fishing industry and fisheries management, what is the role of fisheries science?

5.1 Gaps in the Knowledge of the Fisheries

There are both short-term and long-term decisions to be made. ICES has attempted to serve short-term decisions by providing, on request, estimates of catches and recommendations for Total Allowable Catches (TAC) for the following year. Intermediate-term decisions are served by various analyses of technical, spatial or temporal restrictions in the fishery. Long-term advice has been given in the form of "biological reference points", which aim at giving information on how the fish stock might be exploited under long-term equilibrium conditions (Figure 1). This information would be sufficient if the management had extensive control over the fishing so as to behave as a rational sole owner. Under turbulent decision-making conditions, the short-term catch prediction and the long-term equilibrium analysis provide only a small part of the information needed for the formulation of short-term tactics and long-term strategies.

The following list of missing pieces of information raises questions specific to the Baltic Sea, but they are obviously applicable on a wider

5.1.1 Short-term decisions

1. There is relatively little information on the consequences of any particular choice of TAC on the fisheries, although the consequences for the stocks are clearly spelled out.

The cod stocks in the Baltic Sea have declined and a reduction in the exploitation has been recommended (ICES, 1991). The reduction in the average fishing mortality seems to indicate that all vessels should reduce their effort by a constant proportion (for example, 40% relative to 1989). Yet the effort and catches may differ by several orders of magnitude between vessels. Because of the difference in catching power of individual vessels, a restrictive TAC would, under present management regimes, have structural effects on the fishery. For example, the 20 percent of the vessels which take, say, 60 percent of the catch may be able to continue taking the same absolute amount of catch. To achieve a 40 percent reduction of the catch, the remaining 80 percent of the vessels would have to be forced out of fishing (Figure 2). Knowledge of such details may be essential for international negotiations, although they are not concerned with sectoral distribution issues.
2. Some general information on the effects of overexploiting stocks exists, but for any single year there is little information on the probability of a stock collapse conditional on a choice of TAC which is at variance with the recommendations. This creates problems of perception in a myopic decision-making situation such as the TAC negotiations. Hardly any fishing operation will be able to wipe out a stock within a year. It is nearly always possible to get away with too high an effort for one year and sometimes several. The test comes when some event, such as a sequence of poor year classes or increased predation, causes a collapse, for which remedial actions are difficult. The story of the Baltic sprat, salmon, and cod illustrates this problem (see Thurow, 1991, this volume).

3. A TAC recommendation may give the impression that the stocks and fisheries can be controlled by using a TAC and by moving in the right direction. A complex set of events may, however, send the system off in an opposite direction. In the Baltic Sea, only extremely restrictive TACs could prevent the cod stock from falling below its present historically low level (Figure 3). With higher TACs, it is only a question of the rate of decline. The risk that the stock is driven to a point where the spawning stock biomass becomes so small that it reduces future recruitment cannot be neglected. We may, however, have to get used to the idea that the cod stock is much smaller than it used to be and to develop management strategies accordingly.

5.1.2 Intermediate and long-term decisions

1. Studies of technical, temporal and spatial restrictions have generally focused on the consequences for the fish stock and the fishing mortality. Any of these measures will, however, have structural effects on the fisheries which are relevant from the manager’s point of view, and especially from the point of view of the politician. A hint that losses will concentrate on a particular constituency may bar any protective measures for a stock. This effect has been observed in the Baltic salmon management in Finland. Under these circumstances, scientists should be able to illustrate short- and long-term losses and gains for different sectors in the fishery. National distributional issues are outside the competence of international bodies, but if, for example, changes in mesh size are recommended, the gains and losses for different fleets and fisheries should be analyzed. If the consequences for the different fisheries are not displayed clearly, speculations will take the place of knowledge. Negotiations based on speculations are even more difficult than those based on some agreed body of knowledge.
2. The analysis of technical, temporal and spatial restrictions are usually made under the assumption of *ceteris paribus*. Yet innovation is one of the great strengths of fishermen. A lack of knowledge of the strategies and the variables used for decision making by the fishermen may invalidate any estimate of their effects. For example, restricting fishing for cod during spawning time in the central Baltic Sea may increase effort during other times of the year, unduly restrict fishing for herring and sprat or cause discarding of fish.

3. There is little information on the sensitivity of the recommendations to underlying assumptions concerning the biological system. Management measures may produce unwanted results if the biological system changes. For example, a change of mesh size for the Baltic salmon may look fine on paper, but a change in growth rate or fishing practices may make the measure useless. Similarly, long-term estimates of potential yields taking into account species interactions can be calculated, but changes in the recruitment levels may invalidate the conclusions.

4. There is no reliable information on market demand or other economic factors. The demand may drop drastically if a new toxicant is found in fish, but even without such external impacts, long-term changes are likely and may alter the exploitation of the resources. For example, the demand for herring and sprat has dropped in many countries around the Baltic Sea. Market forces, rather than restrictions by the management, have reduced the fishing effort on salmon in the main basin in the Baltic Sea and have saved wild stocks from collapse.

5.2 Bridging the Information Gap - the Changing Role of Scientists

The list of missing pieces of information that can be made is very long. Sometimes this is interpreted to mean that we need more extensive monitoring, but in order to construct meaningful monitoring programmes, the overall objectives of resource management must be known. In addition, there should be agreed criteria by which we can determine whether an objective has been reached as well as a plan of action in case the monitoring programme suggests an unsatisfactory development.

Scientists cannot, however, always expect clearly defined objectives to be presented by the users of information. Determining the need for information is an interactive process between the producers and the users of the information. There are cases for which we do not need detailed routine monitoring, but rather an analysis of specific functional relationships or ways of comparing conflicting objectives or values. For example, detailed monitoring of fish consumption habits is difficult and expensive, but often demanded. Yet it may be that an analysis of factors affecting market demand would provide much more useful information for the fishing indus-
try and managers alike. Recreational fisheries are an example of a case where routine catch monitoring is insufficient for successful management.

Sustainability may, although it is a vague concept, serve as a starting point for determining the data requirements. Fisheries scientists can then determine a set of variables which will fulfill a basic need for information. All data do not have to be collected with the same frequency. The likely rates of change must be considered (Table 1). There appears, for example, to be little to gain from measuring some contaminants in fish year after year when we know that the rate of change is slow.

<table>
<thead>
<tr>
<th>Rapid  (&gt;1/year)</th>
<th>Intermediate (1/1-5 years)</th>
<th>Slow (&lt;1/5 years)</th>
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<td>Water quality</td>
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<td>Catches</td>
<td>Spawning areas</td>
<td>Species interactions</td>
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<td>Age distribution</td>
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<td>Spatial distribution</td>
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<td>User group relationships</td>
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Table 1 Fields to be included in monitoring and examples of relevant variables and typical rates of change.

Single scientific disciplines cannot produce all the information necessary for management and user decisions. Single disciplines cannot cover all relevant aspects of the decision-making conditions and may even give flawed advice simply by neglecting some driving forces in the system. A typical error is the neglect of economic incentives when framing advice on restricting fishing.

The body producing the advice could be a regional scientific council, which should contain expertise from several disciplines. It would not be necessary to meet every year. Sustainable resource use calls for sustainable strategic solutions with time spans of several years because, for example, most investments require planning horizons of this length. Short-term advice could still be produced by experts from a single discipline such as the stock assessment working groups.

Despite extensive data collection, scientists may not be able to determine unambiguously the limits of sustainability, but statements regarding the risks associated with particular uses of the sea can probably be given. For example, the cod stock and the cod fisheries in the Baltic are in a state with which we have very little experience (Figure 4). We know that the cod, like most fish, has a large potential for reproduction, but we also know that by driving the stock even further down we are likely to increase the risk of recruitment failure.

The results of scientific studies have to be interpreted with and be tightly connected to the ACTUAL decision-making process. The main task will be to present the consequences of various decisions to different users so that these consequences can be debated on a firm platform of facts. This is necessary because most decisions are collective and, hence, advice suited for single decision makers may be inappropriate or too narrow for the negotiations at hand.
may interfere with commercial fishing, and so on. A simple statement on how to maximize yield in weight does not answer all relevant questions and may therefore be discarded completely. The problems become even more complex when we discuss location of industries or allowable levels of discharges.

The greatest strengths of an interdisciplinary advisory body would be in a comprehensive discussion regarding the state of the resources and the consequences of various human activities. Present statements on the environment tend to be only extensive lists of observations, from which detailed implications for different users of the sea may be difficult to extract.

An organization consisting of scientists from different disciplines will not automatically succeed or produce useful information. A necessary first step is to bridge the communication gaps between different disciplines and between users and producers of advice. For the fisheries scientist this means, among other things, producing information intelligible to non-fishery professionals. For example, a catch recommendation in the form of a single figure is not very informative for an economist or a politician who wishes to understand regional consequences of fisheries management. An estimate of fishing mortality is too abstract for an environmental scientist interested in the effect of trawling effort on the benthic community. Other scientists have to meet similar requirements. Fisheries scientists, for example, have suffered from the poor availability of comprehensive statements on the state of nearshore waters which are essential for the reproduction of many fish, including the herring. Thus, our picture of the total health of the system has remained fragmented and more efficient action for improving the conditions might be possible if we could achieve a comprehensive analysis of present conditions.

If problems of communication could be overcome, we would probably find that we do, in fact, know more about how we should use the sea than any single discipline assumes we do. To make this information available, the right questions have to be asked and therefore disciplines should be forced to interact.

Who will then use the information? We will not advance towards sustainability by simply producing information. Politicians, administrators, industries, fishermen and the general public have to be prepared to use the information and change their activities accordingly. On the fisheries side little signs of this can be seen. It might be that not only scientists, but also others should be forced to interact. One potential consequence is that the time of separate regulatory commissions for the environment and the fisheries is past. Outdated traditions must be broken before they become a burden.

![Figure 4](image-url)  
*Recruitment (in millions) versus spawning stock biomass ('000 t) of Baltic cod, main basin. (Basic data from ICES, 1992.)*
Acknowledgements

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REFERENCES


ENVIRONMENTAL DECISION MAKING - DEMANDS ON SCIENTIFIC ADVICE

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ABSTRACT

The need for scientific advice in environmental policy-making is discussed and the specific need for a scientific body that can be drawn on in policy-making on environmental issues of relevance to fisheries and fishery-connected interests is emphasized. ICES, as the oldest intergovernmental organisation concerned with fishery and marine science, is identified as the obvious body to provide this advice and the existing environmental advisory framework within ICES is described. It is argued that a major impediment to providing scientific advice in a form that ensures its optimal incorporation in environmental decision-making is the manner in which this advice is requested. By comparison with the requests for scientific advice being directed to the fisheries management side of ICES, the requests being directed to the environmental advisory body within ICES are broad and not clearly defined. Thus, it can be difficult to identify what advice is actually being requested. It is argued here that there is a need for improved communication between the policy-makers requesting scientific advice and the scientists providing advice. The possibility of establishing a working group composed of scientists from ICES and representatives of the Commissions to formulate requests for scientific advice is suggested.

1 INTRODUCTION

Major changes have occurred in the relationship between scientists concerned with topics related to the marine environment and environmental managers during the last 20 - 30 years. For example, most of the early environmental legislation with the aim of controlling anthropogenic inputs to the environment was brought about as the direct result of actions on the part of scientists who, after having observed the deleterious effects of various substances on marine organisms, became convinced that the dumping of these substances into the marine environment must be restricted. Legislation made in the early 1960s and designed to reduce discharges of mercury can be considered to be an example of this "early" type of environmental legislation. Such legislation can also be said to have been based on the best scientific advice available and it should be noted that the legislation, itself, was preceded by a relatively long period in which scientific information with respect to the effects of mercury on the environment was collected and analysed.

Today, the situation is quite different. A great many new substances have been created during the last 30 years and there is a greater awareness among both legislators and the public at large that the addition of any foreign substance has the potential to alter or affect the marine ecosystem. Thus, there is a tacit assumption (which is probably correct) that the input of all substances to the marine environment must be regulated and it frequently happens that legislators are forced to make regulations before there is sufficient scientific background material upon which to make sound judgements. In addition, there is a growing awareness that there are potential conflicts between various forms of exploitation of the marine environment and the resulting need to regulate different activities impacting aquatic environments.

This new awareness of the need to regulate many, if not all, aspects regarding the use of the marine environment has created the need for a visible and effective structure by which the relevant legislation can be designed. Most would agree that such regulation should be based on science for "without science, environmental policy would be dependent on the intuitively obvious" (Moltke, 1984). However, one of the major problems in developing the structure referred to above is to determine how the relevant scientific information can be made available to legislators in a form that ensures its optimal use in the regulatory process.

In this paper, I will first provide a number of examples as to why scientific input to environmental management is crucial to the protection of fisheries and fisheries-related interests. Thereafter, I will describe the environmental advisory apparatus within ICES and the relationship between this body within ICES and the external agencies involved with environmental management. Finally, I will discuss possible strategies for improving the flow of scientific advice into environmental management.
2 WHY IS SCIENTIFIC ADVICE CRUCIAL TO THE PROTECTION OF FISHERIES?

There are still those who believe that if one does not mention that a fish can get sick, the potential consumer of fish will never know that this is, in fact, the case. However, those who cherish this belief are underestimating the power of today’s electronic media. A few seconds’ clip showing worms in the gills of cod on German television, for example, recently resulted in a dramatic fall in the Danish export of cod to Germany.

It is clear that the fishing industry needs a non-political body to assess the status of fish stocks in order to aid in the protection of the resource that the industry exploits. However, it is just as important to the industry that there is a non-political body that can aid in the protection of the market for fish by being able to provide information as to the level of disease in fish populations and report on any changes therein.

It is also becoming increasingly clear that the "natural" mortality that assessment biologists include in their analysis of fish stocks may contain an environmental component. That is to say that the quality of, or changes in, the environment may play an important role in the survival of fish. Repeated anoxia or hypoxia in a given area can, for example, reduce the biomass or change the composition of bottom fauna in such a way as to reduce the growth rates and/or survival of demersal feeders (Bagge et al., 1990).

Anoxia and hypoxia are most often related to anthropogenic eutrophication processes. However, "natural" environmental events can also affect the survival rates of fish. It is, for example, a well-known phenomenon that the mortality of sole increases during an ice winter in the North Sea. Thus, the estimation of the size of fish stocks can only be improved by a more detailed understanding of the relationship between the mortality within a given stock and environmental factors.

Recruitment to fish stocks may also be affected by the quality of, or changes in, the environment. The decreased salinity in the surface layer of the Baltic Sea resulting from an exceptionally long period in which there has been no inflow of high salinity water to the region has been identified as an important factor in the decline of the Baltic cod stocks. The argument here is that cod eggs sink deeper in the less saline water and, in some areas, sink to depths where there are insufficient oxygen concentrations to allow them to develop and hatch.

Laboratory studies have also shown that the viability of fish eggs can be a function of the concentration of certain organic contaminants in the reproductive organs of the parent fish. Thus, even when the concentrations of these compounds are not such that the survival of the parent fish is threatened, its reproductive potential may be reduced. Ecotoxicology is a fledgling science and sublethal effects of various contaminants (and possible synergistic effects between contaminants) are exceptionally difficult to identify in nature. Nevertheless, the possibility of such effects must be acknowledged, especially in more heavily contaminated waters.

Changes in the environment can also affect the survival of larvae and juvenile fish. The dramatic increase in the presence of filamentous algal mats in coastal regions of the Kattegat has been suggested as a contributing factor in the decline in plaice in the Kattegat, as many of the regions where these mats are found have previously been identified as feeding grounds for newly settled plaice (Bagge et al., 1990). Changes in the composition of phytoplankton and zooplankton populations and/or changes in the timing or frequency of phytoplankton blooms have also been suggested as being a potential threat to the survival of plankton-feeding fish larvae. Thus, scientific descriptions of the interaction between environment/environmental quality and the survival and recruitment of fish can serve much the same purpose as fisheries assessment data. Namely, it provides advice that can be used to protect the resource that the fisheries industry exploits.

Finally, in addition to being a crucial tool in the protection of both the market for fisheries products and the fisheries resource, scientific data are a prerequisite for providing advice that, ultimately, can be used in the protection of the fishing industry itself.

Within both the scientific community and the general public there is an increasing tendency to take a more holistic approach to environmental problems than previously has been the case. In that connection, concerns are being raised by environmental interest groups but also within the scientific community about the effect of fishing and aquaculture activities on the environment. Very little is actually known about the long-term effects of fishing activities on the environment and the lack of unfished control sites makes the execution of studies designed to elucidate the effects difficult. However, a non-political scientific body must contribute to the collaboration of data that can be used in the ultimately political decision concerning which forms of fishery are most suitable to specific areas.

Interestingly, it is also our ‘electronic media age’ which has helped to create this task for environmental scientists. Television documentaries have been used in recent years to educate the general public as to the very intricate ecological relationships in aquatic environments and the potential disturbances that fishing may create in the ecological balance in some regions. While such documentaries serve the very laudable purpose of educating
about nature’s mysteries and miracles, they also have the effect that popular opinion following such a documentary will side with that which is perceived to be the weaker of two adversaries.

A colleague has recently pointed out to me that should there ever be raised an environmental question with respect to a possible competition between sandeel fishermen in the North Sea and the terns that also feed on these fish, many more voices would (rightly or wrongly) be raised in defense of the terns than the fishermen. It is, therefore, essential that there is a non-political body prepared to provide legislators with sober scientific advice concerning the potential effects of fisheries on the environment in order to ensure the sensible protection of all interests in the sea.

The need for scientific advice with respect to the size, etc., of various fish stocks in the protection of the fishing industry is well accepted. It ought to be equally clear that there is also a need for scientific advice on environmental topics to ensure the future of the fishing industry. ICES, as the oldest intergovernmental organisation concerned with fishery and marine science, is the obvious place to turn in order to obtain this advice. And, as most of you already know, the framework for providing this advice already exists within ICES.

3 THE ENVIRONMENTAL ADVISORY FRAMEWORK WITHIN ICES

Before describing the advisory structure within ICES, it is important to note that the primary purpose of the establishment of the Council, in 1902, was not to create an advisory body. It is true that one of the reasons for establishing ICES was concern about the need to adopt regulatory measures in order to conserve North Sea fish stocks in the light of increased fishing pressure due to the introduction of the steam trawler. However, the stated purpose for the establishment of ICES was to foster international cooperation in marine biology and hydrography.

It was not until 1959, when the North-East Atlantic Fisheries Convention (NEAFC) was signed, that ICES became the advisory body that we know it as today. The Convention states that "the Commission shall when possible seek the advice of ICES". Thus, the advisory body within ICES which deals with fisheries is slightly over 30 years old. The Advisory Committee on Marine Pollution, which provides advice on environmental matters, was not established until the Statutory Meeting of 1972 and did not really begin functioning as an advisory organ until the mid-1970s. The history of environmental advice within ICES is, then, only about half as old as that for fisheries.

Thus, the existing advisory structure within ICES can be seen as having two parallel components - one providing advice used in fisheries management, the other providing advice used in environmental management. For various reasons, however, the workings of the environmental advisory body within ICES are less visible than those of the fisheries management advisory body (the Advisory Committee on Fishery Management (ACFM)). It may, therefore, be useful here to give a brief description of the Advisory Committee on Marine Pollution (ACMP) and its activities.

The ACMP is composed of five ex officio members (Chairmen of environmental committees within ICES) and a number (currently 11) of co-opted members. There is no permanently fixed size for ACMP and co-opted members are selected in such a way as to ensure that the range of expertise represented on ACMP is sufficient to be able to address all of the topics for which ACMP is expected to supply scientific advice. In this respect, the environmental advisory body within ICES differs radically from that dealing with fisheries, where there is nationally nominated representation in the membership.

In most other respects, however, the activities of the ACMP resemble those of the ACFM. Each year, "Member Governments of ICES and Regulatory Commissions" present ACMP with a shopping list of questions for which they need scientific advice. In practice, this means that ACMP directs its attention primarily to the requests of the Helsinki and Oslo and Paris Commissions. In order to give an idea of the breadth of topics considered, the requests of the Helsinki Commission that ACMP dealt with in 1990 are presented in Table 1.

As a rule, it is not possible to lift advice directly from single working group reports to answer the questions being posed by the commissions. Thus, in 1990, twenty different study and working group reports were considered by the ACMP in order to supply the advice requested. It is for this reason that expertise on all of the issues dealt with by the ACMP must be represented in its membership. If, for some reason, the necessary expertise is lacking on the membership of ACMP, then external experts must be called in when the topic is handled by the ACMP.

Until 1989, the ACMP had no working groups which answered directly to it. It now has seven. The ACMP can also direct terms of reference to working groups under the various scientific committees within ICES. This change has been made in an attempt to ensure that the necessary scientific background is available to ACMP in order to meet the requests that ICES receives on environmental issues. It must also be said that this change has not met with unanimous approval throughout the entire ICES community. Many of the implicated
working groups have indicated that they feel a divided allegiance between their parent committee and ACMP. How should priorities be set if it is not possible to complete all terms of reference at a given meeting?

Table 1 Requests from the Helsinki Commission to ICES, 1990.

1. To continue the work on evaluating the size of seal populations in the Baltic and to assess their condition in relation to contamination.

2. To provide information on "new contaminants", particularly those of special concern to the Baltic marine environment.

3. To conduct a specific assessment of contaminants in sediments and prepare guidelines for the conduct of "repeat extensive baseline studies" of contaminants in sediments.

4. To provide advice on reliable, intercomparable methods to determine concentrations of suspended particulate matter in sea water.

5. To study the problem of intercomparability of nutrient analyses and coordinate intercalibration exercises on analyses of nutrients and oxygen.

6. To provide information on progress in the intercomparison work on determinations of specific hydrocarbons in marine samples.

7. To provide in 1991 as detailed information as possible on the environmental impact of mariculture in the Baltic Sea area, including amounts and impacts of nutrients and organic matter.

8. To provide information on as quantitative a basis as possible on conditions (physical, chemical, and biological) relevant to the potential development of unusual algal blooms in the Baltic Sea area.

9. To develop a general scheme for identification of chemical substances that might be of concern to the marine environment based on toxicity, chemical properties, etc., and provide guidance for its use relevant to the Baltic Sea.

There is also the concern that the quality of the science upon which environmental advice is to be given will suffer if working groups are required to devote their energies primarily to topics dictated by the various regulatory commissions. This is potentially a very serious problem, especially as there are a number of ICES member countries for which the activities of the Helsinki and Oslo/Paris Commissions are not immediately rele-

vant. If these countries fail to send members to working groups with the argument that the activities of the working groups are being dictated by the commissions, then there is no doubt but that the quality of the science carried out within ICES will fall.

This, in my opinion, is probably the most serious challenge facing the environmental advisory body within ICES. Interestingly, however, it appears that the fisheries advisory body within ICES suffered the same sorts of "growing pains" when it was about the same age as the environmental advisory body is now. Lee (1973), in his capacity of Chairman of the Liaison Committee (predecessor of the ACFM) stated:

"The great strength of ICES lies in its being a scientific forum for the exchange of information and ideas and for the promotion of investigations for the study of the sea, particularly those relating to living resources, as well as being the scientific advisory body to NEAFC....It must be noted, however, that in recent years the scientific proceedings of some of the Subject- and Area-Committees has tended to suffer because of the time involved in dealing with the increasing amount of routine business which results from the need to provide advice to NEAFC."

History seems to repeat itself and within ICES we ought to try to take advantage of that fact. Has it been possible to marry quality science and advisory activities within the Fisheries Committees? If so, how? If not, why not and can the Environmental Committees escape the same fate?

4 THE RELATIONSHIP BETWEEN ACMP AND THE COMMISSIONS

A major problem facing the ACMP is the type of requests for advice it receives from the Commissions. The type of requests being dealt with is also a major difference in the modus operandi between the ACFM and the ACMP. An example of the type of advice requested from ICES by the International Baltic Sea Fishery Commission is presented in Table 2. It can be seen that the types of questions being posed to the ACFM are quite specific. The term "safe biological limits" is undefined (and possibly undefinable); nevertheless, it is quite clear what is being asked for and for what purpose. On the other hand, the questions being handled by the ACMP are much broader and less well defined (see Table 1).

Books could be written on a number of the topics that ACMP is asked to consider each year and it is not immediately clear as to what scientific advice is being requested. This not only compounds the work of ACMP and results in a great deal of wasted effort, it also
decreases the likelihood that the advice which is returned to the Commissions will be in a form that can be used to form the basis for regulation.

In Table 3, I have attempted to rewrite request number 8 from the 1990 requests for advice from the Helsinki Commission to ICES in a manner that I believe would facilitate the work of the advising scientific body (ACMP) and increase the chance of the Commissions receiving help from ICES which can be directly used in environmental decision making. In doing this rewrite, I have had to try and guess why I think the Commission is asking for scientific advice on this issue and what I think would be the most useful information for them to receive in order to do their job well.

Table 2  Request for scientific advice from the International Baltic Sea Fishery Commission (IBSFC) to ICES.

The IBSFC requests ICES to provide its Fifteenth Session with the following advice:

a) assessments of the state of the stocks (by appropriate areas) of Cod, Herring, Salmon and Sprat;

b) estimates of catch options for 1990 inside safe biological limits;

c) the effects of these on the stock and the catch rates;

d) an assessment of the effect of different mesh sizes in the salmon fishery on yield and stock size.

Table 3  Rewrite of Request No. 8 from the Requests of the Helsinki Commission to ICES, 1990.

8. To assess whether or not there has been an increase in the frequency of toxic phytoplankton blooms or phytoplankton blooms in general in the Baltic Sea area in recent years;

To assess whether there has been an effect of anthropogenic activities on the frequency of phytoplankton blooms in the Baltic Sea area.

It is obvious that it should not be necessary for me (or any scientific advisory body) to have to guess what lies behind the Commissions' requests for advice. It must be up to the Commissions to state clearly what is being asked for and why, when advice is being requested.

Of course, in many cases, such as when the potentially deleterious effects of a relatively new compound are being considered, there is insufficient scientific evidence upon which to base sound scientific advice. In such cases, it would be relevant for the Commissions to ask ICES for advice with respect to:

1. What can be stated on the basis of available information;

2. What information would be needed in order to make sound judgements; and

3. When it can be expected that the necessary data will be available (i.e., the duration of time series, etc).

Although the framework for providing environmental advice has been established, surprisingly little effort has been expended in defining the ground rules for establishing a dialogue between environmental policy-makers and scientists. As these two groups have different approaches to environmental problems that are not always compatible, communication between them may not be easy.

The scientific approach has been described by Lee (1973) in a discussion of the problems facing the advisory organ within ICES that deals with fisheries management:

"...biologists may be somewhat conservative, particularly when they are responsible for providing information upon the basis of which decision-making will proceed. There is a tendency to play safe and to wait for more data and, when a division of opinion occurs, to reach agreement at the lowest level."

Policy-makers, on the other hand, do not always have the option of waiting for more data before making a decision. As Wettestad and Andresen (1989) have pointed out:

"although being a necessary input, science does not constitute a sufficient basis for rational management. Sound management policies cannot simply be derived from the findings or hypotheses of scientific research. And precautionary management may have to proceed without any conclusive evidence."

Given this fundamental difference in the approach of scientists and policy-makers, it seems unlikely that we can expect a spontaneous improvement in the communication between these two communities. Thus, it is necessary to establish a well-defined framework within which communication between the two groups can be carried out.
WHERE DO WE GO FROM HERE?

Common sense tells us that sound marine environmental policy making must be based on science. The task for those providing scientific advice must be to ensure that the necessary science is made available to policy-makers in a form that is comprehensible and relevant. A dialogue between the question "askers" and the question "answerers" must be established to ensure that the answer received is in a form that can be used. It must be absolutely clear to the question answerer what is being asked and why. It must also be possible for the question answerers to identify areas in which sufficient scientific evidence is not available in order to give sound scientific advice.

It seems clear that a concerted effort must be made to improve the communication between the Commissions and ICES (ACMP) in order to improve the quality and the usefulness of the scientific advice being provided. I believe that a great deal of improvement in the dialogue between these two groups could be made by focusing on the questions being posed by the Commissions to ICES.

Specifically, I would like to suggest that one (or more) working group(s) be established to draft the requests for scientific advice from the Commissions to ICES. This (these) working group(s) should be comprised of representatives of the Commissions and scientists from ICES (ACMP). At present, the meetings that take place between the Commissions and the ACMP are primarily in connection with the presentation of the ACMP Report. In my opinion, it would be far more interesting and valuable to hold meetings in connection with the preparation and presentation of the lists of requests for advice from the Commissions to ICES.

If ICES is to continue as a competent scientific advisory body on matters relating to the marine environment, then communication between the scientific environmental advisory organ, ACMP, and those requesting advice (in this case, the Commissions) simply must be improved - especially with respect to the definition of the advice being dealt with. The need for better communication grows as our knowledge of the marine environment increases and we become aware of even more topics which are relevant to consider in order to ensure the protection of the marine environment.

With this increased knowledge, the workload for ACMP becomes greater and greater. The ACMP's efficiency in handling the requests of the Commissions will increase through a better definition of the requests being made. The efficiency with which the requests are handled must be increased for, if it is not, the work load of the ACMP will soon be so great that it will not be possible to find qualified scientists who are willing to undertake the job of serving on ACMP on a voluntary basis.

REFERENCES


DISCUSSION OF PAPERS ON SCIENTIFIC REQUIREMENTS

Dr Topping, Chairman of ACMP, opened the discussion by stating that ACMP has already taken Dr Richardson's advice this year. He stated that he had just attended the meeting of the Environment Committee of the Helsinki Commission, and that there had been good communication, for example, on the algal bloom issue. He pointed out that ACMP had taken steps this year to make its report more user friendly, for example, by the inclusion of a matrix table at the end of the report indicating where ACMP advice on each topic can be found in its reports over the past ten years.

Dr Topping felt that scientists should provide advice based on the best possible knowledge, including options or implications of this advice; when the advice has been given, the managers should make the decisions.

Dr Richardson agreed that managers should manage and scientists should do science. However, she did not find the questions asked by managers clear enough for the scientists to be able to present options.

Dr Ferm (Director at the Swedish Environmental Protection Agency) stated that Dr Richardson's paper proposed a way to go forward. It provides a structure so that there is the ability to have the questions properly formulated, and then find the answers. In Sweden, the politicians want to know whether, if the managers make a certain decision to reduce something, the newspapers will stop writing about these problems. In this connection, how
narrowly can we specify the questions to obtain an answer that really means something?

Dr Richardson replied that she did not know whether it was possible to define the question so narrowly that the answer could be 'cut and dried'; however, we can go a long way to improve the questions on the environmental side. In addition, fisheries questions may be expanded, so it may not be so simple in the future.

Dr Hildén mentioned that, although scientists should not regulate, they should address and analyse the effects of doing or not doing a certain action.

Dr Serchuk (Chairman of ACFM) stated that there are many problems with providing the fisheries advice and it is not all straightforward. For example, the term 'safe biological limits' is now being redefined, as it is not clear-cut enough. There are many examples of requests from the fisheries Commissions where the management objectives behind the requests have not been stated. The Commissions need a long-term frame of reference for their work. He further stated that the Dialogue Meetings are very valuable for discussing the management objectives and how to meet them. New types of scientists are needed: management scientists - scientists who will specialize in decision-making.

In reply, Dr Richardson stated that there is a parallel between the fisheries and environmental fields, but fisheries is around 15 years ahead. The environmental side is now facing the problems that the fisheries side faced 15 years ago.

Dr Karnicki noted that both fisheries and environmental fields are very complex. They may run in parallel, but they need links between them. The Baltic is an ideal pilot study area. A Baltic Sea Task Force has been established, but it is not paying attention to the problems in the interaction between fisheries and the environment. More scientific information is needed before managers can formulate better questions.

Dr Melvasalo (Secretary to the Baltic Sea Task Force at the Helsinki Commission) commented on the comparison in Dr Richardson's paper between the questions from the fisheries Commission and HELCOM. On the fisheries side, the questions relate to only one year, and clear answers can be given to clear questions. On the HELCOM side, there are questions that take much longer than one year to answer, and not all advice is via reports. There are many interactions with ICES people who are working with the HELCOM groups. Although some of the HELCOM questions have been stated in two sentences, large quantities of work in HELCOM subgroups have gone into the formulation of these questions. As HELCOM is not a scientific body, ICES is the main scientific advisor. For example, in the case of seals, several years ago there was still hunting of seals and the HELCOM wanted advice on this issue. After receiving the advice of ICES over several years, HELCOM recommended that seal hunting be stopped, but requested ICES to continue monitoring seal stocks.

Dr Melvasalo further reported that ICES has assisted in the development of the HELCOM Baltic Monitoring Programme from the very beginning, providing good advice on matters related to sampling and analysis for the various parameters. At present, there is a major project on sediments that is being coordinated by ICES for HELCOM. She felt that the important thing is not only what is on paper, but also the many personal contacts between ICES scientists and HELCOM groups to develop the work. HELCOM has received much valuable advice despite vague questions.

Professor Thurow mentioned that ICES coined the term 'safe biological limits' and later the fisheries Commissions adopted it out of politeness to ICES, so managers cannot be blamed for using the term. He did not find Dr Hildén's paper concrete enough; it was too theoretical, with very few practical applications to the Baltic Sea. On the other hand, Dr Richardson's paper was very straightforward. However, concerning her statement on the effect of the decreased salinity on cod, the relevant working group has only stated that there has been a decrease in the volume of water suitable for cod spawning/egg development; they have not said that there was an effect on the cod.

In response to the issue of 'safe biological limits', Dr Hildén noted that this concept initially was developed with the view that there was only one owner of a stock, and the concern was how to optimize the use of the stock under this premise. Now, however, it is recognized that the situation is much more complex, and there are many interests that may be involved in the regulation of exploitation of a stock.

Mr Schmiegelow (Commission of the European Community) asked Dr Richardson to elaborate on her statement that ICES has two 'legs': ACMP and ACFM. Are they both used equally? In terms of the questions to these two bodies, some questions may be asked because the scientists think they know the answers. Within IBSFC there is a dialogue between scientists and managers when the questions to ICES are being formulated.

Mr Jakobsson noted that so far fisheries questions have been addressed to ACFM and environmental questions have been addressed to ACFM; now, however, there may be a need for more interactions between these two bodies.

Mr Richert (Association of Sea Fishermen, Poland) asked whether the range and spectrum of the answers to
the questions is known. Perhaps we are just beginning to ask the right questions, e.g., is there a decrease in resources in the Baltic Sea?

Dr Hilden replied that it depends on what the question is. We know from existing research that, with the present level of fishing activity, the cod stocks will decline further. However, if the question is asked as to when the stocks will experience improved recruitment, a large amount of resources would be required to answer this, and even then it may not be possible.

Dr Sosinski (Sea Fisheries Institute, Gdynia) asked what kind of law applies to ICES-related advice and what is the prevailing social conscience. The role of scientists is also to shape public opinion, not only to study science. He stated that the ICES documents are not worked out properly from the legal point of view. When there is an urgent situation, such as a decrease in cod stocks or seal populations, or an increase in unusual algal blooms, there is a need for a legal structure that permits a rapid response. He asked how we can develop the law regarding environmental issues, what kinds of sanctions should be prescribed for environmental offenders, and what kind of training there should be for lawyers working in environmental protection.

Dr Richardson replied that she was not sure that science should shape public opinion - the media does that. Science should have the data available to interpret issues - is a situation normal or unusual? In terms of training lawyers for marine environmental issues, they should be good lawyers, not scientists, but they need a good advisory body to provide the appropriate scientific advice. Laws must be based on science and science should ensure the stability of the law. There is an entire body of science regarding the effectiveness of sanctions and how to have the best implementation of the law.

Dr Thurow finished the discussion of these papers by stating that scientists have the obligation to speak up and tell the public when administrators are not providing the true picture to the public, whether regarding fisheries or environmental problems.
INTRODUCTION

According to the Oxford English Dictionary, management is:

- the judicious use of means to accomplish an end, or

- the executive function of planning, organizing, coordination, directing, controlling and supervising any industrial or business project or activity with responsibility for result.

These definitions clearly indicate the responsibility of management for the final result. Easy to say, difficult to do. In fisheries management, the final result means a stable and efficient performance of the industry.

OBJECTIVES OF MANAGEMENT

Sustainability in fisheries should be considered as an overall main objective of management and it encompasses the following:

- stability of catches and their rational utilization,

- steady supply of the market with fish at reasonable prices and quality, and

- assurance of suitable living conditions for those working in the fishing industry.

However, recently two additional areas to which the management of fisheries should be addressed have emerged: economy and environmental protection.

The industrial, urban and agricultural development of land can pose a risk to the maintenance of adequate environmental quality and biological diversity. Likewise, unsound practices in capture fisheries and aquaculture can be detrimental to the environment and to the sustainable use of marine resources. Therefore, it is not surprising that fisheries management is an extremely complex and difficult task. A number of factors having significant impact on management decisions interact or conflict among themselves, change over time, or are not yet fully known.

COMMUNICATION IS IMPORTANT

There is one fundamental issue common to all types of management: all regulations which are basic tools of management should be clear, easily understood and enforceable. To ensure this, cooperation and communication within a "golden triangle", namely, the regulatory/enforcement agency, science, and industry, must be achieved. A well-balanced solution in this triangle can be obtained only if all parties employ sound knowledge, good will, and common sense.

MANAGEMENT AND FISHERIES

Management of fisheries is often considered in a rather narrow perspective, focusing only on the management of the resources. However, considering the objectives listed above, management must be seen to be much broader and to encompass a wider spectrum; if not, the accountability for the final result of fisheries will be greatly reduced.

There are several factors having an impact on management which may result in conflicting situations. These factors can be divided into the following general groups: biological, ecological, technical, socioeconomic, and political.

4.1 Biological Factors

As these factors have been extensively discussed during this and other Dialogue Meetings, it is not the intention of this paper to reiterate this subject at this time.

4.2 Ecological Factors

These factors can be further divided into two subgroups: natural causes and causes arising from man's activities. The natural causes are beyond our control but their role must be understood and taken into consideration in management decisions. Thus, it is a role of research to study these problems and to provide the necessary advice for management decisions. Unfortunately, nature itself is difficult to predict and our research is still far from being complete.
Let us consider an example from the Baltic Sea. It has been proved that the state of the cod stock is highly dependent on the inflows of well-oxygenated, highly saline waters from the North Sea into the Baltic Deep. These inflows create suitable conditions for egg and larval development thereby determining the strength of the year classes which follow.

According to Kosior and Netzel (1989) and Wojewodzki (1985), the extraordinarily abundant year class of 1976 and the abundant year class of 1977 developed following large inflows of North Sea water in the winter of 1975/1976 and 1977. Only two additional large inflows have been observed since then, in 1979 and 1980, and these were followed by strong year classes which contributed to the extraordinary development of the cod stock in the early and mid-1980s. Since 1982 no significant inflows of North Sea water have been observed, consequently all the year classes after 1980 have been poor (Netzel, 1987). Strong fishing pressure, together with unfavourable natural conditions, resulted in the present "cod crisis" in the Baltic and this is reflected in the lowest catches recorded for the past twenty years. When can we expect an improvement? This will depend, to a great extent, on when the next large effective inflow takes place. According to an educated guess, it should take place in the winter of 1992. Can an improvement in catches be expected in 1996? What will happen if the expected inflow does not take place? Another question arises: what should be the level of spawning stock biomass to assure a reasonably quick recovery of the stock when the inflow occurs or, in other words, how much further should the reduction in commercial catches go if we do not want to exceed the safe biological limits?

The scientists, whether one wants to admit it or not, have been right in their advice to reduce the catches of cod in recent years. In most cases, however, this advice was not put into action. Political and socioeconomic factors have overruled science once again.

As illustrated in Table 1, recommendations of IBSFC were not followed by member states in the past, and now pressure from politicians has led to acceptance of TACs for cod, not only higher than those recommended by ICES (which some member states have considered even too optimistic), but higher than the industry, with increased fishing effort directed on cod, can catch. This was done with knowledge of the uncertain future for the cod stock recovery. Now, as a result of the above, we are faced with a Hamlet-like dilemma: "To fish or not to fish". Some scientists suggest the "not to fish" solution. But this will have a tremendous social impact as the entire sector, which is to date the most economically attractive, will have to be closed down. The social cost of such a decision will be tremendous and obviously for those politicians/administrators who are brave enough to take such a decision, it may be a suicidal one. As politicians are seldom brave, the solution "to fish" will most likely be the one chosen. But at what level? That should be decided next week at the IBSFC Session in Warsaw and it does not promise to be an easy task.

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<th>Year</th>
<th>ICES recommended</th>
<th>Agreed within IBSFC</th>
<th>Real catches</th>
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<td>cod fishing</td>
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1 International Baltic Sea Fisheries Commission.
2 Stock in a very good state; exploitation level to be chosen by IBSFC.

Apart from the natural environmental causes, increasing pollution is a threat to the environment and creates serious problems for fisheries managers. The contamination of fish should be monitored because, when the level of contaminants exceeds the permissible maximum, the fish becomes unfit for human consumption and should be rejected. As the level of contamination often depends on the fishing grounds, species and size of the fish, the cost of monitoring is high. This is, however, a necessary price to be paid to protect and safeguard the consumer. In this context, a positive example can be drawn from the Baltic where the contamination of cod liver with pesticides was reduced to the level at which the sanitary...
Another problem is that of fish parasites, particularly nematodes (*Anisakis* sp.), which has gradually spread eastwards in the Baltic. Though the problem is not a new one, as it was discovered in the late 1960s and early 1970s, and, despite the fact that appropriate ways of processing infested fish have been elaborated, uncontrolled publicity has misrepresented the problem resulting in heavy losses to the herring industry.

The lesson from this, however, is that the quality assurance of fish and fishery products is a part of the overall fisheries management programme and despite the fact that it does not have a direct impact on exploitation of the stocks, it is important for their rational utilization. The problem of quality management in the fishing industry is an issue in its own right and could be the subject of a separate Dialogue Meeting.

4.3 Technical Factors

There are two things needed to fish: the vessel and the gear. Remarkable progress has been made in technical developments in these two areas. Vessels are equipped with more powerful engines, more sophisticated fish finding equipment and they use nets of a size not imagined in the past. In this way, with the same number of vessels, fishing effort or simply efficiency has dramatically increased, creating as a consequence, the present situation of overcapacity of the fishing fleet, not only in the Baltic but also in many other areas, which is much too high for the available resources. Some experts are of the opinion that overcapacity of the EEC fleet may be as much as 40% on average (Serra, 1991). Similar examples can also be drawn from Poland, where in 1980, a total of 1,457 vessels caught 221,800 tonnes, while in 1990 the same number of vessels caught only 110,600 tonnes. At the same time, the power of these vessels grew from 131,000 HP up to 150,000 HP, and gear efficiency also increased. It is obvious that the effort is too high for the available stock and the cost of fishing dangerously narrows the profit. Thus, the number of boats should be reduced to ensure reasonable economic conditions, at least for those who remain in this business. For those who have to leave, some alternative employment should be considered. The reduction of the fishing fleet is only a first step. Help from scientists is needed to find a better way of estimating the fishing effort calculation in future years. In this calculation, the size of the vessel, engine power, type of the gear, number of nets and other factors should be taken into consideration. The technical development in gill nets, apart from the increased efficiency and fishing cost reduction, have also produced a negative impact.

4.4 Economic Factors

A growing demand for fish and fishery products is bringing the total world catch very close to 100 million tonnes, which seems to be almost a maximum sustainable level. A majority of fish stocks are fully used or even over-exploited. In this situation, the economic factor becomes more and more important in managerial decisions. A good example can be drawn from the Baltic fisheries. Cod stocks are in a dramatic state due to fishing pressure and natural factors. But due to reduced supply, the increase in price provides the incentive to continue cod fishing. What should be done to reduce the pressure on the depleted cod stock? This question will have to be answered next week during the session of the International Baltic Fisheries Commission, but can we try to answer it now? Though the cod stock is endangered, during the last few years, the TACs set for herring and sprat have been greatly underutilized. What kind of managerial decisions should be taken to remedy the situation? What kind of incentives should be used to fish these species more heavily? One can say, none. When cod fisheries are finally no longer economically viable, the fishermen will have to fish for herring and sprat, subject to availability of market and suitable prices. If not, they will go bankrupt. But should they? What about social problems, unemployment, etc.? Probably rich countries like the EEC can solve the problem through subsidies but in the case of Poland, considering the state’s present economic situation, the solution is not so simple and joining the EEC is a future song. But despite the economics there is another problem. It is highly probable that a low fishing mortality, together with some environmental changes and low predator pressure, are having a degenerating effect on herring stocks, particularly in the southern Baltic. According to data from the Sea Fisheries Institute in Gdynia, the "condition coefficient" of herring in length classes 10 -
32 cm in the Bornholm and Gdansk Basins showed a significant drop in 1990.

<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Bornholm Basin</td>
<td>0.66</td>
<td>0.69</td>
<td>0.58</td>
</tr>
<tr>
<td>Gdansk Basin</td>
<td>0.66</td>
<td>0.67</td>
<td>0.57</td>
</tr>
</tbody>
</table>

A particularly significant drop in "condition coefficient" was observed in young herring up to 14 cm and in large specimens, above 20 cm in length.

The technological value of herring and of course the price depend very much on its fat content. Data presented below indicate that the fat content in herring in 1990 did not exhibit the usual seasonal fluctuation, in fact, the level was only 30 - 50% of the norm. It should not be necessary to emphasize that herring with such a low fat content fetches a much lower market price and decreased consumer satisfaction (see Table 2).

<table>
<thead>
<tr>
<th>Month</th>
<th>Herring</th>
<th>Sprat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>10.97%</td>
<td>9.28%</td>
</tr>
<tr>
<td>Feb</td>
<td>8.27%</td>
<td>7.35%</td>
</tr>
<tr>
<td>Mar</td>
<td>7.50%</td>
<td>8.54%</td>
</tr>
<tr>
<td>Apr</td>
<td>6.60%</td>
<td>4.84%</td>
</tr>
<tr>
<td>May</td>
<td>4.49%</td>
<td>4.07%</td>
</tr>
<tr>
<td>Jun</td>
<td>3.97%</td>
<td>10.03%</td>
</tr>
<tr>
<td>Jul</td>
<td>10.05%</td>
<td>11.87%</td>
</tr>
<tr>
<td>Aug</td>
<td>15.82%</td>
<td>13.53%</td>
</tr>
<tr>
<td>Sep</td>
<td>13.36%</td>
<td>12.11%</td>
</tr>
<tr>
<td>Oct</td>
<td>12.93%</td>
<td>11.93%</td>
</tr>
<tr>
<td>Nov</td>
<td>13.19%</td>
<td>10.55%</td>
</tr>
<tr>
<td>Dec</td>
<td>11.44%</td>
<td>12.75%</td>
</tr>
</tbody>
</table>

It is not yet clear, but, from a managerial perspective it is important to know whether this situation is due only to natural changes in environmental conditions (cold winters in 1985/87 and very low salinity in 1990) or to a lack of sufficient quality of food resulting from uncontrolled expansion of herring or adverse environmental conditions. Most likely it will be a combination of these factors since it is known that the amount of macroplankton crustacean *Mysis mixta* which usually makes up about 93% of herring summer food was extremely reduced in 1990. This situation requires further scientific studies but whatever the answer will be, the solution will be difficult for economic and technological reasons.

Could fishing of herring for fish meal be a solution to this problem?

### 4.5 Political Factors

Biological, ecological, technical and economic factors influencing management decisions are quite complex but they are governed at least by certain rules. Political factors, on the other hand, are akin to opening a Pandora's Box. All kinds of interest groups wish to reach their own goals and objectives and businesses also put pressure on politicians. Lists of these groups can be rather long, starting from different groups of fishermen, environmentalists, processors, members of parliament, senators and their friends, trade unions, consumers, shipyards, etc. Politicians, who have a great influence over legal matters, and administrators are trying to solve the current problems for the sake of maintaining their own positions. They seldom, however, look further ahead; they tend to support any issue which brings them popularity today rather than prosperity two years later. For these and other reasons, which we can call a "common property of the resource", most management systems have failed.

### 5 CAUSES OF FAILURE

Some of the basic causes of failure are:

- common property of the resource,
- lack of long-term strategy,
- lack of appreciation of scientific advice,
- lack of effective control of fishing effort,
- inefficient enforcement and inspection systems.

Today, economics and markets play the most important role and should therefore be more firmly incorporated in the management strategy. The management concept should be broader and should change from simple resource management to management of fisheries with responsibility for the final result. Here the responsibility should not only be with governments, but with industry as well. The police cannot regulate the traffic without the cooperation of drivers who understand that traffic must go smoothly, not to please the police, but to facilitate the drivers. The advice of scientists concerning the present stock situation and possible future development should be seriously considered. Mikael Hildén, in his paper presented at this meeting, is right when he speaks about the "tyranny of small decisions" in management. A sober, long-term strategy in management is required. This strategy may, and eventually must, be adjusted but only adjusted to the existing situation which in nature is never constant or permanent. Sustainability should be a general objective. Methods of calculating fishing effort
should be elaborated and continuously monitored and the established limits enforced. The whole concept should take into consideration present knowledge about ecosystems and the interrelations therein. Single species management at the present level of exploitation of the seas is no longer valid. This obviously complicates the whole issue but it is time to accept that a "classic orderly landscape painting with benevolent and happy fisherman" (M. Hildén, this volume) no longer exists.

6 THE BALTIC CASE

The Baltic Sea is not an exception where the present management systems have failed. The TAC approach taken by the International Baltic Sea Fishery Commission, as in many other international organizations or countries, has proved to be insufficient to manage, not only the fisheries, but the resources in general. It is high time, therefore, that a new approach is discussed and in this regard the advice from ICES on this matter should be of great importance. The changes discussed in the management of the Baltic fisheries should also take into consideration possible political changes which are likely to take place in the area in the near future. Therefore, it is time IBSFC decided on its objectives and prepared a strategy and programme of action by which these objectives can be achieved.

7 REFERENCES


INTEGRATED ENVIRONMENTAL MANAGEMENT OF THE BALTIC SEA

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1 THE ECOSYSTEM

The Baltic Sea is surrounded by six countries, in clockwise order: Sweden, Finland, the Soviet Union (USSR) (Editor’s note: at the time of the meeting), Poland, Germany and Denmark (see Figure 1).

The Baltic Sea, with a surface area of about 400,000 square kilometres and a volume of 21,000 cubic kilometres, is one of the largest brackish water areas in the world. It is shallow, with an average depth of 55 m and a maximum depth of 459 m. The Baltic Sea is a very peculiar ecosystem because of its relatively high brackishness and almost permanent stratification. The key to the peculiar character of the area is the extremely shallow, narrow Danish Straits, which allow only a very slow water exchange between the Baltic and the North Sea. As a result, the water in the Baltic Sea has a long residence time, in the order of 35 to 40 years, leading to accumulation in water, sediments, and biota of discharged pollutants. This is important because the Baltic Sea is one of the most severely polluted sea areas in the world and serious adverse effects of currently discharged pollutants into the ecosystem will be felt several generations from now.

2 URBAN AREAS

Urban areas contribute approximately twenty-five per cent of the land-based sources of nutrient inputs into the Baltic Sea. Figure 2 presents an overview of the locations of urban areas along the coast. In 1980, about twenty million people lived immediately adjacent to the Baltic Sea, about half in urban areas, out of a total of sixty million inhabitants within the drainage basin. Cities such as Copenhagen, Leningrad (Editor’s note: now St. Petersburg) and Warsaw (through the Vistula River) contribute significant amounts of pollutants to the Baltic Sea.

During the 1970s and 1980s, ambitions began to focus on the removal of nutrients to reduce or prevent eutrophication. The removal of nutrients requires, at a minimum, a biological treatment system (secondary treatment) which removes organic material and, to some extent, nitrogen and phosphorus. The installation of biological treatment systems is expected to dominate the investments in municipal treatment systems around the Baltic Sea for a long period of time. Further reduction of nutrient concentrations in the effluent of wastewater treatment plants (tertiary treatment) is currently being (or has already been) undertaken at great cost in some countries.

3 MINING AND INDUSTRY

Industrial activities in the countries around the Baltic Sea (see Figure 3) are largely based on the local availability of raw materials: ore, timber, and phosphate rock. Related industrial activities, which are well developed in the countries around the Baltic area, include: paper and pulp processing, mining, steel and metal manufacture, and fertilizer production.

Pulp and paper processing is particularly strongly represented. The countries in the Baltic drainage basin produce about twenty-five per cent of the world’s production of pulp, paper and board. The pulp and paper industry in Sweden and in the former USSR is mainly situated along the coast. In Finland and Poland, the industry is located throughout the country. Bleaching plants at pulp mills are by far the dominant source of organochlorine compounds in Sweden and Finland. The industry in Finland and Sweden is responsible for the major part of the pollutant load to the Baltic of chlorinated organic compounds, even though the industry generally uses the best available technology to reduce the discharge of these substances.

Mining and steel and metal manufacturing activities are primarily undertaken in the west of Sweden and in the south of Poland near the border with Czechoslovakia. Some mining activities also take place in Finland (where the metallurgic industry is well developed). Sweden is the largest producer of iron ore in the region: in 1986 around twenty million tonnes were mined in Sweden.

Poland is a major producer of copper ore on a global scale. In 1986, almost thirty million tonnes were mined in the Lublin region. Lead and zinc ore are also mined. The iron ore deposits are virtually exhausted.
Figure 1  Countries around the Baltic Sea (in mid-1991).
Figure 2  Locations of major urban areas in the Baltic Sea drainage basin.
Figure 3  Locations of the main industrial activities in the Baltic Sea drainage basin.
In Finland, iron ore and a small amount of zinc and silver are mined. The mining industry is a major exporting sector.

Fertilizer production in Poland, Finland, Sweden and the former USSR is a major component of the chemical industry in the region. In the Baltic countries, both nitrogenous and phosphate fertilizers are produced in large quantities. This activity has caused heavy discharges of phosphate and nitrogen salts and of cadmium (a contaminant in the raw material) into the environment.

4 AGRICULTURE

Agriculture is important in all the countries around the Baltic Sea. At least in some of the countries, the agricultural sector uses high levels of artificial fertilizers and produces more manure than can comfortably be handled locally. Growing concern over eutrophication has placed agriculture at the top of the list of polluting activities in recent years. This also implies a shift in emphasis from point sources to non-point sources.

The most important emissions from agriculture are nutrients, which form a very significant component of the total nutrient emissions transported by the rivers into the Baltic.

5 THE INTERNATIONAL SITUATION

Rivers and watersheds flowing into the Baltic Sea are the dominant sources for inputs of pollutants to this area, together with atmospheric transport for some contaminants.

In general terms, individual bordering countries are responsible for relatively equal portions of the total input of pollutants into the Baltic Sea. When individual classes of pollutants are considered, however, some countries play a dominant role. This is the case, e.g., with regard to chlorinated organic substances, where Sweden and Finland provide the major part of the inputs. Another example is phosphorus, where Poland is the main input source.

An important part of the international work against pollution of the Baltic is concentrated in the Helsinki Convention. In spring 1988, a major break-through in the work of this Convention occurred. Environment ministers of all countries concerned took a joint decision to reduce the inputs of the most serious types of pollutants into the Baltic Sea over a period of ten years.

This agreement means that Contracting Parties undertake to "use the best available technology to achieve a substantial reduction, of the order of fifty per cent, of the input to the sea area of stable organic substances which are toxic and liable to bioaccumulate, toxic metals and nutrients."

About a year ago, a special Baltic Sea Task Force was established, at the initiative of the prime ministers of the countries concerned. Within the framework of this Task Force, more detailed action plans for the protection of the Baltic Sea are being developed in each country. The intention is that the Task Force shall prioritize among the different environmental threats and suggest technical solutions. To this end, representatives of the World Bank, the Nordic Investment Bank, the European Investment Bank, and the European Bank for Reconstruction and Development also participate in the Task Force.

6 ENVIRONMENTAL GOALS

General and long-term environmental goals for the Baltic Sea should be:

- to maintain vigorous, balanced populations of naturally occurring species;

- to achieve a natural zoning of flora and fauna;

- to prevent the occurrence of sea bottom areas suffering from harmful oxygen deficiency;

- to carry on regular, long-term fishing;

- to consume fish and shellfish from the areas without risk to health; and

- to ensure that pollution does not constitute a restriction on the recreational value of the marine areas.

7 VARYING CONDITIONS

The marine areas of the Baltic Sea differ from each other a great deal. The salinity varies sharply from the Bay of Bothnia's river-diluted water to the Øresund and Kattegat. Different areas also have different levels of sensitivity to environmental effects. The retention time of the water varies from several decades for the Baltic Proper to a few months for the Øresund. The time it takes for various pollutants to disappear ("turnover time") depends on the water's own retention time, as well as on factors such as the rates of degradation, sedimentation, evaporation, etc.

Modelling studies from the Baltic show that there is a very long time lapse between the cessation of the load input and the beginning of a measurable decrease in concentrations in the sea. It takes a long time before a
new equilibrium between input, concentrations, and disappearance is achieved. Even if all countries bordering the Baltic were to reduce their discharges by fifty per cent tomorrow, it would take at least 10 to 15 years before a measurable reduction in concentrations occurred. Remedial measures are thus a matter of both urgency and patience!

8 METALS AND OIL

Cadmium and mercury, and in some areas zinc and arsenic, are the metals which constitute a continuing threat to the marine environment. More progress has been made with respect to regulating discharges and emissions of metals than with regard to stable organic substances. The overall strategy for remedial measures to combat toxic metals is to implement the regulatory programmes which have already been initiated.

In the case of oil pollution, it is also mainly a question of following through with the regulatory programmes which have already been initiated, and whose success depends on international cooperation. Oil entering the marine environment via rivers and atmospheric deposition continues to be a subject of extreme importance. As far as the Baltic is concerned, a further serious threat may be posed by future offshore extraction. If such drilling does begin, extremely extensive environmental protection measures will be necessary. Recommendations in this direction have been adopted by the Helsinki Commission.

9 NUTRIENTS

Eutrophication is the most acute problem in the Baltic Proper. Nutrient inputs come from several countries around the Baltic, particularly via large discharges of inadequately treated waste water from cities and industrial plants in the eastern European drainage basin.

During this century, the load of nitrogen and phosphorus in the Baltic has increased four-fold and eight-fold, respectively. From 1900 until 1950, the load of both nitrogen and phosphorus had doubled. From 1950 to the present day, the nitrogen load has doubled whereas the phosphorus load has increased four-fold. This means that, compared to previous conditions, there is presently a surplus in the supply of phosphorus to the Baltic Sea. Increased nitrogen fixation via nitrogen-fixing algae in the Baltic suggests that the nitrogen being supplied via the external load is not sufficient for all the phosphorus to be utilised for production. Not only is the total nutrient load too high, it is also in a state of imbalance. Against this background, we must consider whether a long-term pollution abatement strategy should prioritize the removal of nitrogen or phosphorus.

The fertilizer industry, in particular, and, perhaps to a lesser extent, the pulp and paper industry, and the iron and steel industry are important sources of nutrient inputs from the industrial sector. Existing international agreements and arrangements will make it necessary for all countries around the Baltic Sea to assess carefully the most effective means of achieving a fifty per cent reduction of nutrient inputs before 1995 (as compared to 1987).

With regard to municipal sewage, some Baltic countries are in the process of constructing biological treatment plants for their major cities. Other Baltic countries have already built such installations and are adding further facilities to their existing sewage treatment plants, in order to reduce nutrient discharges. And, in some cases, where the sewage treatment plants themselves operate reasonably efficiently, overflow situations and leakages from the piping system are becoming more and more important as discharge sources.

Agriculture is probably the major source of inputs of nutrients, and especially of nitrogen. Measures need to be taken to reduce the input of nutrients from this sector. Such measures include a prohibition of the spreading of manure on frozen soil. The nutrients in the manure should instead be used only on land areas where growing crops can use the nitrogen and phosphorus provided. This may mean that storage tanks and basins will have to be built by many farmers.

Other measures that can be important in reducing the input of nutrients from agriculture are:

- increasing the proportion of farm land that is covered by crops or grass during wintertime,
- technical measures to avoid evaporation of ammonia from the soil immediately after the spreading of manure, and
- active advice and support to farmers in environmental matters.

More details about how such a policy is being carried out in Sweden are described in the Swedish Action Program for preventing marine pollution.

10 STABLE ORGANIC SUBSTANCES

Today, about ten million organic substances are described in the literature. About three hundred thousand new substances are added each year. Only a small fraction of these, however, come to a practical use. It can be estimated that between fifty thousand and one hundred thousand different chemical substances are in more
general use around the world. Most of these are organic substances.

PCBs, DDT, dioxins and dibenzofurans are examples of substances which have been very much in focus in recent debates. Against the background of the very large number of existing substances, one can assume that the above-mentioned examples are only the tip of the iceberg (see Figure 4).

The development within this field can very briefly be summarized by saying that the old and known problems are decreasing, but not vanishing completely. At the same time, new problems are arising at an alarming rate.

Organic substances which are not degraded, or which are degraded at a lower rate than that corresponding to their inputs, are being enriched in the environment. Most stable organic substances are soluble in fat, and are thus enriched in living material. Sooner or later, many more such substances than those we know about today will reach concentrations that will cause negative effects somewhere in the ecosystem. We must be prepared to encounter further serious environmental hazards from presently unknown toxic substances.

The only way to be safe from such environmental surprises is to reduce the input of man-made stable organic substances to virtually zero.

In general terms, the organic substances with the largest proven or expected environmental risks are today found within the group of chlorinated organic substances. The major source of inputs of such substances to the Baltic environment is the pulp and paper industry. The chemical industry, and other industries using a lot of chemicals, such as the textile industry, the tanning industry, the plastic and rubber industry, the mining industry and the graphical industry, can also give rise to considerable inputs of these substances.

One large source, and certainly the most difficult to handle, is the general use and distribution in our society of stable organic substances in constructions (e.g., asbestos), consumer goods (e.g., cadmium in pigments) and chemical products (e.g., chlorinated solvents). It is becoming more and more obvious that potentially hazardous substances are being incorporated into social structures, through the products we use, in much larger amounts than they leave the active society in the shape of waste of different types. Sooner or later these substances will reach the environment, but in the meantime we are losing control of their ultimate fate.

A considerable effort has been made to reduce the inputs of stable organic substances from the Swedish pulp and paper industry. This programme has been developed jointly between national authorities and the industrial sector itself and has cost a fortune in research and investment monies.

The first phase of the clean-up is well under way, and within a few years all pulp and paper industries with bleacheries in Sweden will have reduced their discharges of chlorinated organic material by about fifty per cent, compared to 1988.

Phases two and three will further reduce the discharges over the next decade by seventy-five per cent. It should be noted that sufficient technology has not yet been developed to carry out the programme in its entirety (see Table 1).

<table>
<thead>
<tr>
<th>Year</th>
<th>Discharge of AOX tonnes/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>14,000</td>
</tr>
<tr>
<td>1992</td>
<td>7,500</td>
</tr>
<tr>
<td>1995</td>
<td>3,700</td>
</tr>
<tr>
<td>2000</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Total cost around 1,000,000,000 USD.

AOX = Adsorbable organohalogen compounds.

Any policy to reduce the risks caused by discharges of stable organic substances must be built upon the precautionary principle. The discharge of such substances from industry must be inventoried. The use of chemical products within certain industrial sectors should also be carefully investigated. In this effort, the principle of substitution is central. This principle simply means that anyone who uses a chemical product should strive to change to the use of a substitute which is potentially less hazardous.

11 THE FUTURE

All decisions taken in order to protect the Baltic Sea from environmental deterioration should, ideally, have a solid scientific basis. This has been the case with mercury, for example. Research on its potential environmental hazard has led to almost world-wide acceptance of the necessity to reduce discharges and inputs. International action plans (e.g., within HELCOM) consequently contain mercury as a prime target.
Figure 4  The decrease in the concentrations of DDE in guillemot eggs from the Baltic Sea from 1968-1989.
The situation is similar for toxic metals in general, and for a few organic compounds. Although gaps in scientific knowledge exist, decision-makers nevertheless have a good scientific basis for their actions.

In Sweden, decision-makers and scientists agree that the present target for the reduction of inputs of toxic metals (for the Baltic, fifty per cent between 1987 and 1995) will be sufficient for the foreseeable future. The two exceptions to this are mercury and cadmium, where at least a seventy-five per cent reduction is needed in order to bring the inputs down to safe levels, according to Swedish opinion. The international agreement of a fifty per cent input reduction goal for the Baltic Sea shall be fulfilled by 1995 for toxic metals.

Even before that time, it will be necessary to make new decisions or to set new goals for the future. The question then will arise as to whether or not the fifty per cent reduction has brought input levels sufficiently close to background inputs in order for the Baltic Sea, as a whole, to be properly safeguarded. For mercury and cadmium, it may be necessary to establish a new goal. All this, of course, requires that the reduction goal that has been set is being fulfilled by all bordering countries. If this should not be the case, it will be necessary to decide what to do with previously set goals. Will it perhaps be more cost effective to allow a reduction rate lower than fifty per cent for certain metals, and to put more effort on certain other metals, with a possibility of going beyond fifty per cent?

When we turn to nutrients, the situation is different from that of the toxic metals, but a reasonably good scientific basis for decision-making is also available here.

During the 1950s and 1960s, it was possible to develop the Vollenweider model to make a prognosis of the effect on freshwater eutrophication of a specified reduction in the inputs of nutrients. The more recent decisions by the environment ministers to reduce inputs of nutrients to the marine environment by fifty per cent is, however, based more on a general assessment of what the eutrophication situation in the sea was when inputs were about fifty per cent lower than they are today. This is, in other words, a type of retrospective analysis.

For nutrients, the connection between the traditional ecosystem approach, on the one hand, and the fisheries activities, on the other, is evident. As the concentrations of nutrients in any water area increase, species which require more nutrients (e.g., certain species of consumable fish) will thrive. This has for a long time been an argument against too stringent measures to reduce the nutrient inputs to the Baltic. Today, however, there appears to be a general agreement that we must reduce the nutrient levels. The question then becomes at which level we shall stop. Shall we aim for pre-industrial levels, which can most likely support a fish production which is much lower than the optimal production (i.e., from a fisheries point of view), or shall we seek some other balance point?

Any nutrient level above the natural, pre-industrial level will lead to a non-natural ecosystem balance in the Baltic. The production of seafood must perhaps be given higher priority than the need to establish, again, a completely "natural" environment. And even if we agree that a virgin, pre-industrial, ecological system is neither desirable nor achievable, the question remains as to how much of an artificial change we shall accept. What scientific research do we need in order to provide a sufficient scientific background for very difficult decisions of this type?

And last, but not least, we have the effects of the fisheries activities themselves to consider. To what extent are the low cod catches in the Baltic today dependent on over-fishing, and to what extent do they depend on other factors, such as a low level of hatching, due to anoxic conditions in the deeper areas of the Baltic? Is the decreasing salinity of the deep bottom waters more important than the lack of oxygen?

What significance does the fine-mesh net fishing have for the ecology of the Baltic in general, and the production of fish specifically? What does trawling mean, seen in a long-term perspective, for the bottom-living organisms? Is repeated trawling of bottom areas resuspending pollutants, thus increasing the present hazard to the Baltic Sea environment?

For stable organic substances, the situation, both as regards scientists and decision-makers, is quite different (as compared with toxic metals or nutrients).

Ministers for the environment have, within the HELCOM context, taken a decision to reduce inputs of persistent substances, which are toxic or liable to accumulate, by fifty per cent before 1995. This decision is not based on detailed scientific research concerning each individual compound. Rather, it expresses a general anxiety, among scientists and politicians, as well as among the population in general, regarding the use of man-made, organic compounds in today's society.

Past experience with various stable organic substances should already have led to greater care when introducing new substances. Unfortunately, this does not always seem to have been the case. Instead, we are still discovering new groups of relatively stable substances in the environment.

Those which are of most current interest are brominated aromatic substances (principally polybrominated diphenyl...
ethers), which have been increasingly used as flameproofing agents. They have been found in most biological samples, including seals from the northern Arctic Ocean. In addition, analyses of laminated sediments from the Baltic Sea suggest that the concentrations of these compounds are increasing rapidly. In order not to risk creating a new PCB type of problem, we must reduce the use of these substances (see Figure 5). This may give rise to a conflict between environmental demands and fire safety requirements, unless it is possible to develop substitute products which are less harmful to the environment.

With regard to stable organic substances, the questions are more plentiful than the answers. What do we mean by a stable substance? Should it be stable over a period of one month, one year, ten years, or what? Or is it sufficient that it is stable enough to accumulate in the food web? How shall we get the resources to monitor our marine environment for stable and man-made organic substances? How can we establish critical levels of these substances, which are previously unknown to ecological systems? Should such limits be based on observable ecological effects, or must we consider the potential risks involved at levels where we can only observe small changes in individual organisms or populations? Or, is the only acceptable long-term goal to achieve a zero input level? Does zero mean almost zero or absolute zero? The list of questions can, of course, be made much longer. And one crucial question is: how can we, through a coordinated research and investigation effort, provide the answers needed?

It is always very difficult to compare apples with pears. In attempting to set priorities among different types of pollutants, such as stable organic substances, toxic metals and nutrients, we have at least come a short distance along the path in this task.

When it comes to assessing the relative importance of the effects of inputs of pollutants as compared to the effects of the fisheries activities, we are probably trying to compare apples, not with pears, but with bears (or something similar). If we are to get any substantial increase in our knowledge before the turn of the century, which I believe is necessary, we must increase our efforts immediately in this area. ICES, and all the different experts working within the ICES sphere, provides one of the best foundations for such an integrated research and investigative effort. For that reason, I believe that it is very important to aim for a high degree of cooperation between the environmental side and the fisheries side of the ICES structure.

12 CONCLUSIONS

To conclude, it is evident that a number of different decisions will have to be made during the coming years, decisions of crucial importance for the health of the Baltic Sea. The activities which result from these decisions will be very, very expensive for the bordering countries. And, of course, there are considerable uncertainties involved: technical, economic, scientific, and political.

Of particular interest for the ICES Dialogue Meeting are the scientific uncertainties. Some have been pointed out in this paper; many have been addressed in other presentations during this meeting:

- What is the long-term goal for inputs of toxic metals?
- Can a suitable balance between the positive and negative effects of nutrient inputs be agreed upon?
- What are the operative intermediate goals for inputs of stable organic substances?
- Do we know where the limits for a sustainable fishery are?
- How far is it reasonable to go in input reductions, if harmonized actions are not carried out elsewhere around the Baltic Sea?

This line of reasoning leads me to the following belief. Unless we can better define which questions the decision-makers need to have answered, we are likely to allocate the resources we spend on research in a suboptimal way. On the other hand, a better definition of the critical questions will provide a powerful argument for the allocation of extra research money. After all, the research money needed is relatively small compared to the rather enormous sums required for investments associated with pollution-control measures, as well as operation, training of staff, and maintenance of these facilities.

With total expenditures in the range of several tens of billions of dollars, just imagine what only one percent of that money could do, if strategically allocated to research.
Figure 5  Temporal trends in concentrations of brominated diphenyl ethers in guillemot eggs from the Baltic Sea. (TeBDE = Tetrabrominated diphenyl ether; PeBDE = Pentabrominated diphenyl ether.)
DISCUSSION OF MANAGEMENT PAPERS

Dr Pekka Niskanen stated that management work in IBSFC has been carried out for 17 years. He could understand the criticism of the results, however, because they have not been as good as he would like. Part of the problem has been that socio-economic considerations often conflict with scientific advice. The Total Allowable Catch (TAC) is a practical management tool, but only as long as it is adhered to. He thought, however, that there would be less deviation from scientific advice in the future.

Professor Thurow indicated that the IBSFC should listen more closely to the scientific advice it receives.

Dr Hildén stated that the fisheries management paper raises the important question of identifying objectives and how to achieve them. It is very relevant to identify clearly what you want to regulate, because this decision influences the type of research that must be conducted. Dr Karnicki had suggested the introduction of individual transferable quotas to overcome the problems associated with management of a common property, but he had also suggested fishing effort regulation. Do we want to aim for systems which regulate themselves rather than forceful management? The two approaches have very different implications for research.

Dr Karnicki said that self-regulation is certainly preferable.

Dr Richardson pointed out that there are a number of different management objectives which do not make sense scientifically, e.g., a reduction of inputs of trace metals to 50% above background, a natural distribution of flora and fauna; but what are background inputs of trace metals and what are natural distributions of flora and fauna? These questions can never be answered, so how can a role be found for the scientist in this type of decision making?

Dr Ferr replied that the reason that he had worded the long-term goals in that way was that they had been formulated on the basis of the available information from scientists. He was willing to receive new advice so that more appropriate goals could be formulated.

Dr Kleniewski (Polish Ministry of Transportation and Maritime Economy) stated that, as a policy-maker, he was aware of the issues involved in fisheries and ecology, but he also had financial constraints in terms of possible actions. Cooperation was very important, particularly when an accident has occurred, e.g., Chernobyl. Thus, mechanisms must be established to ensure more comprehensive cooperation. He felt that we should now begin to think about developing a common fisheries policy for the Baltic Sea as well as a common environmental policy. International control should also be increased, as the IBSFC has no control over the enforcement of the decisions it makes.

Mr Jakobsson declared that it was not time to think, but rather it was time to act, as the situation in the Baltic Sea is very serious, particularly in relation to the cod stocks.

Dr Karnicki noted that, with regard to the IBSFC, it is not the Commission itself, but the member nations who make the decisions and they must also enforce them. He agreed, however, that the IBSFC should consider its objectives and develop a common policy. The IBSFC should have taken drastic action for cod two years ago.

Mr Terring commented that fisheries management has failed with regard to the tools for management; there is a large over-capacity, decreasing stocks, etc. The advice has been good, but the management tools chosen are wrong. For example, if you want to decrease fishing effort, you can regulate this using maximum horsepower of fishing vessels, capacity, etc., but the fishermen will simply find ways to compensate for this and the measures only increase their costs. Thus, the only rational solution is individual quotas. He felt that environmental management is in the same position, e.g., spending a great deal of money to decrease the discharge of nutrients from municipal and industrial sources, when a large portion of the nutrient inputs derive from agriculture. He felt that economic incentives, e.g., taxes on fertilizers, would be more useful.

Dr Karnicki agreed to a certain extent on the proposal to regulate more through economics, but felt that these can also be circumvented. Dr Ferr also agreed that there is merit in economic tools, but they do not always work.

Mr Schmiegelow felt that the goals of 50% reduction of contaminants and the fishery goals regarding cod were unrealistic. Regarding cod, he queried whether there is any possibility of predicting when the next inflow of salt water to the Baltic Sea will occur. Managers would like to know when this will happen.

Dr Karnicki noted that one should evaluate what is probable and what is not; one must evaluate uncertain information and act on it, taking the risks into account. He believes that managers have not taken into account the risk associated with the rapidly declining cod stocks.

Dr Serchuk pointed out that we are focusing here on cod, but that is only the tip of the iceberg. Addressing only one component of the fisheries system is a problem. The trend regarding cod has been evident for some time; but this is a fisheries system problem, because if we reduce fishing effort on cod, it will be transferred to another species.

Dr Karnicki said there is a need to transfer fishing effort from cod to herring. Baltic herring stocks are at a high level and this has resulted in poor quality of herring due to under-nourishment.
MUNICIPAL AND INDUSTRIAL DISCHARGERS: THE PULP AND PAPER INDUSTRY AS A CASE EXAMPLE

K. Mukala
Soil and Water Ltd.
Helsinki, Finland

ABSTRACT

The contribution of industrial and municipal discharges to the pollution load of the Baltic Sea is evaluated. The significance of deposition from the atmosphere is brought into perspective but not discussed in detail.

The main recommendations and declarations by the Helsinki Commission concerning municipal effluent treatment are summarized. Municipal effluent treatment practices during the late 1980s up to the present, along with needed efforts to meet targets set by the Helsinki Commission, are briefly reviewed for the countries around the Baltic Sea.

The aim of investing in municipal effluent treatment has been to improve the quality of the inland and coastal waters. Scandinavia and Germany are considering, or have already carried out, investments in improved biological treatment for nitrogen removal or tertiary treatment for phosphorus removal, while other countries are still lacking basic secondary treatment systems. The minimum cost principle would most likely favour secondary treatment installations in the eastern European countries and possibly tertiary treatment in the large coastal cities along the Baltic Sea.

The pulp and paper industry has been selected as an example of an industrial discharger. Another example to be reviewed is Finland’s experience on water pollution control measures. Trends in other countries around the Baltic Sea are also discussed. Today, environmental control measures are requested from mills in order to meet the requirements of official permits, to satisfy the clients and customers and, in the future, to minimize the cost of production, i.e., due to taxes, levies set for raw materials or discharges of environmentally harmful compounds. In addition to the efforts to reduce conventional effluent parameters such as suspended solids and organics, the main effort of the pulp and paper industry is to reduce the discharge of chlorinated organic compounds.

INTRODUCTION

Many countries around the Baltic Sea have successfully passed a period of basic investments for sewage networks and sewage treatment plants. Now they are considering an implementation of more advanced measures. On the other hand, other countries around the Baltic are struggling with economic problems, with limited resources for modern environmental pollution control, including municipal effluent treatment.

Environmental protection measures for industrial discharges are industry and even plant specific. The pulp and paper industry is one of the major industrial polluters of the Baltic Sea and, thus, it has been selected as a case study for this paper.

Even though atmospheric deposition may play a significant role in terms of the total load of some substances, such as nitrogen and heavy metals, into the Baltic Sea, these are only briefly mentioned in this presentation.

GENERAL INFORMATION ON THE IMPORTANCE OF DIFFERENT POLLUTERS TO THE BALTIC SEA

There are various parameters to consider, but phosphorus and nitrogen are taken as examples to illustrate the annual distribution of the total loading into the Baltic Sea, excluding the Kattegat (Ambio, 1990):

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t/yr</td>
<td>%</td>
</tr>
<tr>
<td>Land and coastal areas</td>
<td>480,000</td>
<td>49</td>
</tr>
<tr>
<td>Atmospheric deposition</td>
<td>370,000</td>
<td>38</td>
</tr>
<tr>
<td>Fixation from air</td>
<td>130,000</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>980,000</td>
<td>100</td>
</tr>
</tbody>
</table>

It should be remembered that non-point source nutrients can originate from the atmosphere and arrive in the sea via river input. These are included in the estimates of land input.
As an example, the estimate of the breakdown of nitrogen and phosphorus loadings into the waterways of Finland in 1989 is (Finnish Ministry of the Environment, 1989):

<table>
<thead>
<tr>
<th></th>
<th>Nitrogen</th>
<th>Phosphorus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t/yr</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>t/yr</td>
<td>%</td>
</tr>
<tr>
<td><strong>Point sources, sub-total</strong></td>
<td>23,300</td>
<td>17.5</td>
</tr>
<tr>
<td>- pulp and paper industry</td>
<td>4,400</td>
<td>3</td>
</tr>
<tr>
<td>- other industry</td>
<td>1,900</td>
<td>1</td>
</tr>
<tr>
<td>- communities</td>
<td>14,500</td>
<td>11</td>
</tr>
<tr>
<td>- fish farming</td>
<td>2,000</td>
<td>2</td>
</tr>
<tr>
<td>- fur farming</td>
<td>500</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Diffuse sources, sub-total</strong></td>
<td>41,500</td>
<td>32.5</td>
</tr>
<tr>
<td>- sewerless settlement</td>
<td>4,000</td>
<td>3</td>
</tr>
<tr>
<td>- arable farming</td>
<td>31,000</td>
<td>24</td>
</tr>
<tr>
<td>- cattle farming</td>
<td>1,100</td>
<td>1</td>
</tr>
<tr>
<td>- forest industry</td>
<td>5,000</td>
<td>4</td>
</tr>
<tr>
<td>- peat production</td>
<td>400</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Other sources, sub-total</strong></td>
<td>66,700</td>
<td>50</td>
</tr>
<tr>
<td>- natural run-off</td>
<td>45,000</td>
<td>34</td>
</tr>
<tr>
<td>- wind-borne load</td>
<td>21,700</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total loading</strong></td>
<td>131,500</td>
<td>100</td>
</tr>
</tbody>
</table>

The figures given for diffuse sources and other sources are based on estimates. The loadings from arable farming fluctuate annually, in the range of 20,000 - 40,000 t/yr for nitrogen and 2,000 - 4,000 t/yr for phosphorus. These two estimates show the importance of each activity to the total load into the Baltic Sea. Degradation in the watercourses, prior to discharge to the sea, has not been considered.

Agricultural and other diffuse sources are the major contributors of nutrients from all countries along the Baltic Sea. Typical for Finland is the high removal rate of organics and phosphorus from municipal effluents. Also typical is the dominance of forest industries in comparison to other industries.

Municipal and industrial discharges are not always the dominant polluters when the Baltic Sea is considered as a whole. However, they do often have a significant impact on the inland watercourses, as well as on coastal waters.

### 3 MUNICIPAL DISCHARCERS

#### 3.1 Summary of the Main Recommendations and Declarations of the Helsinki Commission (HELCOM)

The most significant declarations concerning municipal effluent treatment can be summarized as follows:

- HELCOM Recommendations 8/3 and 9/2
  - BOD₅:
    - reduction >90% and
  - BOD₅ in effluent <15 mg/l
  - Total phosphorus:
    - in effluent <1.5 mgP/l
  These recommendations are valid for wastewater treatment plants serving more than 10,000 person equivalents and should be realized as soon as possible and not later than 1998.

  The figures given should be calculated as yearly average values for the total amount of influent sewage.

- HELCOM Declaration 9/16, annex 18
  "In order to fulfill these objectives, current and new efforts on the reduction of the load of pollutants should aim at a substantive reduction of the substances most harmful to the ecosystem of the Baltic Sea, especially of
  - heavy metals and toxic or persistent organic substances, and
  - nutrients
  for example in the order of 50% of the total discharges of each of them, as soon as possible but not later than 1995."

  The requested reduction of around 50% is in comparison to the loadings during 1987. It must also be recognized that the reduction of nutrients considers the total national loads, not the portion discharged only from municipal effluents.

#### 3.2 Effluent Treatment Practice in the late 1980s in the Baltic Sea Countries

A professional estimation was made to give an idea of the state of wastewater treatment practice during the late 1980s in the Baltic Countries.

This information is compiled and presented in Table 1 below.
Table 1  Typical figures for a municipal effluent treatment plant during the late 1980s in the Baltic Countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Method</th>
<th>BOD-red.</th>
<th>Tot. P</th>
<th>NH$_3$-N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>mg/l</td>
<td>mg/l</td>
</tr>
<tr>
<td>Denmark</td>
<td>AS</td>
<td>90</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Finland</td>
<td>AS with simultaneous</td>
<td>90</td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>precipitation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>FRG</td>
<td>90</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>GDR</td>
<td>50</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Poland</td>
<td>Chemical treatment</td>
<td>50</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Sweden</td>
<td>AS with post-precipitation</td>
<td>90</td>
<td>0.5</td>
<td>20</td>
</tr>
<tr>
<td>USSR</td>
<td>Mechanical treatment</td>
<td>30</td>
<td>15</td>
<td>35</td>
</tr>
</tbody>
</table>

AS = Activated sludge treatment plant.

The treatment efforts during the early 1990s can be summarized as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>BOD</th>
<th>N</th>
<th>P</th>
<th>SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
</tr>
<tr>
<td>Finland</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Germany</td>
<td>FRG</td>
<td>+</td>
<td>+</td>
<td>(+)</td>
</tr>
<tr>
<td></td>
<td>GDR</td>
<td>(+)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Poland</td>
<td>(+)</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Sweden</td>
<td>+</td>
<td>(+)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>USSR</td>
<td>(+)</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

SS = Suspended solids.

+ = High reduction rate.

(+) = Removed partly or removed efficiently in only some areas.

= Not normally removed.

Typically, in Denmark priority in nutrient removal has been given to nitrification. In Finland and in parts of Sweden, the main emphasis has been given to phosphorus removal. The different approaches take into account the local N/P balances in recipient waters. In Finland and in parts of Sweden, the water courses include many lakes where the minimum nutrient is normally phosphorus instead of nitrogen.

3.3 Meeting the Goals of HELCOM

The difficulties in meeting the HELCOM targets can be summarized as follows:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BOD$_3$ &lt; 15 mg/l</th>
<th>Phosphorus &lt; 1.5 mg/l</th>
<th>50% reduction from 1987 for nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target year</td>
<td>1998</td>
<td>1998</td>
<td>1995</td>
</tr>
<tr>
<td>Denmark</td>
<td>Achieved</td>
<td>Minor investments</td>
<td>Minor investments</td>
</tr>
<tr>
<td>Finland</td>
<td>Achieved</td>
<td>Achieved</td>
<td>Minor investments Improved operation</td>
</tr>
<tr>
<td>Germany</td>
<td>FRG</td>
<td>Operation costs incr.</td>
<td>Implementation under way</td>
</tr>
<tr>
<td>GDR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>Heavy investments needed, financing possible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Achieved</td>
<td>Achieved</td>
<td>Implementation under way</td>
</tr>
<tr>
<td>USSR</td>
<td>Heavy investments needed, financing a problem</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.4 Costs of the Wastewater Treatment

To give a general idea of the costs involved, some basic figures are given.

When conventional municipal effluent treatment practice with activated sludge treatment is applied, the investment cost of the wastewater treatment plant ranges from 20 - 40 % of the total investment cost, including the sewerage network. The investment cost of a large sewage treatment plant is around 200 - 500 USD/population equivalent.

Municipalities in Finland normally charge the consumers 0.5 - 1.0 USD/m$^3$ of treated effluent. This covers all operation, maintenance and capital costs. The average amount of sewage discharged/population equivalent is about 0.3 m$^3$/d.

3.5 Some General Remarks

Rapid progress will be seen in wastewater treatment practices in Germany in the areas of the former GDR.

There are many concrete plans ready for implementation that can improve the environmental conditions in Poland.
and in the former USSR, financed partly by neighbouring countries.

In many cases, biological treatment with activated sludge or chemical treatment would be included which produces problems with sludge disposal. In many European countries, the allowable heavy metal concentration limits in sludge for agricultural use have recently been lowered. Sludge management problems seem to be increasing in the 1990s in all Baltic Sea countries.

The aim of investing in municipal effluent treatment has been to improve the quality of the inland and coastal waters. Scandinavia and Germany are considering, or have already carried out, investments in improved biological treatment for nitrogen removal or tertiary treatment for phosphorus removal, while other countries are still lacking basic secondary treatment systems. The minimum cost principle would most likely favour secondary treatment installations in the eastern European countries and possibly tertiary treatment in the large coastal cities along the Baltic Sea.

4 INDUSTRIAL DISCHARGERS IN GENERAL

There are no exact data available on the industrial contribution with respect to total direct loading of pollutants to the Baltic Sea, or to the catchment area. Clearly, industries play an important role when heavy metal loadings are considered, both due to effluent discharges and due to emissions to the atmosphere. It is also typical that the discharges vary a great deal between plants, depending on the production process applied and, thus, generalization is extremely difficult even within the same industrial field. This leads to the need to study industrial plants on an individual basis.

The main industries of environmental concern are:

- metallurgical industries,
- mining,
- chemical industries,
- forest industries, and
- food industries.

Forest industries, i.e., pulp and paper industries, will be discussed more thoroughly in this context.

5 PULP AND PAPER-INDUSTRIES AS DISCHARGERS

5.1 Pulp and Paper Industries in General

Table 2 gives pulp and paper production figures in 1989 for the main producer countries around the Baltic Sea. It must be remembered that only a small fraction of the pulp and paper production in Germany and not all production in the former USSR takes place in the catchment area of the Baltic Sea.

<table>
<thead>
<tr>
<th>Product</th>
<th>Finland</th>
<th>Sweden</th>
<th>Germany FRG</th>
<th>GDR</th>
<th>Poland</th>
<th>USSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphate pulp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- bleached</td>
<td>4490</td>
<td>3806</td>
<td>0</td>
<td>36</td>
<td>204</td>
<td>1916</td>
</tr>
<tr>
<td>- unbleached</td>
<td>734</td>
<td>2197</td>
<td>0</td>
<td>90</td>
<td>335</td>
<td>2669</td>
</tr>
<tr>
<td>Sulphite pulp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- bleached</td>
<td>85</td>
<td>579</td>
<td>647</td>
<td>268</td>
<td>44</td>
<td>892</td>
</tr>
<tr>
<td>- unbleached</td>
<td>69</td>
<td>170</td>
<td>7</td>
<td>101</td>
<td>19</td>
<td>1188</td>
</tr>
<tr>
<td>Semi-chemical pulp</td>
<td>373</td>
<td>285</td>
<td>82</td>
<td>0</td>
<td>107</td>
<td>595</td>
</tr>
<tr>
<td>Mechanical pulp</td>
<td>3203</td>
<td>3001</td>
<td>1271</td>
<td>166</td>
<td>106</td>
<td>2150</td>
</tr>
<tr>
<td>Other (dissolving)</td>
<td>164</td>
<td>300</td>
<td>138</td>
<td>8</td>
<td>45</td>
<td>690</td>
</tr>
<tr>
<td>Total pulp</td>
<td>9119</td>
<td>10338</td>
<td>2418</td>
<td>669</td>
<td>860</td>
<td>10100</td>
</tr>
<tr>
<td>Pulp mills, pcs.</td>
<td>46</td>
<td>54</td>
<td>34</td>
<td>19</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>Total paper &amp; board</td>
<td>8751</td>
<td>8362</td>
<td>11277</td>
<td>1360</td>
<td>1397</td>
<td>11000</td>
</tr>
<tr>
<td>Paper &amp; board mills, pcs.</td>
<td>46</td>
<td>54</td>
<td>174</td>
<td>21</td>
<td>47</td>
<td>173</td>
</tr>
<tr>
<td>Recycled fibre</td>
<td>378</td>
<td>890</td>
<td>5623</td>
<td>666</td>
<td>495</td>
<td>3000</td>
</tr>
<tr>
<td>Average production/mill (calculated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- pulp</td>
<td>200</td>
<td>190</td>
<td>71</td>
<td>35</td>
<td>43</td>
<td>190</td>
</tr>
<tr>
<td>- paper/board</td>
<td>190</td>
<td>150</td>
<td>65</td>
<td>65</td>
<td>30</td>
<td>64</td>
</tr>
</tbody>
</table>

The total pulp production in Denmark in 1989 was 112,000 t and the total paper and board production was 328,000 t.

The total number of pulp and paper mills in Finland is about 50 and in Sweden about 80. Typical for Finland and Sweden is a larger mill size compared to the many small mills used in central and eastern European countries. In Finland, several mills are situated inland, whereas in Sweden most of the mills are coastal. In both Finland and Sweden the forest industry is export-oriented, whereas in the other Baltic countries the forest products are mainly used domestically.

Particularly in Finland, the forest industry plays a major role in the national economy. The forest industry accounts for about 50% of Finland’s net foreign exchange earnings.

Also typical for Finland and Sweden in comparison to the central European countries is the relatively small
amount of recycled fiber used. This is due to the small amount of domestic waste paper available relative to production rates, as it is an export-oriented industry.

Table 3 Wastewater loads from pulp and paper industries (Junna and Ruonala, 1990; Lagergren and Nyström, 1990).

<table>
<thead>
<tr>
<th>Year</th>
<th>1988</th>
<th>1988</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>Finland</td>
<td>Sweden</td>
</tr>
<tr>
<td>SS</td>
<td>t/yr</td>
<td>62,000</td>
</tr>
<tr>
<td>BOD&lt;sub&gt;7&lt;/sub&gt;</td>
<td>t/yr</td>
<td>138,000</td>
</tr>
<tr>
<td>COD</td>
<td>t/yr</td>
<td>587,000</td>
</tr>
<tr>
<td>AOX</td>
<td>t/yr</td>
<td>13,000</td>
</tr>
<tr>
<td>- 1987 estimate (6)</td>
<td></td>
<td>9,700</td>
</tr>
<tr>
<td>Tot. N</td>
<td>t/yr</td>
<td>4,450</td>
</tr>
<tr>
<td>Tot. P</td>
<td>t/yr</td>
<td>800</td>
</tr>
</tbody>
</table>

SS = Suspended solids.
BOD<sub>7</sub> = Biochemical oxygen demand in 7 days.
COD = Chemical oxygen demand.
AOX = Total chlorinated organic compounds (Adsorbable Organic Halogen).
Tot. N = Total nitrogen.
Tot. P = Total phosphorus.

Despite the extensive measures taken in Finland and Sweden, the pulp and paper industry continues to discharge more dissolved organic substances than any other sector. Within the pulp and paper industry, pulp production is the main polluter.

5.2 Finnish Experience from the Pollution Control of Pulp and Paper Industries

5.2.1 Development of wastewater loads

The production and the development of effluent loads to recipients from the Finnish pulp and paper industry can be seen in Figures 1 and 2.

The production in the pulp and paper industry increased considerably during the 1970s and 1980s. However, the BOD<sub>7</sub> and the suspended solids loads decreased during this time owing to decreasing trends in the rate of wastewater loadings per production output. This was due to the external and internal pollution control measures which were introduced after the late 1960s. This was also due to a change in processes: all except two sulphite pulp mills were shut down and replaced by other pulping methods.

In the late 1980s, new investments towards production led to a requirement of efficient biological treatment from the mills. Most of the plants constructed were activated sludge treatment plants.

The main goals for the pulp and paper industry, in reducing effluent load up to 1995, are the following:

- BOD<sub>7</sub> < 160 t/d (1988 400 t/d)
- P < 1.5 t/d (1988 2.3 t/d)
- CODcr < 65 kg/t bleached pulp
- AOX < 1.4 kg/t bleached pulp (1989 normally 2 - 4 kg/t)

5.2.2 Methods and results of external effluent treatment

Mechanical treatment was the first stage

The load of solids to the recipient was decreased to almost the present level during the early 1970s. Mechanical treatment plants were built simultaneously with the implementation of internal process measures to prevent fiber loss. In primary treatment, the suspended solids reduction is normally about 80 - 90% and the BOD<sub>7</sub> reduction with pulp mill effluent is normally 0 - 20%; some paper mills have up to 80%.

Biological treatment started with aerated lagoons

During the 1970s, a few aerated lagoons were built, mostly for pulp mills. At most six aerated lagoons were in operation and their efficiency was improved during the 1980s. The annual average BOD<sub>7</sub> removal has been in the range of 50 - 75%. Total organic chlorine and chlorinated phenol removal has been about 10 - 50%.

In 1984 the first activated sludge plant was put into operation

By the end of the 1980s, twenty activated sludge plants and three anaerobic treatment plants were built or were under construction. By 1995, all major Finnish mills will have activated sludge treatment or its equivalent in operation. The first plants were primarily designed for high or normal sludge loading, those now under construction are of normal or low-load type. This is mainly to improve the COD and AOX reduction rates, as well as to minimize the excess sludge production.
Figure 1  Trends in the production of paper/paperboard and pulp in Finland and associated discharges of suspended solids and BOD₇; locations of biological treatment plants in Finland.
Figure 2  (a) Emissions of organically bound chlorine in relation to pulp production in Finland.  
(b) Consumption of chlorine in relation to pulp production in Finland.  
(c) Nitrogen load in Finnish waterways in relation to forest industry production.  
(d) Phosphorus load in Finnish waterways in relation to forest industry production.
In the activated sludge plants, BOD reductions of over 90% can be achieved. COD removal can be higher than 70% for paper mills and around 50% for pulp mills. The AOX reduction normally varies between 30 and 50%. Chlorinated phenols, most of which have a high acute toxicity, are removed to varying degrees, up to > 90%. The overall removal of resin acids exceeds 90%.

Accidental spills from the manufacturing processes present a risk for the biological process. Figure 3 shows some preventive methods for risk elimination at activated sludge plants.

In the activated sludge process, excess sludge to be handled and disposed of averages 0.5 kg dry solids/t BOD$_7$-reduced. The sludge is normally dewatered and burned with the bark in the bark boilers or placed in a landfill.

Tertiary treatment is not yet widely applied

The first tertiary treatment stage, in Finland, for pulp and paper mills (flotation with chemical precipitation to reduce the phosphorus load after activated sludge treatment) was taken into operation at United Paper Mills Ltd’s Jämsänkoski mill in late 1990.

5.2.3 Costs of environmental pollution control

To give an idea of the costs involved, the total cost of environmental control measures, including air pollution control and internal measures for pollution control, are about 10 - 20% of a greenfield pulp mill investment.

The cost of an activated sludge effluent treatment plant for a modern pulp mill is around 12 - 48 million USD and the annual operation and maintenance cost is about 2.4 - 4.8 million USD, in other words about 7 USD/t of pulp.

5.2.4 Development trends

Internal measures

Slowly degradable compounds originate mostly from the bleaching process. The proportion of bleached pulp in pulp manufacturing has increased continuously.

A summary of the main effects of some internal measures on different control parameters is presented in Table 4.

Table 4 Decreasing effects of some internal process measures on effluent discharge (Junna and Ruomala, 1990).

<table>
<thead>
<tr>
<th></th>
<th>BOD$_7$</th>
<th>COD$_{cr}$</th>
<th>P-tot</th>
<th>AOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extended cooking</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen delignification</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closing water recycles</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Use of chlorine dioxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of peroxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improved washing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Dry debarking</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

+ = Main effect. Naturally, each measure affects all loading parameters to some extent.

It is estimated (Junna and Ruonala, 1990) that by 1992 Finland’s sulphate pulp production will have >40% oxygen bleaching and 25% extended cooking.

External measures

In the near future, activated sludge treatment will be the basic method for the treatment of effluents from Finnish pulp and paper mills. Pre-treatment, improvements and modifications with regard to the activated sludge plant will be the goals for further development and research work. The primary concern of such work will be the removal of slowly degradable organic compounds, toxic compounds, and nutrients.

Of the target values for 1995, the reduction of AOX requires both internal and external measures.

The target for phosphorus, in general, means that the concentration in effluent must be less than 1 mg/l. This can be problematic due to the fact that nutrients normally need to be added during aerobic biological purification.

5.3 Trends in Other Countries of the Baltic Sea

Sweden

The emphasis in Sweden is placed on discharges of chlorinated organic substances and on internal methods to control such discharges (Lagergren and Nyström, 1990).

By the end of 1992, all plants producing bleached chemical pulp will have commenced taking measures which will reduce the AOX discharge to a level of 2 kg/ADt. As far as it is possible in the light of technical and other circumstances, the discharges should be reduced to below the stated level.
Figure 3 Biological effluent treatment plant - elimination of risks (Soil and Water Ltd.).
The Swedish Environmental Protection Agency has suggested in its report "Hav 90" (Sea 90) the following schedule for the reduction of AOX (expressed in kg/air dry tonne of bleached pulp):

<table>
<thead>
<tr>
<th>Mill type</th>
<th>1982</th>
<th>1995</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kraft softwood</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Kraft hardwood</td>
<td>1</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Sulphite</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

¹Measures performed at all plants.

The other parameters which have been included in the permits are: dissolved organic substances as BOD and COD, chlorate and nutrient salts.

Some inland paper and board mills have already had an intensive external effluent treatment in the 1970s. In general, the main emphasis has been to minimize the effluent discharge by internal measures. Nearly half of the pulp mills apply only primary sedimentation. The biological treatment plants for chemical pulp mills are aerated lagoons.

**Former USSR**

In the former USSR there are some pulp mills, close to the Finnish border, equipped with intensive external treatment, including activated sludge plants. These mills are the Vyborg pulp mill and the mills in Svetogorsk. The latter has the biggest tertiary treatment plant in the world for pulp and paper industry effluent, including flotation followed by sand filtration.

On the other hand, there are mills which lack modern measures for environmental pollution control.

**Germany**

In Germany, the most significant law dates from 1976 (Wasserhaushaltgesetz). It specifies the use of internal process and external measures of wastewater treatment in the pulp and paper industry. It also specifies the minimum requirements for the specific wastewater loads from various manufacturing processes. The increasing requirements have made the construction of biological treatment plants necessary for almost all mills.

New requirements, such as 1.0 kg AOX/t of sulphite pulp production, have been in effect since 1 January 1990.

The situation of the mills in the former GDR is not exactly known, partly because current development is very rapid. Paper companies in the former West Germany and in other western nations are replacing the domestic East German companies. The production capacity of the West German paper industry is increasing by about five per cent per year, but previous capacity in the east will be shut down due to the stricter environmental regulations and free market competition. It will take some time before new investments with modern technology are made possible in the east.

Currently in Germany, new regulations have been or will be passed concerning the reduction of packaging waste and the increased recycling of printed matter.

In Germany, serious consideration is being given to banning the use of chlorine completely in the bleaching of pulp, within the next few years.

Germany is the largest importer of pulp and paper products in Europe and the second largest in the world after the United States. Thus, developments in German legislation and market demands are extremely important for the large exporters of forest industry products such as Finland and Sweden.

**Poland**

The largest problem with regard to environmental pollution control measures for the pulp and paper mills in Poland is the lack of funding possibilities.

**5.4 Other Aspects**

**Closed cycle mill concept**

The 0-mill concept (i.e., a mill without discharge to the environment) is not considerably closer to reality than earlier, at least for pulp mills with chlorine as the bleaching agent. Increased recycling creates corrosion problems which have not been overcome technically. Other hindrances are the complexity of this approach and the cost.

In spite of this, the 0-mill concept has some new wind in its sails. It has been placed as a final target in a Swedish research programme. In Canada, some peroxide bleach chemi-thermo-mechanical pulp mills are applying novel techniques, such as freezing or evaporation with steam stripping, to close their water cycles (MiljöAktuellt, 1991). These techniques consume a considerable amount of energy, which may limit their further application.

**Relevance of the AOX parameter**

AOX (Adsorbable Organic Halogen) is a total parameter which provides a picture of the quantity of halogenated organic material, but almost no information on the "quality" of the material and its precise effects on the environment. For example, it is not entirely clear whether the effects on the environment diminish in
proportion to discharges or whether the most dangerous fractions disappear first. Investigations have shown greater reductions of dioxins and chloroguaiacol values than AOX values. Extensive studies are being carried out, at least in Finland and Sweden, to better characterize AOX and to determine its significance as these discharges approach zero.

Not all chlorinated compounds are environmentally hazardous. Chlorinated compounds are environmentally hazardous if they are highly toxic, or are moderately toxic and persistent, or if they are bioaccumulating and, therefore, not readily biodegradable.

5.5 Environmentally Friendly Products

5.5.1 General

Environmental legislation is not the only motivation for doing business in an environmentally acceptable way. Products are sold today with the label "environmentally friendly", which qualifies as the most overused phrase of the 1990s. One could also call it ecomarketing.

The most common sublabels for environmentally friendly products in the pulp and paper industry are "chlorine free" and "produced from recycled fiber".

When the way a product is produced, or the constituents it includes, influences the marketing of the final product, mill managers are most apt to become intensively involved with environmental aspects.

5.5.2 Official ecolabelling schemes

The first country to run an official ecolabelling scheme was West Germany. The "Blue Angel" scheme has been in use since 1978. Since then, ecolabelling schemes or proposals for them have been introduced in many places, notably in the Nordic countries with their "White Swan" eco-logo, in Canada with its "Environment Choice", and in Japan with its "Eco-mark" scheme. The European Community has put forward some initial ideas for an EC-wide ecolabelling scheme.

The basic idea is to consider the total life cycle of the product, i.e., "from the cradle to the grave", and its effects on the environment.

5.5.3 Eco-analysis techniques

Over the last few years, a number of new techniques for analysing environmental performance have emerged, but these are generally applicable to a specific site or company rather than to a product type (Webb, 1991). Some techniques are not clearly defined, but a concise summary is given as follows:

- Environmental impact assessment
  - procedure to predict impact before implementing a project
- Environmental auditing
  - on-going process of evaluating company performance/risks
- Eco-profiling or life-cycle analysis
  - producing an inventory of product impact from "cradle to grave"
- Eco-balancing
  - comparison of eco-profiles for a product type made from different raw materials

The last two techniques are relevant to ecolabelling. It must be realized, however, that even though the discharge during the life-cycle of two comparable products might be equal, the impact to the environment could differ significantly due to differing local circumstances.

5.5.4 General comments

Accuracy in ecolabelling will never reach scientific perfection, but its application may result in improvements towards:

- better knowledge and awareness of the environmental aspects of a product on the part of consumers, and
- better utilization of raw materials and energy in industrial processes.

6 SUMMARY AND CONCLUSIONS

So far the treatment requirements for the municipal effluent dischargers have been based on a need to improve or maintain the acceptable quality of inland or coastal recipients. The HELCOM recommendations may have increased political pressure to improve sewage treatment levels in the eastern European countries.

Aerobic biological treatment produces sludge. The heavy metal content in the sludge of municipal effluent treatment plants may limit sludge utilization for agricultural purposes, particularly in the eastern European countries. This is also the case in western countries where the concentrations of heavy metals permitted in sludge for agricultural use have been decreased recently.
While the basic pollution control measures for industrial and municipal discharges have already been implemented in many countries around the Baltic Sea, the relative significance of the other sources has increased. For the control of nutrients, it is essential to reduce the load from diffuse sources such as agriculture.

For control of nitrogen and heavy metal loads to the Baltic Sea, atmospheric deposition is a significant factor.

Industry, in general, is willing to invest as much as necessary for environmental pollution control measures, as long as all producers face the same responsibilities, i.e., the additional cost can be transferred to the price of the final product. The problems arise when this does not hold true, which is often the case in reality.

The unit cost for the reduction of discharge of most compounds will increase the closer we come to the zero discharge level. This may create additional pollution elsewhere, for instance, by increased energy consumption. Therefore, it is extremely important that scientists clearly demonstrate the benefits which are achievable by further pollution control measures.

HELCOM recommendations for 1995 have been taken seriously by the pulp and paper industries and the targets for phosphorus, COD and AOX load reductions will most probably be met, at least by Scandinavian producers. However, reaching the present targets will not be enough for all consumers and clients. The market demand for environmentally friendly products forces the producers to do their utmost to reduce or eliminate discharges of any kind.

The latest trend is to put taxes, levies, etc., on discharge compounds which are considered harmful to the environment.

REFERENCES


Supplementary literature


The press contains almost daily reports regarding the pollution of the seas, wherein they state that the Baltic will be dead in a few years, that fish are contaminated or unedible, and similar other statements. This is often supplemented by speculations about future developments based either on prolongation of past trends or on pure fiction.

This is evidently not very helpful to the marketing of fish and naturally leaves the public in great doubt about whether it is safe to eat fish and whether the ecosystem in the sea is collapsing.

In this paper, I will discuss whether the headlines give a fair impression of the current state of affairs. It is my view that the open sea is only affected to a limited extent, and that the resources are not harmed by these present developments.

It is, in my view, perfectly safe to eat fish from the Baltic Sea.

1 OBJECTIVES
In my view, the objectives of fisheries management and environmental management are relatively clear.

The three main objectives of fisheries and environmental management in the Baltic Sea, as well as anywhere else, can be summarized as follows:

- maintenance of ecological balance and diversity of life in the sea,
- maximization of profits from fisheries in the long term, and
- removal of waste at the smallest possible cost.

In practical terms, the problem is somewhat more difficult, however.

In relation to the first objective, for example, do we want to maintain this balance for its own sake, or do we want to achieve the most profitable species composition?

Do we for instance want to preserve a large stock of marine mammals (seals or whales) at the expense of fisheries, or do we want to maintain a certain number of marine mammals? If we ask the opinion of fishermen in areas with many marine mammals, the answer will no doubt differ from the answer we get if we ask environmentalists.

If we consider only fish, the question is still relevant. Do we want a "natural" balance between the various species of fish, or do we want to take into account that species eat each other or compete for the same food and hence seek the most valuable/profitable combination of species?

On the third objective there are qualifications, too. It is impossible to remove all waste, be it contaminants or nutrients. On the other hand, it is evident that the emission of certain waste can be of such a magnitude or character that it threatens all life in the sea, and this everyone would consider unacceptable.

But even small quantities of certain substances may harm the economic interests of certain industries, such as the fishing industry, without threatening life in the sea as such.

Can we, in this case, argue that fisheries should be maintained at all costs - or should we accept that fisheries must cease to exist if the economic benefits from using the working site of the fisherman as a dump for other industries is higher than the economic benefits from fishing?

Or to take the other extreme, how valuable is the sea in terms of recreational activities? Should sports fishermen, numbering millions of people, have preference over professional fishermen, accounting for relatively few people and relatively limited economic interests?

The answers to these questions will always depend on a political judgement.

For the fishing industry there is no doubt that it is not acceptable when pollution from other activities reaches such an extent that it inflicts injury on the fishing industry, either directly by affecting the stocks or indirectly
by affecting the quality and hence the price or marketability of the fish.

Optimizing the economic yield from fisheries is mainly a problem for fisheries management as such and thus outside the scope of this paper.

The relevant issue is the interaction between environmental management and fisheries management. I shall, therefore, exclude the discussion of interaction between fish species, size composition, etc., and concentrate on the direct impact of environmental management.

The quality of the environment mainly affects fisheries in two ways, i.e.,
- direct impact on the resource, and
- direct impact on the quality/marketability of the fish.

2 IMPACT OF POLLUTION

Marine pollution consists of a number of components which can be divided into the following groups:

1. Inorganic substances (examples: mercury, lead, copper, etc.). These occur naturally in sea water.

2. Organic substances (examples: DDT, PCB, etc.). These substances do not occur naturally in sea water.

3. Radioactive isotopes. These occur naturally in sea water.

4. Eutrophication (over-fertilization). Nitrogen and phosphorus are essential for all life in the sea.

In the following section, each of these will be analyzed with a view to determine whether they have or have not had an impact on the resource itself, and whether they have had an impact on the edibility of fish caught in the sea.

2.1 Inorganic Substances

Inorganic substances like mercury, magnesium, lead, copper and the other elements occur as a natural part of sea water, but in most cases in very small quantities. This is one of the reasons why sea water is salty.

Most of these elements are essential for all living creatures, but some of them have given rise to concern because they are concentrated at the highest levels in the food chain (i.e., human beings) and because levels in fish are relatively high compared to most other food. This is particularly true for heavy metals like lead and mercury.

The World Health Organization (WHO) has determined standards for the daily intake of such substances, and fish from the Baltic Sea have not given rise to concern in this respect.

What has given rise to concern, however, is that the levels of mercury and lead measured in fish have been increasing for a number of years. The trend turned, however, about 15 years ago and now the levels are much lower than before, measuring at about 0.05 mg/kg.

The Danish health authorities have monitored fish over a number of years and have concluded in reports issued as late as 1990 that the levels of heavy metals in fish from the Baltic constitute no health risk.

2.2 Organic Substances

Organic substances do not naturally occur in the sea and there are a large number of different substances that are discharged or deposited via the atmosphere into the sea. The best known of these are DDT and PCBs.

DDT has given cause for concern because it was widely used as a cheap and relatively harmless insecticide. When DDT production was initiated, however, it was not clear that the substance is rather stable and thus remains in nature for a long time. Furthermore, it is accumulated in the food chain.

This problem has also been dealt with in an effective way to the extent that present concentrations in fish are now down to one-tenth of the level of a few years ago.

The same development is true for PCB, though its concentration has not decreased as markedly.

2.3 Radioactive Isotopes

Radioactive variants of some elements occur naturally in sea water in extremely small quantities.

In this area, problems are often dramatized to an alarming extent. It should be noted that radioactive materials are very easy to detect and the problem is therefore well known. There is no problem with radiation from fish in the Baltic Sea.

2.4 Eutrophication (over-fertilization)

Eutrophication is normally understood to mean the emission of too much nitrogen and phosphorus into the sea.

The consequences of eutrophication are plankton blooms or algal growth in excess of what can be absorbed by natural life cycles of the sea.
Plankton blooms not only occur in areas where nitrogen and phosphorus are discharged, but are part of life in many parts of the Pacific and Atlantic Oceans where the concentrations of nutrients are high due to hydrographic and/or biological conditions.

If there is an over-production of algae, the algae will die and consume oxygen in the process of degeneration. This process creates areas near the bottom of the sea with reduced oxygen concentrations and fish cannot live in such areas.

It should be noted, however, that nitrogen and phosphorus are essential for all life, and that rich fishing waters always depend on the presence of large concentrations of nitrogen and phosphorus. It should also be noted that eutrophication may threaten the fish stocks, but that it does not harm the quality of the surviving fish.

There is no question that the very high levels of fish stocks in the Baltic Sea in the 1970s and early 1980s, to a large extent, was due to the increase in emission of nitrogen and phosphorus in the post-war period.

On the other hand, the stock levels cannot be increased further without consequences for the ecological balance in the sea, and - at least in certain areas - a considerable reduction in stock levels is necessary.

The issue is complicated in the Baltic Sea by the fact that a very important factor for the survival of cod eggs is the level of salinity in the water.

During the last fifteen years, only limited amounts of salt water have flowed into the Baltic Sea from the North Sea and so the general level of salinity has dropped. The cod eggs float in the higher salinity water which at present lies close to or next to the bottom where anoxic conditions seriously reduce hatching success. These conditions, therefore, result in poor recruitment of young cod to the fishery.

High levels of fishing mortality compound the serious situation for the stock.

Things may change radically, however, when a large inflow of fresh salt water takes place.

3 CONSEQUENCES FOR MARKETING OF FISH

As mentioned above, pollution may affect the development of stocks and the quality of fish, but so far the real effects have been limited.

The issue is unfortunately not only how the real situation is, but much more how the situation is presented to the public.

The media brings one alarming story after another on the pollution of the areas and they do not give a true account of the situation.

Stories about eutrophication of the coastal waters in certain areas are often mixed with the issue of whether it is safe to eat fish.

This is of course not the only example of the news media dramatizing the description of realities far beyond the facts - that is the rule rather than the exception.

The problem, as I see it, is that the media are very often encouraged by governmental bodies or scientists who pursue an interest of their own rather than trying to provide a true account of the situation.

Two examples will illustrate my point.

In 1987, a German television magazine showed pictures of fish infected by parasitic nematodes. As everyone in the business knows, this is a natural phenomenon that occurs at all times and which is properly dealt with by processors when preparing the fish.

Nevertheless, a German official, who is also a veterinarian, claimed that nematode infection is determined mainly by two factors, the quality (freshness) of the fish and the pollution in the catch area.

This is, of course, a totally inaccurate statement which would mean nothing were it not for the fact that it originated from a government expert. The consequences for the industry were, as is well known, disastrous.

The other example is from Denmark in 1989 where we had a plankton bloom in the Kattegat and the Skagerrak of an algae by the name of Chrysochromulina polylepis. This algae was termed - by an official from the Ministry of the Environment - "the killer algae", and the news media carried stories for a whole week encouraged by that same ministry. Statements such as "the largest environmental catastrophe" and "all life in the Kattegat may be extinct in a year's time", etc., were released.

This is not only wrong information; it is deliberate misinformation. When such sensational stories originate within a governmental body, one cannot blame the media for transmitting them and one cannot be surprised that the public is alarmed.

It is, therefore, my plea to the governmental representatives and scientists present today to help to disseminate accurate information and to prevent the systematic use of misinformation as illustrated by my examples.
DISCUSSION OF INDUSTRY PRESENTATIONS

Dr Karnicki brought up the question of how much of taxpayers' money should be spent on research. He felt that taxpayers should support appropriate applied research; money for applied research comes partly from industry, which has recently been contributing less to such research because there are fewer fishing areas. This leaves open the question of who should pay for basic research.

Mr Tørring called upon scientists to bring the truth about the Baltic Sea fisheries out into the open so that the real situation can be known.

Dr Ferm stated that Sweden has guidelines for the reduction of discharges of stable organic substances, phasing down the discharge of these substances, measured as Adsorbable Organic Halogen (AOX), to a maximum of 2,000 t/yr by the year 2000. In terms of Mr Tørring's comment regarding the use of pricing structures in regulating the use of natural resources and in pollution control, Dr Ferm commented that this can be very difficult. In the case of non-renewable resources, some might say that the cost of using them is infinite and thus cannot be assigned. In the area of pollution control, it is clear that the price of fertilizers should be increased by several hundred percent, however, this would have serious consequences on the farmers.

Commenting that Mr Tørring gave the impression in his paper that the Baltic Sea is clean, Mr Jakobsson asked Dr Ferm whether he agreed. In reply, Dr Ferm stated that the concentration of mercury in fish from some areas of the Baltic Sea is so high that pregnant women should not consume these fish. In addition, the concentrations of certain organic contaminants, e.g., dioxins, polybrominated diphenylethers, can be rather high, but they are not yet critical.

Mr Tørring replied that fishing is prohibited in the areas that are heavily contaminated with mercury. Industry used the World Health Organization's weekly maximum limits for the consumption of the various contaminants in their assessment of the quality of fish for human consumption, and he felt that these had been developed with adequate safety margins.

SUMMARY AND COMMENTS by Dr Fredric M. Serchuk, Chairman, ICES Advisory Committee on Fishery Management (ACFM)

Professor Thurow, in his excellent presentation yesterday afternoon, noted that he considered his review of the 'Fish and Fisheries in the Baltic Sea' to be somewhat of a detective or crime story. I would like to expand and extend his analogy to my own presentation. Since my comments occur at the end of the Dialogue Meeting, I see them as the last chapter of Professor Thurow's detective story. Normally the last chapter of such a story features colourful characters, mistaken identities, unexpected events, and a novel or surprise ending. My summary remarks will contain aspects touching upon all of these elements.

Firstly, let me congratulate all of the speakers for their very informative and enlightening presentations. A review of the main subjects addressed and conclusions made by each of the speakers (see overview box) indicates that we should all possess greater knowledge and a better appreciation of fisheries and environmental issues in the Baltic than we had at the start of this meeting.

However, we can be misled into believing that increased knowledge alone is enough to help us solve/resolve our problems. It is not! Very often, the way we see the problem is the problem. By this, I mean that how we view the world is not straightforward. Each of us sees the world differently in terms of our own perceptions and understanding.

As an example of this, here is a picture (Figure 1) in which some people see a very pretty lady, while others see a poor, older woman (Figure 2). But there is only one picture. This situation is very much similar to the singular problem of managing the Baltic Sea as dually perceived from environmental and fisheries perspectives. The picture illustrates how we think about problems - our paradigms - and demonstrates how our mental perceptions of things can be very different from reality. Our perceptions are shaped by, among other things, our principles and values. As such, our mental perceptions are extremely powerful and very difficult to change. However, if we are to make any real progress in addressing and resolving complex issues that involve people with a wide variety of interests and backgrounds - such as how to manage the Baltic Sea - it is essential that we change our approach. Business as usual will not do.

In developing a new approach to problem solving, simply changing our behaviours and attitudes will not be sufficient. Most importantly, we need to shift the way we think about problems; that is, change our mental maps of the world - our paradigms. To understand why this is so, assume that we would like to go to the Polish Sea Fisheries Institute in Gdynia and have been given a map to help us reach our destination. Through an error, the map provided to us is labelled 'Gdynia' but (unbeknownst to us) it is really a map of Szczecin. Using the map, we might walk faster and be more diligent in trying to get to the Institute (i.e., change our behaviour) or we could think more positively about getting there (i.e., change our attitudes), but - at the end of the day - we would still be lost. What is required is a whole new approach to the problem. The same is true in considering "How to Use the Sea".
OVERVIEW OF THE EIGHTH ICES DIALOGUE MEETING

Dr Brügmann: Environmental Review
- Hydrography and morphometry affect processes
- Time scales of events and processes are important
- Eutrophication evident since mid-1960s
- Need ‘early warning signals’ of system changes
- Identify natural vs. man-induced changes
- Develop realistic criteria of ecosystem health

Prof. Thurow: Fish and Fisheries Review
- Historical overview of stock and fishery trends
- Distribution and biology of important stocks
- Total fish community dynamics
- Stock assessments of major finfish species
- Quality of assessments and scientific advice
- Develop more reliable estimates of F, R, M, & SSB

Mr Hilden: Fisheries Advice and Decision Making
- Conflict between objectives and values
- Decision strategies - static and dynamic
- Role of science - short/intermediate/long-term
- Gaps: Consequences/risks/assumptions
- Management objectives - evaluation criteria
- Develop interdisciplinary advisory system

Dr Richardson: Environmental Decision Making
- Scientific input to environmental management
- ICES advisory framework - role of ACMP
- ICES and the commissions - what and why advice
- Improved communications to enhance advice
- Establish working group to draft requests for advice

Dr Karnicki: Management and Fisheries
- Management objectives: fish/economy/environment
- Communication/cooperation among parties
- Management factors: biological, ecological, technical, socio-economic, and political considerations
- Causes of management failure (5 points)
- Need for a long-term management strategy

Dr Ferm: Integrated Environmental Management
- Situational analysis - population/industry/agriculture
- Helsinki Commissions - Baltic Sea Task Force
- Long-term environmental goals for the Baltic
- Remedial measures to reduce human impacts
- Conflicting objectives - acceptable risks
- Integrated approach to ecosystem problems

Mr Mukala: Municipal/Industrial Discharges
- Sources of nutrient/chemical loadings
- HELCOM standards for effluent treatment
- Effluent treatment practices and costs
- Pulp/paper industry: a case history
- Control measures - benefits must be clear

Mr Törnling: Fisheries and Environmental Management
- Media headlines: fact or fiction?
- Management objectives: conflicts and perceptions
- Pollution impacts on resources and fish edibility: inorganics/organics/radioactive isotopes/and eutrophication
- Scientific disinformation: stick to the facts!
Figure 1 A picture.

Figure 2 Two possible perceptions of the picture in Figure 1.
On several occasions during this meeting, various speakers have commented upon the commercial, recreational, and socio-economic importance of the Baltic Sea. Given these remarks, it seems quite appropriate and logical to pose the following question to ourselves: "How valuable is the Baltic ecosystem?"

In thinking about this, we should recognize that the Baltic, like other ecosystems, functions according to 'natural laws' (Figure 3) and that enlightened management of the Baltic requires an appreciation of these constraints. In wisely utilizing the ecological capabilities of the Baltic Sea, we need particularly to realize that "all our actions have consequences" (Law Number 4 restated).

Within this context, the answer to "How valuable is the Baltic ecosystem?" depends on how we answer a much more critical and imposing question: "What kind of world do we want to live in?"

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**EIGHTH ICES DIALOGUE MEETING**

'LAWS OF NATURE'

1. EVERYTHING IS CONNECTED TO EVERYTHING ELSE
2. EVERYTHING MUST GO SOMEWHERE
3. NATURE KNOWS BEST
4. THERE IS NO SUCH THING AS A FREE LUNCH

BARRY COMMONER, 1971: 'THE CLOSING CIRCLE'

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**Figure 3** Laws of nature.

**GENERAL DISCUSSION**

On the basis of the discussions during the meeting and the lunch break, the Environment Rapporteur presented a draft proposal of a recommendation, that had been prepared in consultation with several of the speakers and participants, that ICES should establish a small group to (1) review the information needs, and their priority over 5- and 10-year time perspectives, for management decisions regarding fisheries/environmental issues in the Baltic Sea, (2) transform these information needs into scientific research objectives, (3) develop appropriate research programmes to meet these objectives, (4) specify the level of uncertainty anticipated in the answers, and (5) develop cost estimates for the conduct of these scientific programmes. This group should comprise senior scientists and scientific administrators, working interactively with relevant ICES and other working groups and, for the first task, be supplemented with representatives from IBSFC and HELCOM.

In the discussion of this proposal, Mr Andersen (Danish Ministry of Fisheries) opposed this proposal on the basis that it represents a precedent for future Dialogue Meet-
Mr Schmiegelow agreed with Mr Andersen. He was not certain of the competence of IBSFC and HELCOM in this regard, but the EEC does not have the procedures to adopt such a proposal. It would need to have unanimous support. He also did not know how this would affect the next Dialogue Meeting.

Dr Ferm, noting that the ideas contained in the proposal were mainly his (but not the impetus to put the proposal forward to the meeting), pointed out that many international meetings adopt resolutions. He felt that if a good idea could be developed here, it should be carried forward.

Dr N.A. Nielsen, noting that many speakers and commentators have emphasized the need for fisheries and environmental scientists to work together, stated that fisheries research is better developed, but the environmental studies will take a very long time. For cod in the Baltic Sea, actions need to be taken quickly. For the group proposed above to do its job properly regarding fisheries, it will require a lot of work. Clear priorities will need to be developed, taking also into account political views. The projects that will be conducted will need to be carefully selected. He stated that we need to think carefully before we select a procedure for how to develop research projects and priorities.

Mr Pekka Niskanen felt that the substance of the proposal was good, but was hesitant as to whether a working group was needed to deal with these questions. He thought that they could possibly be developed by ACFM and ACMP and then transmitted to the Commissions.

Mr Jakobsson stated that ICES should encourage more cooperation between ACFM and ACMP in the development of integrated advice.

Dr Topping agreed that there should be closer cooperation between ACFM and ACMP. He noted that there are a number of common factors between the two groups: (1) they try to characterize the situation - the size of the fish stocks, or the state of the environment; (2) they provide proposals for regulation - of fish catches, etc., or of waste discharge to the sea to minimize environmental damage. Man has an impact on the environment and its resources, and scientists must take the initiative in establishing a dialogue between scientists and managers. He pointed out, however, that there is little time during the meetings of ACFM and ACMP for reflective thought and, if they do develop something new, they will need to be able to communicate it to the right people.

Dr Karnicki stated that he was not familiar with ICES procedures, but he would like some form of conclusions from the Dialogue Meeting. He felt that, as a general conclusion of this meeting, we could agree that there is a need for a long-term strategy and that steps should be taken to decide how to elaborate this strategy. He contended that something concrete should come out of this meeting.

Mr Jakobsson pointed out that something indeed will come out of this meeting, as all the papers and a summary of the discussion will be published by ICES. He also stated that, now that this proposal has been put forward, it will come to the attention of ICES in any case. One of the reasons for this meeting is that ICES is taking one step after another, progressing slowly, to develop more integrated advice on marine ecosystems and the marine environment.

Dr Sosinski stated that, from the point of view of the fishermen, the Baltic Sea is in great decline, and a number of the other uses of the sea have not been covered in this meeting, e.g., shipping and recreation. The use of the Baltic Sea depends on the socioeconomic conditions in each of the countries around the Baltic Sea, as to whether it is used in a very specialized way or in a more ordinary way, such as for traditional fishing. He then thanked the sponsors for organizing this Dialogue Meeting.

CLOSING OF THE DIALOGUE MEETING

In closing, Mr Jakobsson agreed that the meeting had not covered all the issues regarding the Baltic Sea, but this will certainly not be the last Dialogue Meeting on the Baltic Sea. He decided that no vote would be taken on the proposal presented, but he noted that the meeting agreed that ICES should take steps to increase the interdisciplinary cooperation between fisheries and environmental work. Mr Jakobsson felt that the papers presented to the meeting had been very good, and that the discussions had been very objective, indeed more objective than at previous Dialogue Meetings.

Mr Jakobsson then thanked the speakers and participants for their excellent contributions. He thanked the Sea Fisheries Institute as the host institute for the excellent facilities and support, and also thanked the interpreters and technicians for their valuable work.

On behalf of the participants, Professor Thurow thanked Mr Jakobsson for his excellent chairing of the meeting and also the ICES General Secretary, Dr E. Anderson, for the careful and complete preparations for the meeting.

Mr Jakobsson then closed the Eighth Dialogue Meeting.
## EIGHTH ICES DIALOGUE MEETING

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