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No. 149

ASSESSMENT OF THE ENVIRONMENTAL CONDITIONS IN THE SKAGERRAK AND KATTEGAT

by

ICES Working Group on Pollution Related
Studies in the Skagerrak and Kattegat

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PREFACE

In 1982, the Nordic Council of Ministers requested ICES to establish a forum through which scientists working in the Skagerrak/Kattegat area could present their results for discussions, and identify research and investigation projects of common interest. The forum should function as a coordination mechanism for the activities in the Skagerrak/Kattegat area.

The Bureau initiated that a group of representatives from Denmark, Norway, and Sweden met during the 70th Statutory Meeting of ICES to discuss the questions raised by the ICES General Secretary.

The result of the discussions led to a recommendation from the Marine Environmental Quality Committee (MEQC) and finally to a resolution from the ICES Council about the establishment of a Working Group.

The Group finished its work in January 1986, and presented the Assessment of the Environmental Conditions in the Skagerrak and Kattegat in April 1986. During the ICES 74th Statutory Meeting in October 1986, it was decided to publish the assessment in the Cooperative Research Report series.

I am thankful to Dr J.E. Portmann who has given valuable comments on the draft of the assessment, and to Dr J.F. Pawlak for editing help.

Per T. Hognestad
Chairman
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in the Skagerrak and Kattegat

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INTRODUCTION

At the ICES Statutory Meeting in 1982, the Council adopted the following resolution (C.Res.1982/2:3):

It was decided that:

(a) a Working Group on Pollution Related Studies in the Skagerrak and Kattegat should be established under the chairmanship of Dr P. Hognestad to promote cooperation and coordination of research (physical, chemical and biological) related to pollution studies in the Skagerrak-Kattegat area by

  (i) preparing an assessment of the situation in the area with respect to natural and man-made conditions in water,
  (ii) promoting interactions and discussions among scientists active in the area,
  (iii) considering the priorities in such studies, keeping in mind the available national and international resources, and
  (iv) planning international research and projects.

(b) The Group should consist of scientists from Denmark, Sweden and Norway and members of other relevant ICES Working Groups engaged in work in the area. The first meeting of the Working Group should take place for two days in Copenhagen in spring 1983.

(c) The Council will review this resolution after two years.

The Group held its first meeting in spring 1983 with the Council's resolution as terms of reference and with participants from Denmark, Sweden, Norway and Federal Republic of Germany. The Group had four meetings: in Copenhagen 4-5 May 1983 (C.M.1983/E:29), in Copenhagen 28-29 May 1984 (C.M. 1984 /E:21), in Gothenburg 30-31 January 1985 (C.M.1985/E:6) and in Hirtshals 14-16 January 1986 (C.M.1986/E:36). In addition, three informal meetings were held (Gothenburg 13 October 1983, Copenhagen 11 October 1984 and London 10 October 1985). The ICES Environment Officer and members of the Group have acted as rapporteurs at the meetings.

Concerning regional assessments, the ACMP requested the Group to prepare the present assessment according to Guidelines for the Preparation of Regional Environmental Assessments (ICES 1982). These quidelines have been followed as far as practicable.

The area concerned, the Skagerrak and Kattegat, is defined by two slightly different sets of borders: the ICES statistical borders for the Skagerrak and Kattegat (Fig. 1) and the

hydrographical borders for the Skagerrak and Kattegat (Fig. 2). The differences are of minor concern for the present assessment.

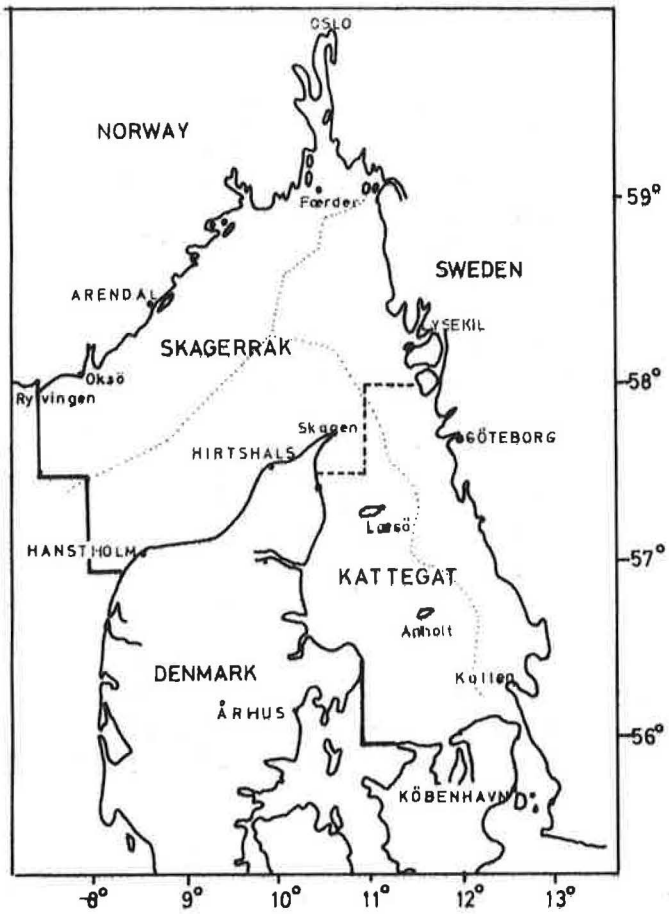

Fig.1. ICES'statistical borders for Skagerrak and Kattegat

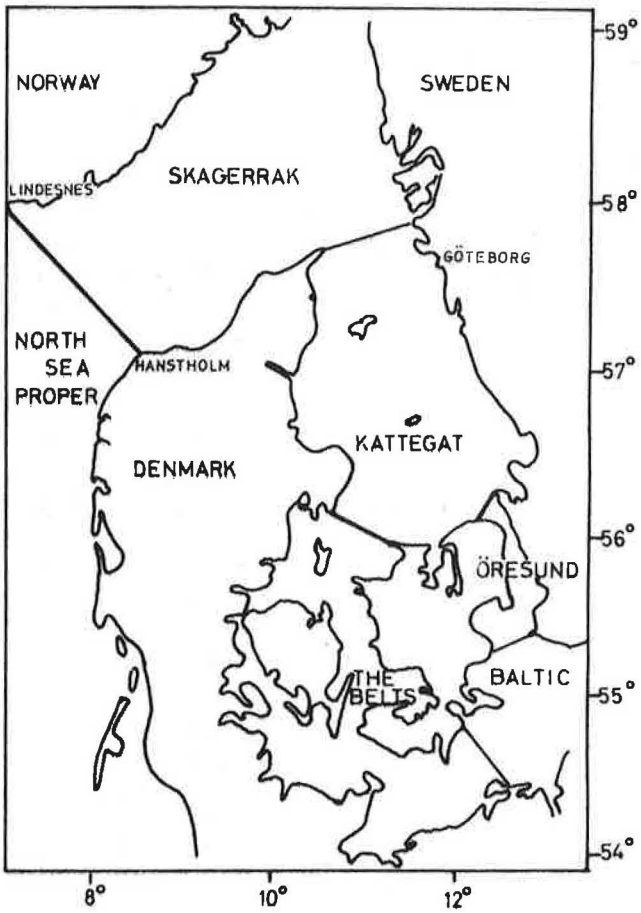

Fig.2. Hydrographical borders for Skagerrak and Kattegat (Svansson 1984).

1. SUMMARY

In relation to physical oceanography, it is assumed that man-made influences are mainly local and coastal, but this question has not been examined in detail.

In relation to the chemical oceanography of the open waters in the Skagerrak and Kattegat, there is evidence that there has been an increase in inorganic nitrogen and total phosphorus in the Kattegat. There is no general increasing trend in phosphate. Data on primary production show, with the exception of the southern parts, no evidence of increase in the open waters in the Kattegat. In the Skagerrak the nutrient distribution demonstrates the doming of water masses.

In general, higher concentrations of contaminants occur both in the water masses and the bottom sediments near the coast compared with the open sea, especially in the Kattegat. On average the concentrations are lower in the Skagerrak than in the Kattegat.

Under the heading general biology and fisheries are indicated the commercially most important species. The fish catch per unit area in the Skagerrak and Kattegat is high. There is a marked decrease in the number of species from the North Sea through the Skagerrak and Kattegat to the Baltic.

The different stocks in the fishery fluctuate, partly due to natural causes, but also to overfishing and/or discharges along the coast. Lack of reliable data makes it difficult to make accurate estimates of stocks.

Pollution has adversely affected the fisheries, at least in some coastal areas, and occasional mass mortalities of Norwegian lobster in the Kattegat have been reported.

The effects of pollutants on the benthos are described, and large scale changes have been recorded during this century.

The effects of blooms of toxic/non-toxic planktonic algae are also described. Up to 1985 several algal blooms have been observed to have had direct toxic effects, and in some cases indirect effects by causing oxygen deficiency when the blooms collapsed and decayed. In Norway and Sweden mortality of caged fish has been observed, and mussels have been found to be toxic, especially in recent years.

2. PHYSICAL OCEANOGRAPHY

2.1 General circulation and physical oceanography

The Skagerrak is sometimes assumed to be a part (a bight) of the North Sea. The Kattegat together with the Belt Sea is often called the Transition Area between the Baltic and the North Sea. The Kattegat is shallow with a mean depth of 23 m, deeper in the eastern part than in the western. The Norwegian Trench (the Rinne) connects the Skagerrak with the North Sea proper and has its deepest part, 725 m, in the Skagerrak. The mean depth in the Skagerrak is 210 m.

In general terms, the average flow in the Kattegat consists of an ingoing deep current and an outgoing surface current, the latter being a mixture of deep flow water and about 450 km^3/year fresh water from the Baltic Sea (Fig. 3).

In the Skagerrak, the outflowing Kattegat surface water continues along the coast of Sweden and Norway as a rather narrow coastal current (Fig. 4). It overrides a much larger flow of at least 15 000 km^3/year which comes in from the North Sea from mainly three directions (cf. Figs. 3 and 4):

a) the English Channel and flowing along the Danish West Coast,
b) the Orkney-Shetland flowing directly eastwards, and
c) from the outer part of the Norwegian Trench mainly at a subsurface level.

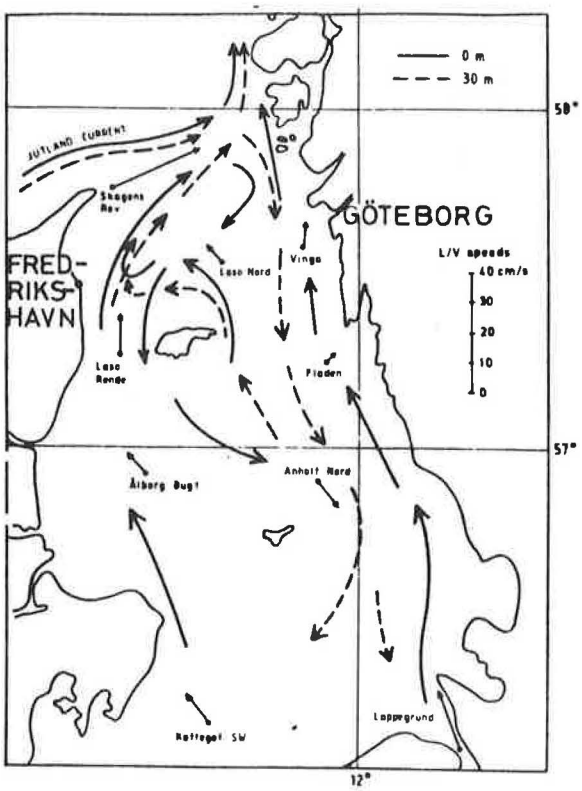

Fig. 3. Probable pattern of mean currents in Kattegat. Light vessel means, 1964, are inserted (Svansson 1984).

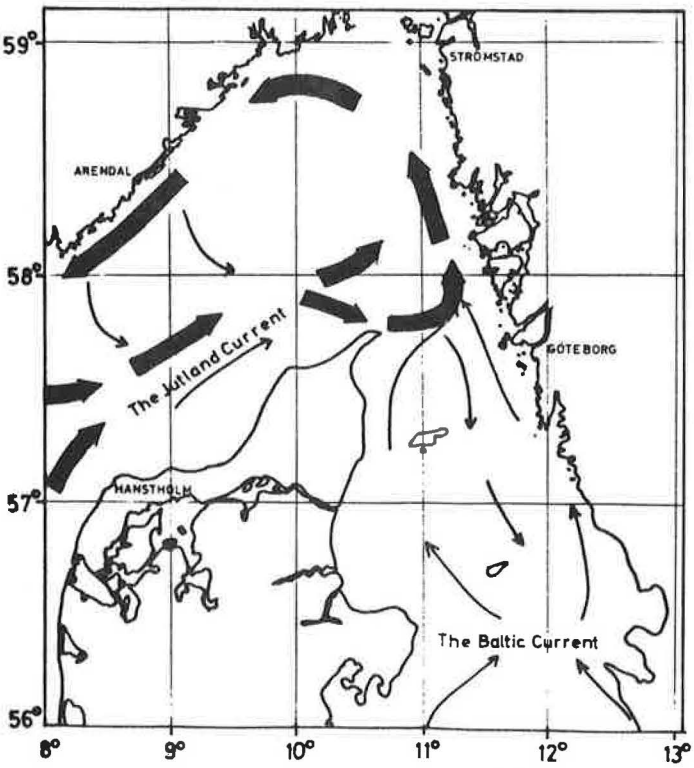

Fig. 4. A simplified map of the surface currents of the Skagerrak and Kattegat. Reproduced from Svansson (1975). Compare the later version of probable Kattegat currents pattern in Fig. 3. Note that the Jutland current here includes all three branches mentioned in chapter 2.1.

In conclusion, most of the water entering the North Sea continues into Skagerrak and leaves it again into the North Sea.

The currents in the Kattegat are weakest in summer, mostly due to weak wind erosion and weak Baltic outflow. There is possibly an additional influence from the Skagerrak current, the seasonal variation of which we know rather little. The Skagerrak counter clockwise circulation seems to consist of two components, one more steady and one transient, the latter of which is wind-driven. This latter component enhances the steady component during westerly winds and weakens it during easterly winds.

The surface salinity in the Kattegat varies between 15 o/oo in the south and 29 o/oo in the north. At a place where the annual mean is 21 o/oo there is a minimum in May of 18 o/oo and a maximum in January of 24 o/oo. At depths greater than 20 m the seasonal variations are only 1 or 2 o/oo. At the position just mentioned, the mean salinity at 20 m is 31 o/oo. The halocline is often rather thin and sharp. There are short-term large variabilities both in currents and other physical-chemical parameters due to the fact that the Kattegat is a transition channel for water flowing to and from the Baltic Sea. The salinity also increases from Sweden to Denmark in an east-west transect in the Kattegat. The tidal current in the Kattegat is 10-20 cm/s, whereas in the Skagerrak it is only 1-2 cm/s.

In the Skagerrak the salinity is lowest along the Norwegian and Swedish coasts, increasing, however, from the border with the Kattegat to the North Sea border. At times winds change conditions so that the low saline band of water is moved out from the coast by off-shore transport. At greater depths, in both the trench water as well as in the Skagerrak Deep (sill depth 270 m), the variations are very small. The so-called 1970's anomaly (of salinity), first found in the Faroe-Shetland Channel, is easily tracable in data collected at 200 m depth in the Skagerrak (34.95 instead of normal 35.15 o/oo).

The seasonal temperature variations are larger in the Baltic/Kattegat surface water than in the deeper incoming North Sea water. In February the mean coastal surface water is 2°C, whereas the incoming North Sea water is 3-4°C. In August the coastal water is 17°C and the off-shore Skagerrak water about 16°C.

The anti-clockwise circulation in the Skagerrak favours an upwelling (doming) in the central part. The upwelling reaches up to the thermocline (in the warm seasons) at about 10 m depth.

As the thermocline deepens considerably towards the coast, it takes on the shape of a dome. The effect of the doming is to create good conditions for a high primary production of planktonic algae, which is of great importance in the area. In the Kattegat the depth of the surface layers seems to vary from year to year. It is possible that the plankton production may vary accordingly (Pingree et al. 1982).

It is at present assumed that the vertical transport between surface and deep layers in the Kattegat is one-way, i.e. upwards, mostly due to wind erosion. Oxygen diminishes in the deep layer to a minimum in the autumn, but the oxygen demand is larger than the resulting oxygen concentration shows. It is assumed that the additional oxygen is advected from the Skagerrak in the deep inflow (Pedersen 1980, Jacobsen 1982).

The water exchange between the Skagerrak and the North Sea proper is generally effective, the turnover time being a few weeks in the region of currents, a little longer in the coastal areas and in the deep central part below 270 m. The turnover time for the Kattegat is longer, half a year or so. The elevated contents of some radioactive substances in the North Sea are therefore quickly transported also to the Skagerrak and the Kattegat, leading to nearly as high concentrations as in the (eastern) North Sea proper. Particles are trapped in deeper parts.

The water exchange between the Kattegat and the Baltic on the other hand is very small. The radioactive substance ought to reach only one-tenth of its original concentration in the innermost part of the Baltic and moreover not before 36 years. If there is a source of a substance, e.g. phosphorus in the Baltic, there will be an increase in the concentration of this substance also in the Kattegat and the Skagerrak which would take several years (and at steady state the whole annual supply will pass through the area). The net outflow of phosphorus at the border between the Skagerrak and Kattegat for the years 1975-77 was determined to be 15 000 tons/year, whereas the supply to the Baltic is supposed to be five times this figure. One reason for the discrepancy may be the slow build-up of phosphorus in the Baltic water; sedimentation is another possible explanation.

Studies of long-term variations have shown that the correlation between temperature and salinity is higher in the ocean than in a shelf sea area like the North Sea. The general increases of temperature in the 1930s seem to have started 10 years earlier in the western part of the Atlantic. Also maxima around 1950 and 1960 (and 1975?) can be traced back in the same manner. The shelf sea salinity is probably related to precipitation. During the last 100 years there has been a slight increase in salinity, possibily related to a slight decrease in fresh water supply from rivers. There is further a 3-5 year periodicity in salinity which is of importance for the inflow of water to the Baltic deeps.

Special attention must be paid to the conditions along the Swedish west coast, as there often is a marked gradient in concentrations of pollutants in an offshore direction. Blanton (1984) points out that ocean currents associated with frontal zones favour the transport of material alongshore. In his investigations long-front diffusions were higher by an order of magnitude than cross-front diffusions. Using the observations from the Göteborg-Fredrikshavn section (cf. Fig. 3) (Szaron 1979, Svansson 1984) the Baltic current along the

Swedish coast can be assumed to reach out to approximately 8 n.m. off the coast in the section, and to have a depth of around 10 m. With this assumption, and the currents reported by Szaron, the mean transport should be in the region of 8000 m^3/s. The characteristic salinity to the south of the mouth of river Göta is about 22 o/oo. Theoretically the 500 m^3/s from the river Göta should reduce this salinity to 20.7 o/oo. The coastal water at the northern part of the Swedish west coast (Kosterfjord, close to the Norwegian border) has a mean salinity according to measurements in 1982-84 of 25 o/oo as a result of mixing with water from the Skagerrak with a salinity ranging from 26-30 o/oo. The fresh water supply from the shores north of the river Göta is only 60-70 m^3/s and may be neglected in the calculations. Thus the near shore water at the north coast of Bohuslän seems to retain at least 40% of the identity of the water outside Göteborg, which is 200 km to the south. The width of the zone is roughly 10-20 km. The near shore areas show significantly higher concentrations of total phosphorus and nitrogen (Fig. 5), the range of total phosphorus being from more than 40 to 20 mg/m^3 (lower values in the summer) in the near shore area down to 25 to 10 mg/m^3 in the true Skagerrak water; the corresponding range of total nitrogen is from more than 400 mg/m^3 down to less than 250 mg/m^3. Accordingly, the many observations of eutrophication effects in Swedish waters should not be taken as evidence of the state of Skagerrak in its entirety.

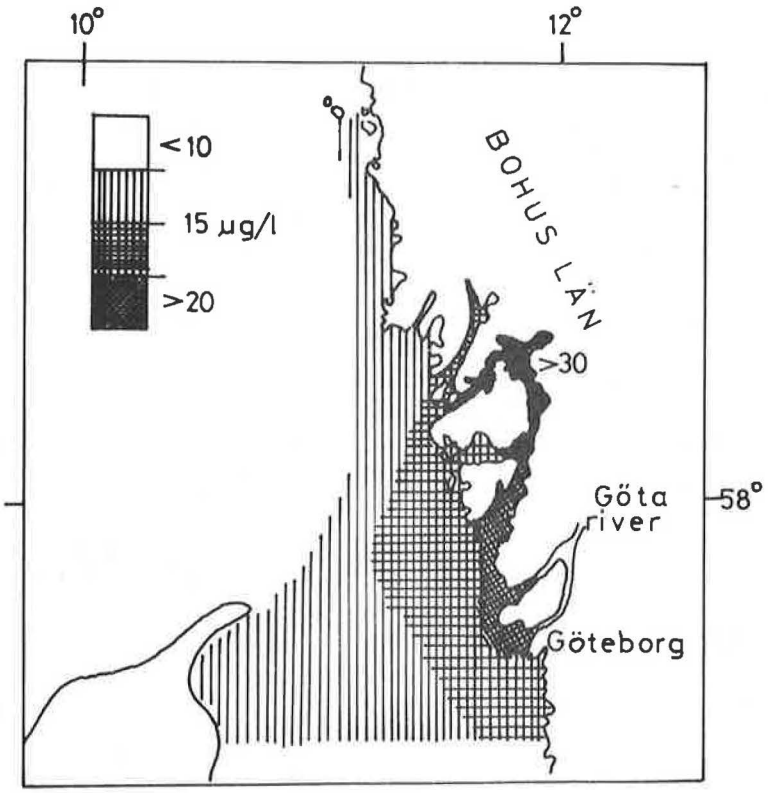

Fig. 5. Early autumn distribution of total phosphorus between Kattegat and Skagerrak (Söderström 1984).

2.2 Extent of anthropogenic modifications of the physical oceanography

The anthropogenic modifications to the physical oceanography of the Skagerrak-Kattegat area are probably mostly local and coastal. They have not been thoroughly examined and the following lines contain more hints and guesses than clear facts. The main modifications considered were:

a) changed river flow both in the Skagerrak-Kattegat area, but also from the Baltic,
b) changes of cross-section areas in the Belt Sea,
c) changed temperature conditions,
d) changed optical conditions,
e) changed air-sea exchanges due to sea surface pollution.

Changed river water flow

Regulations of river flow for hydroelectric power purposes have changed the seasonal distribution of run-off. In order to maintain a relatively large electric power production during winter time, when the demand is high, large reservoirs have been built up especially in Norway and Sweden (Ehlin 1981, Aswall 1976). The largest effects are at the local level, e.g., changed flow of nutrients, some of which may now settle near the river mouth rather than being carried out to the open sea. There may also be consequences in relation to the ability of anadromous fish (salmonids) to negotiate a river.

The changes in fresh water flow may possibly influence the salinity, temperature, etc., of the whole Kattegat-Skagerrak area. In this regard, the flow of low-salinity surface water from the Baltic Sea, amounting to around 450 km^3/year, is more important than the direct river water flows to the Kattegat of 30 km^3/year and to the Skagerrak of 70 km^3/year.

Alterations of cross-sections (bottom topography)

Building a bridge with associated embankments across the Great Belt has been discussed. There are also discussions of building bridges and/or tunnels between Denmark and Sweden in the Öresund. Such constructions may influence the water exchange between the Kattegat and the Baltic. A consequence may be a differed hydrography of the Baltic (Bo Pedersen 1981), but probably not of the Kattegat and Skagerrak.

Changed temperature conditions

Discharge of warm water from industry or power plants affects the marine environment to some extent, depending on local conditions.

Ringhals Nuclear Power Plant is probably the largest outlet of anthropogenically induced heat transport to the sea in the area. The consequences are, however, only local, but the raised temperature level can nevertheless be recognized from weather satellites (Wennerberg 1980).

Changed optical conditions

Secchi disc depth is reported to have decreased in the Swedish coastal areas of the Skagerrak, but data are unfortunately few (Söderström, pers. comm.). The reason could be that the content of particles in the sea water has increased in the coastal zone in the last decades. However, dissolved so-called yellow substances have also increased in the Baltic (Bladh 1972), probably due to forest industry discharges. There are not sufficient data to draw conclusions for the Skagerrak-Kattegat area.

Changed air-sea exchange due to sea surface pollution

There is no indication of such changes due to, e.g., oil pollution in the area.

3. CHEMICAL AND BIOLOGICAL OCEANOGRAPHY

3.1 General marine chemistry - nutrients and primary production

Input of nutrients

Nutrients are transported to the Skagerrak/Kattegat areas from the Baltic Sea through the Belts and Öresund, from land-based sources, from the southern part of the North Sea via the Jutland current, from inflowing Atlantic deep-water and from the atmosphere.

Discharges containing nutrients and organic substances in different forms occur from industries and towns. In recent years, parts of the potential input have been removed at source by the establishment of treatment plants and other protective measures. But there is a considerable net input of organic substances through the Öresund and the Belts, some of which pass through the area into the North Sea.

There is also a direct or indirect transport of nitrogen compounds from agriculture, especially into the Kattegat. Most of the direct transport occurs through rivers, while the indirect transport occurs via the atmosphere.

Table 1 shows estimates of the annual input of total N and total P to the Kattegat during the period 1974-1981. (Miljøstyrelsen 1983, 1984, Malmgren-Hansen 1984).

Table 1

Input of total nitrogen (TN) and total phosphorus (TP) from Denmark, Sweden and the atmosphere to the Kattegat during the period 1975-1981. Estimated from Miljøstyrelsen (1984).

Year	Denmark Tonnes per annum TN	Denmark Tonnes per annum TP	Sweden Tonnes per annum TN	Sweden Tonnes per annum TP	Atmosphere Tonnes per annum TN	Atmosphere Tonnes per annum TP
1975	34.078	3.065	33.084	1.065	-	-
1976	28.740	2.945	23.523	897	-	-
1977	34.752	3.080	50.124	1.470	-	-
1978	36.685	3.124	41.943	1.260	13.524	315
1979	38.924	3.171	37.297	1.179	22.932	315
1980	44.994	3.310	48.702	1.442	18.123	315
1981	51.675	3.461	51.237	1.269	18.501	315

Table 2 shows estimates of the total input of nitrogen and phosphorus to the Skagerrak in 1980.

Table 2

Input of total nitrogen (TN) and total phosphorus (TP) from Denmark, Norway, Sweden and the atmosphere to the Skagerrak, 1980.

	TN Tonnes per annum	TP Tonnes per annum
Denmark	1.329	328
Norway	34.265	1.855
Sweden	19.644	698
Atmosphere	32.000	325
Total	87.238	3.206

Kattegat

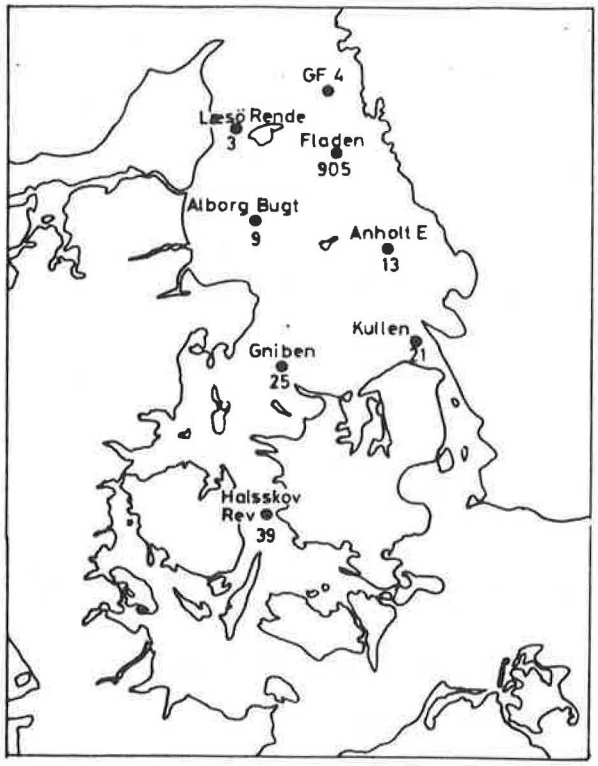

Fig. 6. Monitoring stations in the Kattegat from which data have been used in Figs. 7-9.

The estimated proportions of land sources of total N and total P to the Kattegat are:

Source	Total-N	Total-P	COD
Urban discharges	30%	75%	55%
Industries, direct outlets	5%	10%	25%
Land drainage	40%	5%	0%
Agriculture, husbandry, villages	25%	10%	20%

For Kattegat it has been estimated that the average phosphorus load has increased by a factor of 3-7 and the nitrogen load by a factor of 4 between 1930 and 1980 (Edler 1984).

Fig. 7A and B show nitrogen data from two stations (905 Fladen and 13 Anholt E) in the open Kattegat. The data indicate a gradual increase in the winter concentrations of nitrogen nutrients in the Kattegat water down to 30 m depth and in the summer concentrations in the bottom water during the period from 1969 to 1983/84.

The phosphate data from the Kattegat (Fig. 8A, B) for both winter and summer do not show a significant increasing trend over time during the period 1966-84 (Svansson 1984). An increase in phosphate may have taken place before the middle of the 1960's, as in the Sound and the Baltic, but too few data exist to prove this (Ærtebjerg et al. 1981). However, the concentrations of total-P have increased significantly since 1969 (Fig. 8C) (Svansson 1984).

The primary production has been measured in the Kattegat, Great Belt and the Sound since the 1950's. The results indicate that the mean summer production has increased significantly in the Great Belt since the middle of the 1960's and probably also in the Sound and the southern parts of the Kattegat (Fig. 9A). However, based on data from Anholt Knob Lightship and station 13 (Fig. 9B) (Miljøstyrelsen 1984) there is no general trend in the primary production in the Kattegat proper.

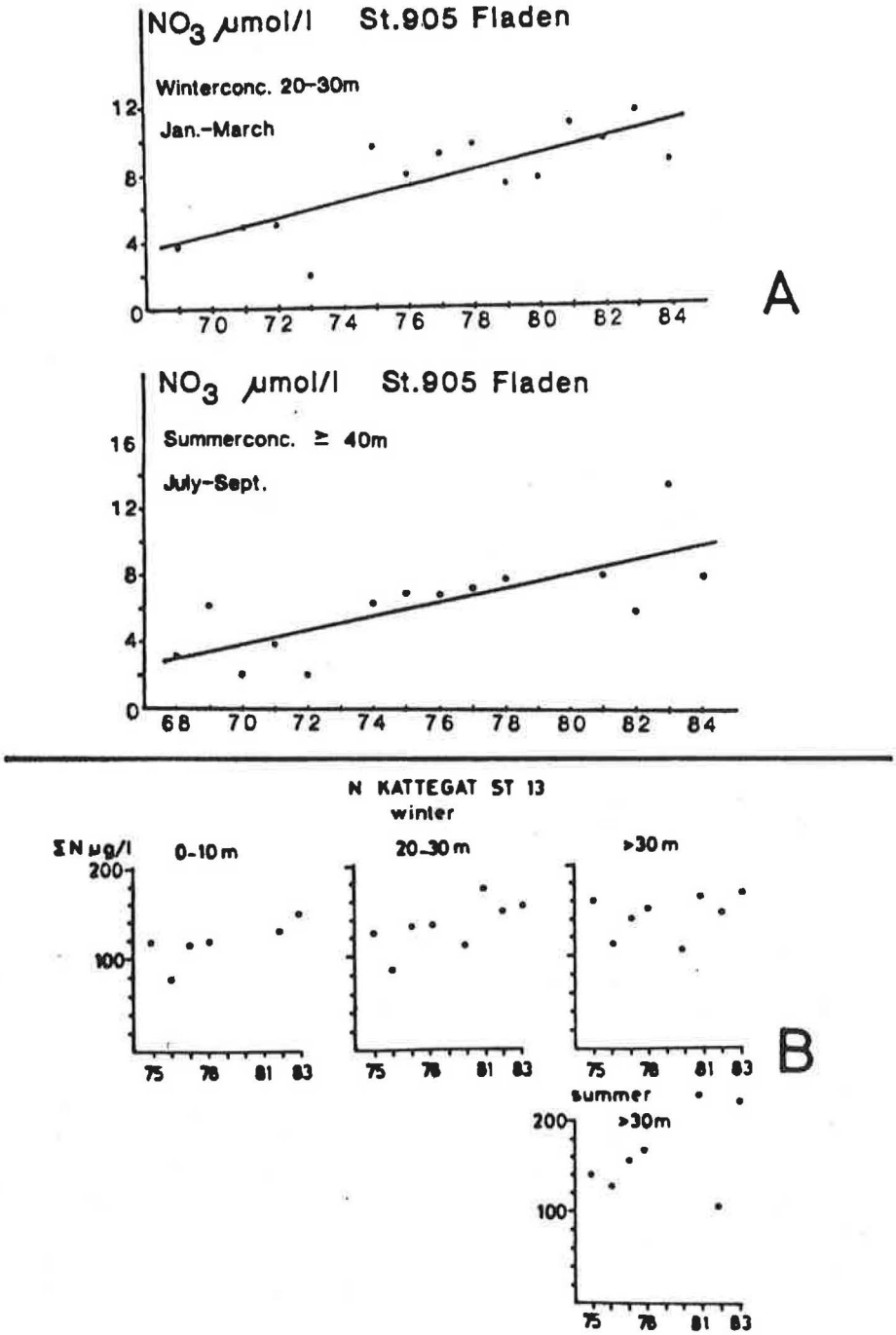

Fig. 7. Mean winter (January-March) and summer (July-September) concentrations of nitrogen nutrients in the open Kattegat in the different water layers. A) 1969-84 at station 905 Fladen and B) 1975-83 at station 13 Anholt E. (Σ N=NO_3 + NO_2 + NH_4).

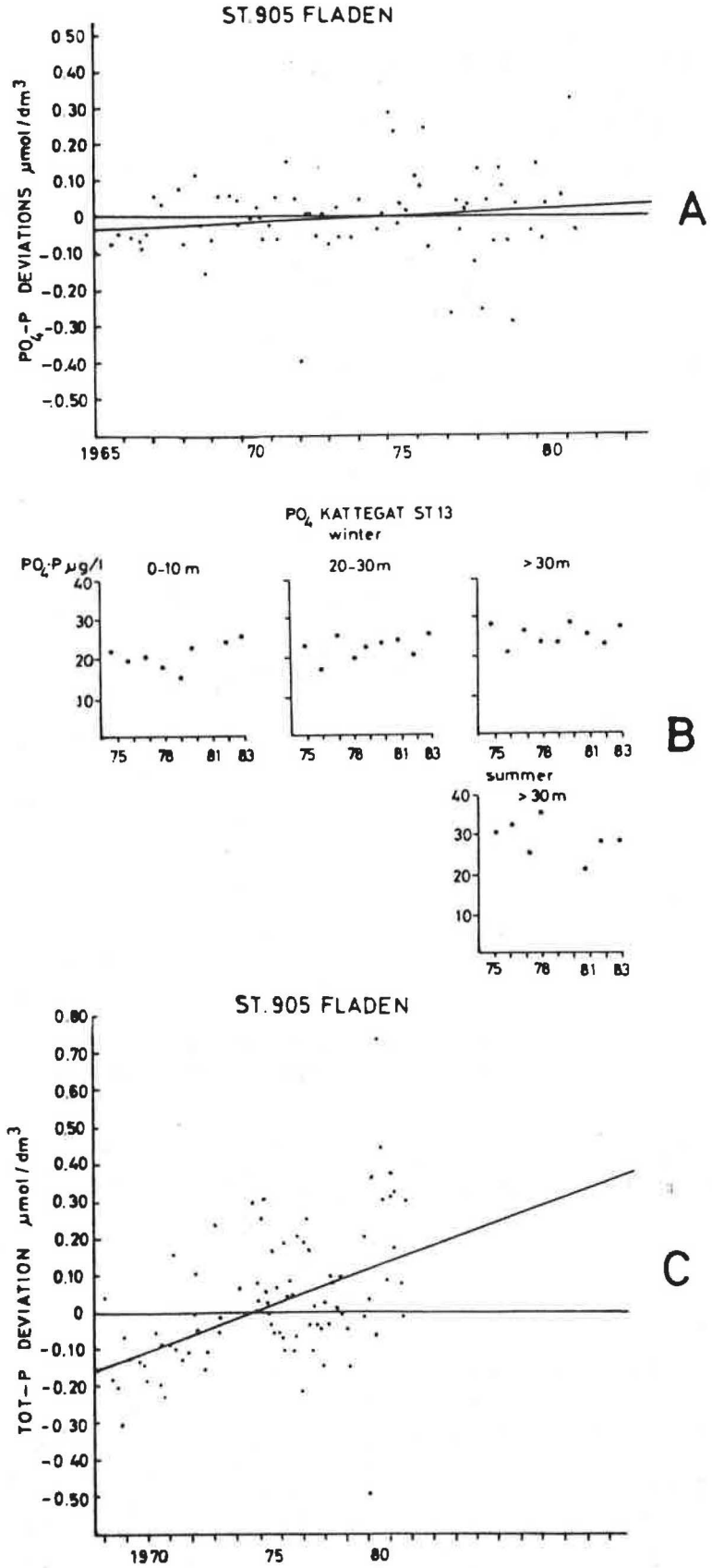

Fig. 8. Phosphorus concentrations in Kattegat water.
A) Deviations from montyly mean concentrations of PO_4-P 1965-81 at station 905 Fladen.
B) Mean winter and summer concentrations of PO_4-P in different waters layers 1975-83 at station 13 Anholt E.
C) Deviations from monthly mean concentrations of Total-P 1968-81 at station 905 Fladen.

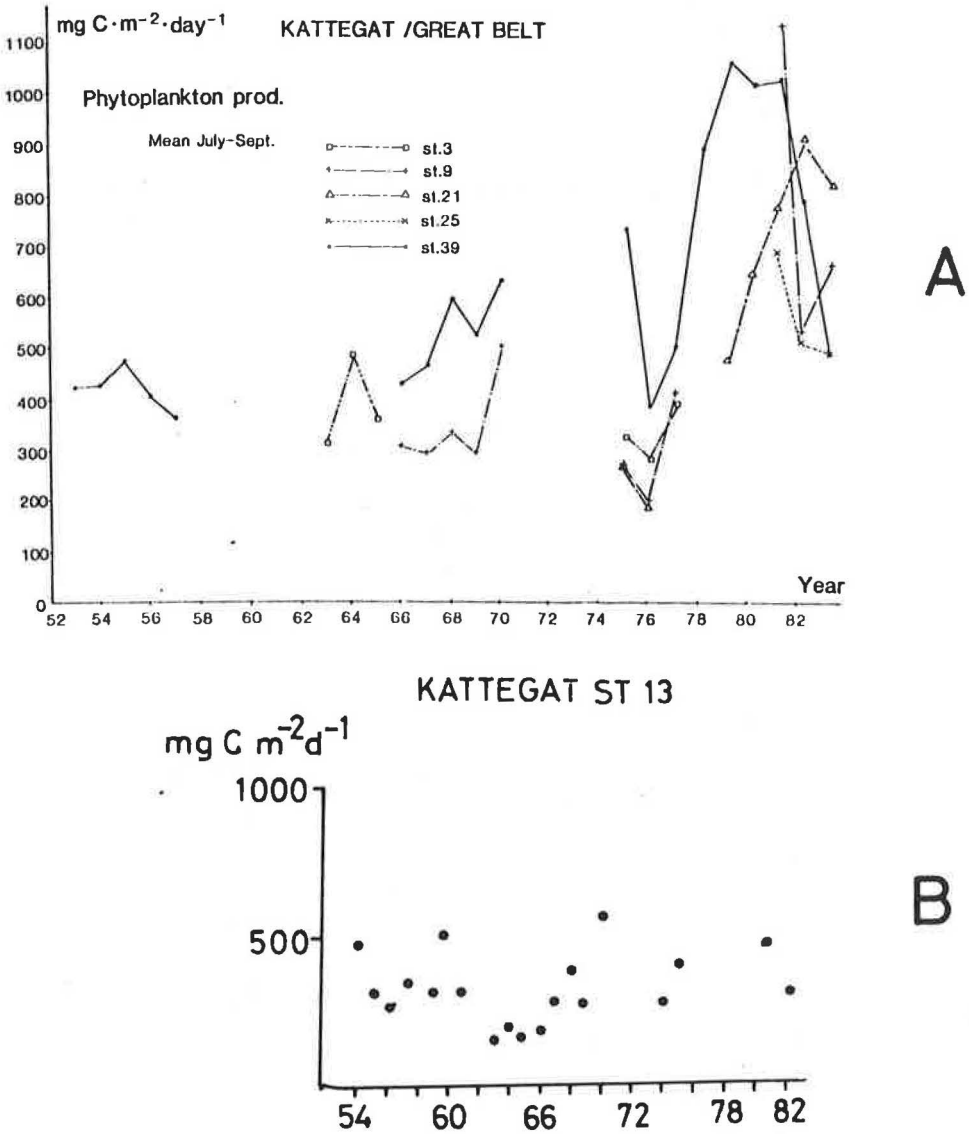

Fig. 9. Mean summer (July-September) primary production at different stations in Kattegat 1954-82/83.

While the concentrations of phosphate have not increased during the last 15 years, the nitrogen nutrients and the total-P have increased significantly in the Kattegat since 1970. This is correlated to the above mentioned increase in primary production in the Great Belt and southern Kattegat. The concentrations of nitrogen in the southern Kattegat/Great Belt are correlated directly with the winter drainage from land (Miljøstyrelsen 1984).

The geographic and bathymetric configuration of the area and the special hydrographical features result in an accumulation of P and N especially in the Kattegat, and also in more enclosed parts of the Skagerrak coast. This can cause large plankton blooms and, after breakdown of organic matter, low oxygen concentrations in sensitive parts of the area.

Fig. 10 shows areas with low oxygen concentrations and fish deaths in 1981 when the conditions were the worst up to 1986.

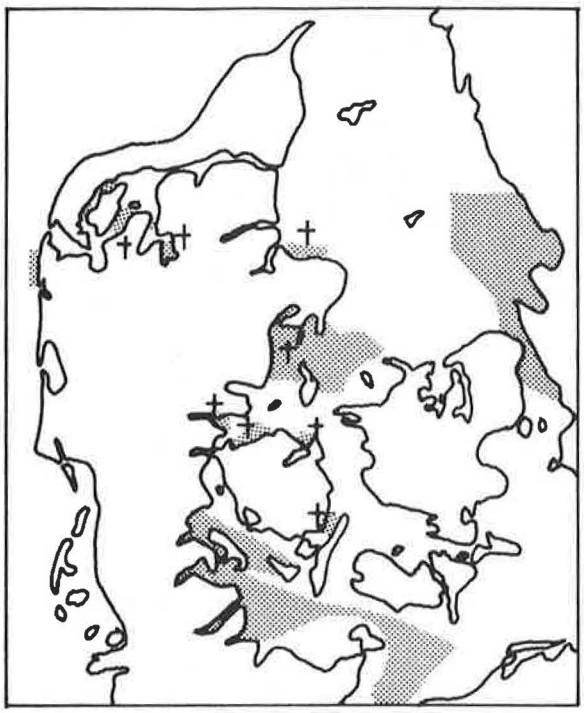

Fig. 10. Areas in the Kattegat and adjacent waters with low oxygen concentrations and fish deaths (crosses) in 1981.

Skagerrak

Based on studies in summer and late autumn on the distribution of nitrate and phosphate in the Skagerrak, the main sources of nutrients to the primary production in the open water masses of the Skagerrak are indicated in Figs. 12-17.

Fig. 11 presents the cross-sections referred to in the following text. Fig. 12 presents the vertical distribution of phosphate and nitrate in a summer situation at the western entrance (Oksøy-Hanstholm, I) to the Skagerrak, while Fig. 13 represents the same parameters in a late autumn situation.

The inflowing water via the Jutland current is found in the shallow shelf off Hanstholm. The nitrate values from June 1982 (Fig. 12) indicate a fairly small inflow, while the phosphate values do not present the same clear picture of enriched shelfwater.

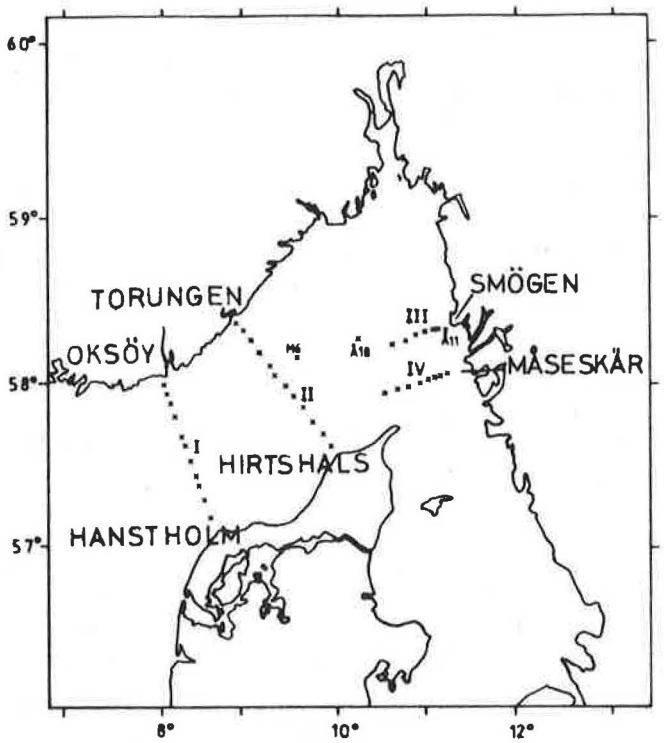

Fig. 11. The cross-sections referred to in the text. Oksøy-Hanstholm (I), Torungen-Hirtshals (II), Å 11 (Smögen) to M 6 in the middle of Skagerrak (III) and from Måseskär at the Swedish coast to the southwest (IV).

In the November situation, as presented in Fig. 13, the phosphate values indicate a pronounced inflow, while the nitrate values do not reflect such an inflow. However, the nitrate profiles for the shallow part give the same picture as the profiles for the phosphate.

The profiles indicate the magnitude of the inflowing water. Compared to the total water masses and the amount of nutrients in the Skagerrak, the influence of the Jutland current is limited.

The profiles from the cross-section Torungen-Hirtshals (II) may represent the main waterbody of the Skagerrak. Figs. 14 and 15 are typical examples of the nutrient distribution of a late autumn situation in this area. The inflowing water from the southern North Sea is found close to the Danish coast as the fairly high phosphate values (Fig. 14) and nitrate values (Fig. 15) indicate. The nutrient distribution clearly demonstrates the doming of the water masses.

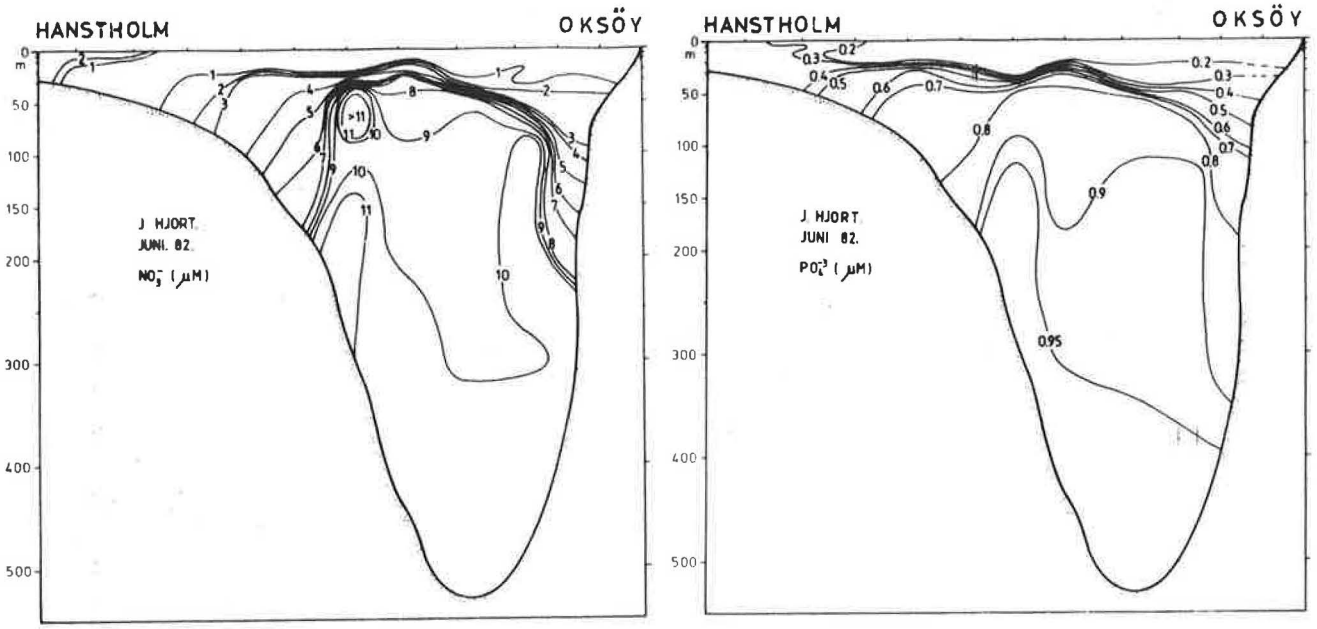

Fig. 12. Nitrate and phosphate distribution, Oksøy-Hanstholm (I), June 1982 (Føyn, pers. comm.).

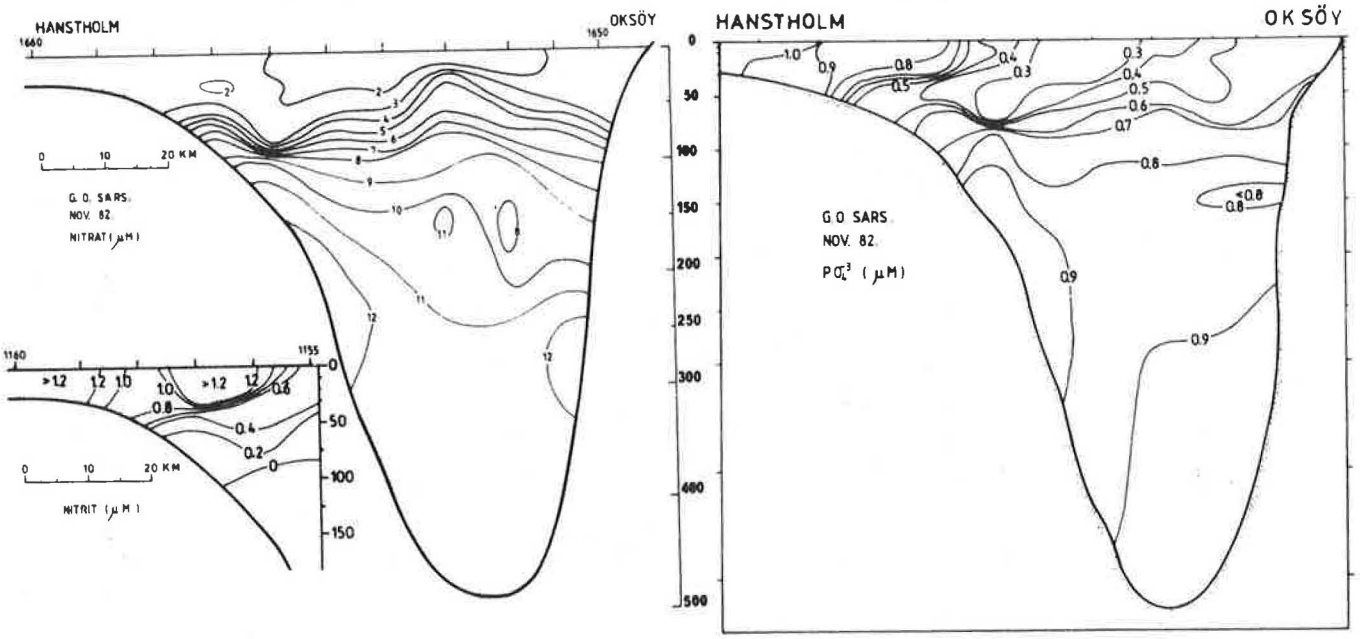

Fig. 13. Nitrate and nitrite and phosphate distribution, Oksøy-Hanstholm (I) November 1982 (Føyn, pers. comm.).

Svansson (1984, pers. comm.) has calculated the mean phosphate values of the period 1958-1982 for the cross section III (cf. Fig. 11), and Fig. 16 presents these values for a summer situation. As can be seen, the isolines for the mean phosphate distribution indicate the same doming tendency as is demonstrated from the cross sections further out in the Skagerrak.

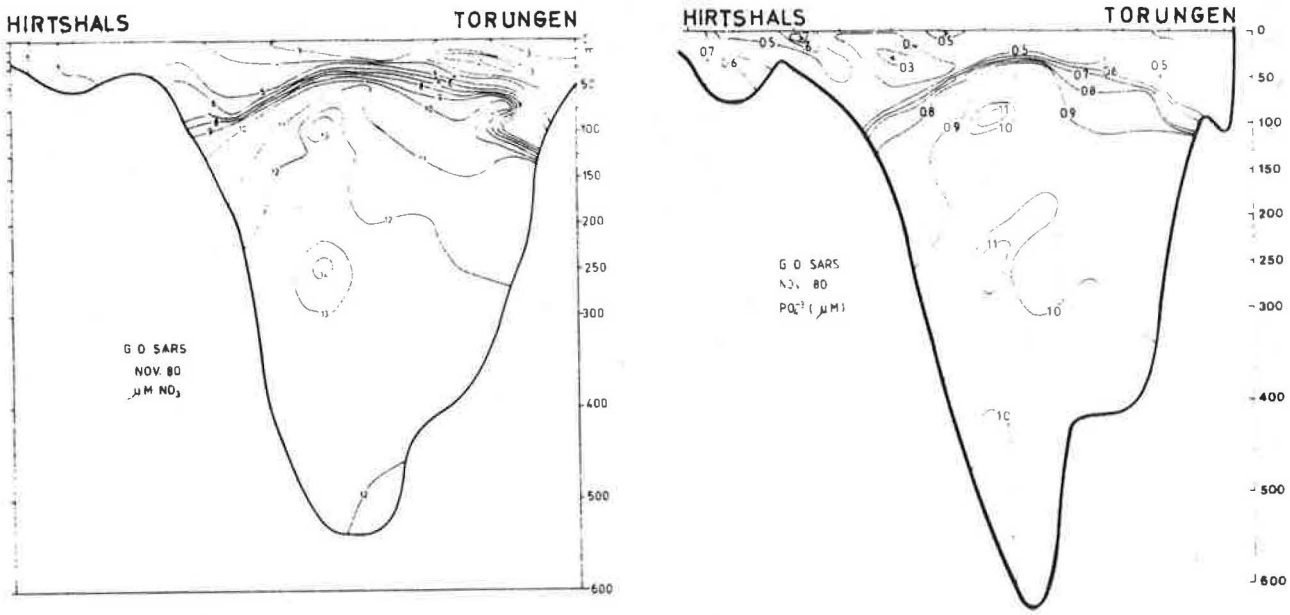

Fig. 14. Nitrate and phosphate distribution, Torungen-Hirtshals (II) November 1980 (Føyn, pers. comm.).

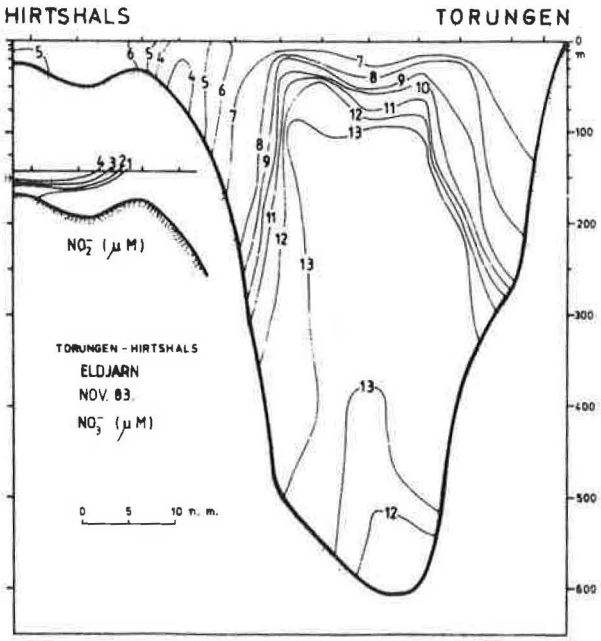

Fig. 15. Nitrate and nitrite distribution, Torungen-Hirtshals (II) November 1983 (Føyn, pers. comm.).

Pingree et al. (1982) have described the doming in the Skagerrak and the vertical distribution of plankton. Their work demonstrates the importance of the doming on the primary production. As seen in Figs. 14, 15 and 16, the doming provides a significant supply of nutrients to the euphotic zone throughout the year.

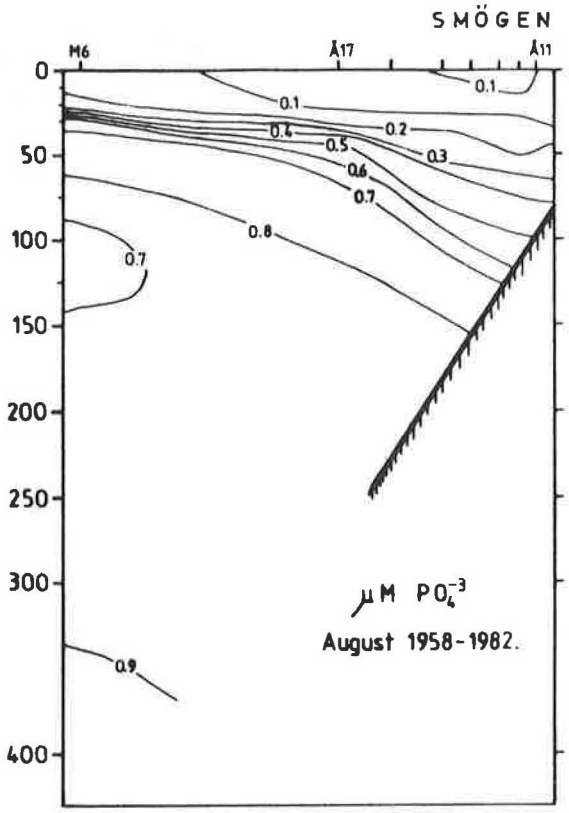

Fig. 16. Mean phosphate distribution, Å 11 - M 6 (III), August 1958-1982 (Svansson 1984, pers. comm.).

Fig. 17 describes a late autumn distribution of phosphate and nitrate in a cross-section (Fig. 11, IV) which may represent the influence from the Kattegat on the open Skagerrak water masses. The nitrate values give no indication of a supply of nutrients via the Baltic current, while the phosphate distribution indicates that there is a core of phosphate-rich water close to the coast of Sweden. However, the magnitude of this contribution to the total amount of nutrients in the Skagerrak may be said to be small.

Dahl and Danielssen (1981) have described the development of the primary production for the first six months of the year for the cross-section Torungen-Hirtshals (cf. Fig. 11, II). They observed especially high production on a station 10 nautical miles from the Norwegian coast and indicated that this may be an effect of local upwelling. This has been confirmed by later investigations (Anon. 1982, 1983, 1984 and 1985).

Observations of winter situations (January-February) show higher concentrations of nutrients in the inflowing water both from the Kattegat and from the southern North Sea via the Jutland current. This increased influx to the Skagerrak has no influence on the open water masses but it will, however, add to the nutrient load arising from land run-off in nearshore shallow waters and thereby lead to local eutrophication.

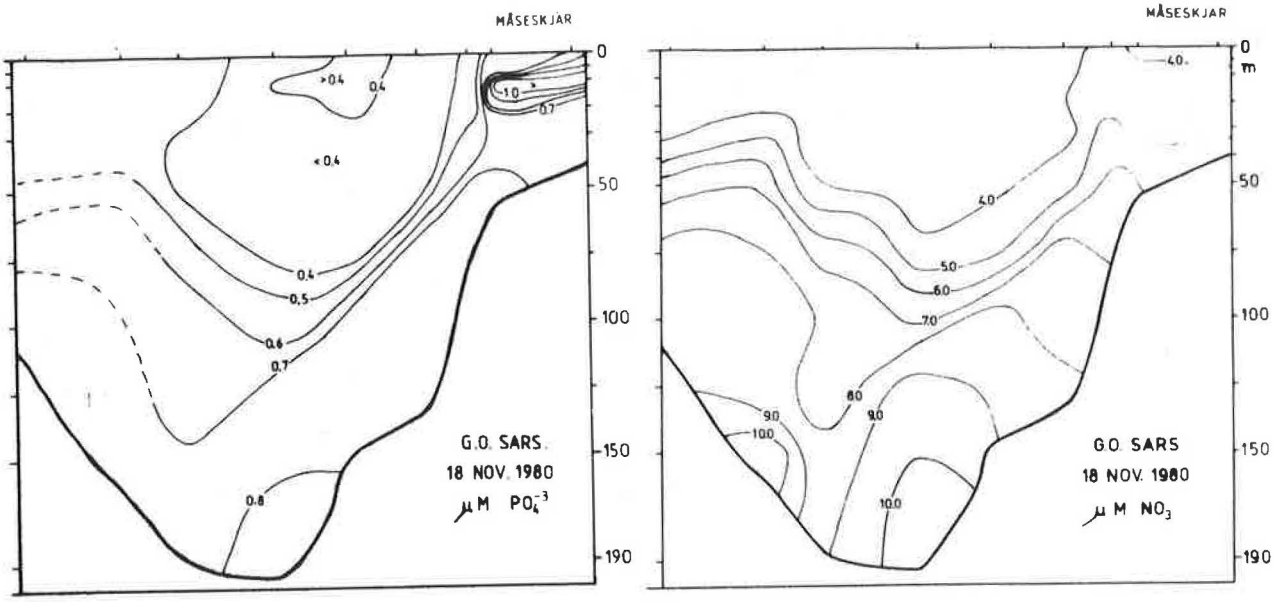

Fig. 17. Nitrate and phosphate distribution, Måseskär - SW (IV) November 1980 (Føyn, pers. comm.).

Based on the nutrient observations and the primary production referred to above, the conclusion can be drawn that the main source for nutrients to the euphotic layer of the open Skagerrak water masses is the doming of the nutrient-rich deep water of the Skagerrak. Since the main supply of nutrients to the Skagerrak deep water is by the inflow of Atlantic water, it follows that there are little or no anthropogenic effects on the nutrients and primary production of the <u>open</u> water masses of the Skagerrak.

3.2 Contaminants

Organochlorines

Due to analytical difficulties only very few observations have been made on organochlorine concentrations in sea water. More investigations have been carried out on the concentrations in fish and other organisms.

On the whole the concentrations of organochlorines in biota are rather low, seldom exceeding 0.2 mg/kg DDT or PCBs and 0.02 mg/kg dieldrin, HCB, α-HCH, β-HCH and γ-HCH (lindane) in muscle tissue of fish (wet weight) (Dybern and Jensen 1978, Olsson and Reutergårdh 1984). There is a tendency to higher concentrations, e.g. in mussels, near the coast than in the open sea. This is especially the case in the Swedish archipelago, and in more polluted waters near industrial centres (Dybern and Jensen 1978)

Generally the average concentrations in the Kattegat are lower than those in the Baltic Sea but higher than those in the open Skagerrak. At least in some parts of the area there seems to be a slight decrease in the levels during recent years (Olsson and Reutergårdh 1984).

Metals

Metal concentrations in sea water are shown in Table 3 A and B. There is often a tendency to higher concentrations in coastal areas than in the open sea (ICES 1974).

Table 3

A. Metals in the water from Skagerrak and Kattegat in µg/l (unfiltered). The stations are situated 1 nautical mile from the coasts. (Gustavsson 1984, pers. comm.).

	Cd		Hg		Pb		Cu	
Detect. limit	0.005		0.003		0.04		0.05	
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd
Skagerrak								
1979	0.12	0.05	0.01		0.65		0.70	
1980	0.08	0.02	0.06	0.04				
1981	0.09	0.07	0.05	0.03				
1982	0.13	0.04	0.025	0.02				
Kattegat								
1979	0.05	0.02	0.07	0.03				
1980	0.07	0.03	0.06	0.04	0.57	0.11	1.2	0.3
1981	0.04	0.01	0.04	0.02				
1982	0.05	0.02	0.02	0.01				

B. Metals in sea water from three transects in the open Skagerrak, 1982, in µg/l (unfiltered). (Eisma et al. 1984).

	Mean	Sd
Fe	8	9
Co	0.016	0.011
Ni	0.215	0.101
Cu	0.215	0.101
Zn	0.397	0.232
Cd	0.023	0.009
Pb	0.049	0.026

The levels in the Øresund are generally considerably higher than those of the Kattegat, and the Øresund thus seems to act as an important source for the latter area.

The levels of mercury in fish and mussels are generally lower than 0.5 mg/kg wet weight, with an average of <0.1 mg/kg. The highest levels are found in some polluted coastal areas, e.g., at the Swedish west coast and in the Oslo Fjord. Other metals as Cd, Cu, Cr, Zn and Pb show great variations in biota. For at least some of these metals there seems to be a slight tendency to higher values in some coastal areas (ICES 1974).

Investigations of trace metal concentrations in suspended particulate matter in the Skagerrak have shown that aluminium, present in detrital silicate material, show the lowest concentrations toward the North Sea and the highest concentrations near the Danish coast. The general picture shows diminishing concentrations away from the coast. Iron is present in aluminosilicates and oxide/hydroxide particles, with a certain amount tied up in organic matter. Iron concentrations decrease with increasing distance from the coast. Manganese is a trace constituent in most detrital silicates; the highest concentrations of manganese were found in waters below 250 m in the Skagerrak (ICES 1983).

Also in the bottom sediments there is a tendency of increased metal levels in coastal areas, due to the near distance to the sources, the sedimentation processes and the general environmental conditions which favor deposition. In general, Hg and Cd are the two most frequently enriched metals, both in coastal and open sea sediments. Trace metal input to the open sea (as evidenced in sediments, water and biota) may to a large extent be due to atmospheric deposition (Cato 1983).

Table 4 gives an impression of the concentrations of Hg, Pb and Cu as well as of organic carbon in surface sediments in some areas along the Swedish west coast (Olausson 1975). Repeated investigations seem to indicate that these levels generally remained the same throughout the 1970's and the beginning of the 1980's.

Table 4

Organic carbon and heavy metal concentrations in the superficial sediment of some areas along the Swedish west coast. With the exception of Gullmarsfjord, the analyses have been carried out according to the methods given by Olausson (1975).

Regime	Date of investigation	No of samples	Org.Carbon (Org.C) (mg/g) Range	Mean	Mercury (Hg) (ng/g) Range	Mean	Lead (Pb) µg/g) Range	Mean	Copper (Cu) (µg/g) Range	Mean	Reference
Askimsviken Bay	1973	20	1.6-61.8	13.3	<5-2200	265	2-38	9.1	2.3-22	7.4	Cato et al. 1978
Upper Välen	1973	6	37.2-156	94.0	1010-2480	1350	135-292	190	72-132	97	Cato 1977
Göteborg archipelago	1982	32	6.1-36.6	21.8	116-3510	768	0.01-22	9.9	1.4-12	5.0	Cato unpubl.
Orust-Tjörn water-system	1970	29	16.3-70.6	31.1	136-335	253	8-25	15	5-48	14	Olausson 1975
Byfjorden	1970-74	9[1]	9.0-51.0	33.5	5-1200	179	9-39	23	5-50	21	Olausson 1975
Gullmarsfjorden	1981	12	8.0-40	31.4	60-180	128	20-50	39	5-27	22	Joslin 1982
Brofjorden	1972	67	10.8-65.2	33.0	31-294	160	0.3-31	16	2.3-12	7.9	Cato 1977
Idefjorden	1975	11	30.0-180	81.4	670-2900	1420	53-210	115	20-176	94	Olausson and Engvall, unpubl.
Kattegat	1970	66	4.0-24-7	11.2	27-220	121	1-23	11.5	1-13	4.6	Olausson 1975
Skagerrak	1970	49	2.0-27.0	16.9	15-198	78	3-22	10.5	1-9	5.0	Olausson 1975

1 The site numbers of org. carbon are 15 and of mercury 58

Radioactive substances

Radionuclides (e.g., ^{54}Mn, ^{58}Co, ^{60}Co, ^{65}Zn and ^{110}Ag) are released in small quantities from the nuclear power plant at Ringhals on the Swedish Kattegat coast. The same substances are also released from the nuclear plant at Barsebäck in the Øresund. However, the quantities are very low and can only be traced in the neighbourhood of the power stations. Many of them have a short lifetime and pose no risk either to sea life or human beings (Grimås 1983).

However, increased levels of ^{137}Cs have recently been found in the whole Kattegat-Skagerrak area. Levels have also increased in the North Sea and it is considered that the increase is due to discharges from the Sellafield (Windscale) nuclear power plant (Grimås 1983) and possibly also from other similar plants (Aarkrog et al. 1983).

Petroleum hydrocarbons

Several severe oil spills from ships have occurred in the area. They have been shown to cause temporary damage to shores and biota, but in no case has the damage been persistent.

Some measurements of the content of oil in sea water in the northern Kattegat and in the Skagerrak show values which only very occasionally exceed 2 µg/l (comm. from Nat. Fish. Board of Sweden, Hydrographical Lab.). This value is much below the level of 50 µg/l which has been observed to have effects on fish eggs and larvae.

4. BIOLOGY

4.1 General biology

The biological conditions are governed by the physical and chemical relationships. The area shows a great diversity of biotopes and environments due to the great variations in temperature, salinity, oxygen, nutrients and bottom topography encountered in the region. In both the Skagerrak and Kattegat these facts therefore give an extremely variable platform for the biological display, which has distribution from protected areas along the coasts and in the fjords to open ocean, and from the beach in the tidal zone down to the seabed at 700 m depth. There are great variations in the pelagic environment during the seasons of the year both concerning the diversity of species and abundance. The total number of macro-infaunal species decreases markedly from the Skagerrak to the Baltic Sea: from 1500 species in the Skagerrak to 836 species in the Kattegat and 77 in the Baltic Sea.

4.2 Biological trends and disturbances (anthropogenic activity)

The climatic change in Northern Europe recorded to have started around 1970, was registered also in slightly increased temperatures in the sea. However, after 1974/75 the sea temperature in Kattegat/Skagerrak has shown a slightly decreasing tendency in the surface water.

Some biological effects caused by changes in the marine environment have been reported including a general decline in the stocks of sprat and a simultaneous increase in the herring stocks in the North Sea, and the occurrence of phytoplankton species not recorded previously in the area.

Benthos

The infaunal benthos and the attached flora and fauna of hard surfaces are widely recognised as being good indicators of long-term changes in the sea. Whereas the plankton is subjected to continuous large and small-scale changes in water movements, the benthic systems are relatively static and must, therefore, respond to changes in the overlying water column and integrate these changes over time. Benthic ecosystems are usually rich in species and hence in a diversity of feeding and life-history types which can respond to a variety of stimulii.

It is usually much easier to show effects of pollutant influences on the benthos than on planktonic or pelagic systems. As in all biological effects monitoring, it is not, however, easy to distinguish pollutant effects from natural long-term cycles, the duration of which can be very large (Grey and Christie 1983).

One of the longest running marine monitoring studies is that conducted by Lundälv (1985) at a series of fixed subtidal sites on rocky substrata in the Gullmarfjord, Skagerrak. The general trend in the ascidian Ciona intestinalis over a 13-year period was an increase in numbers from a minimum in 1970 to a maximum in 1973, followed by a decline in 1975-76 and a less marked peak again in 1980. Other species of ascidians showed similar variations. These data suggest that all sites were influenced by the same common, largescale factor(s) as the sites covered a distance of 62 km of coastline. All the sites were below the influence of Baltic water and can thus be taken to indicate trends in hydrographic conditions in the Skagerrak. There is no clear indication that these results indicate effects of pollution (or eutrophication), but they illustrate the extreme importance of ensuring that data cover long periods of time so that changes over short time periods, as for example the increase in C. intestinalis between 1970 and 1973, or decline from 1973-76, are not perhaps mistakenly interpreted as effects of pollution.

Long-term data covering the same period are also available for the soft-bottom benthos of the Skagerrak (Josefson 1981). Josefson's data cover stations at 100 m, 300 m and 600 m depth in a transect from the west coast of Sweden to the Skagerrak deep. From 1970 the communities studied have shown remarkable stability with very little change in numbers, biomass or species abundance over time. It is highly unlikely that such deep communities will show rapid responses over time since they are below the influence of surface waters and the processes that occur therein. This is because, although any slow, long-term increase in nutrient concentrations in the surface water will lead to increased primary production and hence secondary production, the benthic communities are probably not tightly coupled to the primary production cycle, with the result that small changes will not influence the deep benthos. In the Oslofjord at an unpolluted site, Valderhaug and Gray (1984) found that at only 30 m depth a sediment-living community showed little change over time despite varying primary production in the overlying water.

Rosenberg and Møller (1979) surveyed a large number of coastal sites north of Gothenburg and compared their findings to an earlier investigation of Molander (1928) done in the 1920's in Åbyfjord, Gullmarsfjord, Ellosfjord and Stigfjord. Although they found 2-3 times as many species, ten-fold increases in abundance and a significant increase in biomass, they concluded: "The differences were small following the exclusion of some small abundant species", and "The significant difference in number of species and abundance ..... is probably due to the difference in sorting technique". However, it should be noted that recently Josefson and Smith (1984) have recorded significant changes in the biomass of soft-sediment benthos in the Skagerrak-Kattegat during the 1970's. Whether or not these changes are due to long-term climatic events, as was suggested for the hard-bottom system, or to eutrophication or other causes cannot be ascertained.

The first attempt at quantifying the abundance of sediment-living benthos in the Kattegat was made in the first decade of this century by C.G. Petersen. Whilst techniques have improved, Petersen's extensive work gives a reasonable baseline for examining change. In 1984 Pearson, Josefson and Rosenberg (1985) revisited most of Petersen's stations using as closely as possible exactly the same sites, sampling and sorting methods. Preliminary results from 24 sites show that:

1. Biomass was significantly lower in 1984 at all 24 stations.
2. The greatest change was in the northwest Kattegat.
3. The dominance pattern was markedly altered.
4. The average weight of individuals was lower in 1984.
5. *Echinocardium cordatum*, *Turritella communis*, *Apporrhais pes-pelicani* and *Nucula* spp. had lower biomass at all 24 stations.
6. *Amphiura filiformis* and *Eumenia crassa* had significantly higher numbers at the southernmost 12 stations.

There is, therefore, little doubt that significant changes have occurred in the benthos of both the Kattegat and Skagerrak since the observations in the 1910's and 1920's. There are several hypotheses which may explain such changes:

a) natural long-term hydrographic changes (see Gray and Christie (1983) for a short review),
b) eutrophication which probably affects the Kattegat, but there is little indication that the Skagerrak is yet affected,
c) bottom trawling, which has increased in the areas concerned,
d) predation pressure from bottom-living fish has changed, thus influencing infaunal communities.

Clearly much carefully designed research is needed to test these hypotheses before conclusions can be drawn as to the causes of the recorded changes.

Phytoplankton

One species of algae which has been the subject of much discussion recently is Gyrodinium aureolum, first described from the east coast of the USA in 1957. The next record of the species was in 1966 in Norway. Since then it has established its main distribution in Western Europe (east of the UK, period summer. From Friesland to Bergen, Norway, and in the Skagerrak/Kattegat. Period autumn). About 25 blooms have been observed of which half occurred between 1979 and 1982; most of these were accompanied either by direct toxic effects or in some cases indirect effects due to oxygen deficiency during and/or after the blooms. The northernmost locality where blooms have occurred and caused fish mortality is at Senja, North Norway. G. aureolum has caused fish mortality in Norway in 1966, 1976, 1981 and 1982 (Dahl et al. 1985). In Sweden it killed fish and cultivated mussels in 1981.

The first record of Prorocentrum minimum in the area concerned was in 1979 (Norway). Blooms have since been recorded in the Kattegat in autumn 1981 and occasionally thereafter. The most dense concentrations are observed in sheltered polluted fjords (1979, Oslofjord 1.8×10^9 cells/liter, Vejlefjord, Denmark, August 1983 1×10^9 cells/liter). The species is recorded all over in open waters, even in the Baltic Sea.

In the autumn of 1980 and 1981 dinoflagellates of the genus Ceratium bloomed in the southeast part of the Kattegat and oxygen depletion accompanied these blooms (Edler et al. 1982). High concentrations of Ceratium have been associated with mortality of caged fish in Norway and Sweden. The dinoflagellate Dinophysis acuta was observed in the late summer and autumn 1984 at the Swedish coast in concentrations of up to 23 000 cells per liter. Cultivated mussels were found to be toxic at this time and the sale of mussels from the Swedish west coast was banned from October 1984 to August 1985. The same picture occurred along the Norwegian Skagerrak coast. The most likely reason for their toxicity was the presence of D. acuta in the water.

The yellow alga Distephanus speculum was recorded in May 1983 in the Kattegat with the largest concentrations (25 x 10^6 cells) in East Jutland fjords. The specimens were atypical without a silicate skeleton, and may be identical with a flagellate recorded in Scottish blooms. Fish mortality was observed concurrently with blooms. Oxygen deficiency was not observed.

The PSP (Paralytic Shellfish Poison) producing dinoflagellate Gonyaulax tamarensis is commonly found in Western European waters and is monitored in the mussel and oyster producing countries, including Norway. The bloom recorded at the south coast of Norway in 1981 with consequent mass mortality of fishes and invertebrates, was probably due to Gyrodinium aureolum, not Gymnodinium breve. Three other non-toxic species of genus Gonyaulax have been recorded annually from the area concerned, and recently also G. tamarensis has been recorded from the Skagerrak (Hasle, pers. comm.).

In the Baltic Sea and southern Swedish-Danish waters the blue-green alga Nodularia spumigena often blooms. The species has not been recorded in damaging concentrations in the Kattegat, but in the dry years 1975 and 1976 it occurred along the Swedish west coast south of Lysekil (Söderström, pers. comm.).

It appears that the possible combination of the effects of climatic changes on the species composition and the introduction of new species, as well as of the increased impact of anthropogenic activity on the environment, has had one evident unwanted effect, namely, an increase in the strength and frequency of blooms of plankton algae, toxic or non-toxic. (See Annex 2 for list of toxic species). This has been particularly evident in the coastal areas of the Kattegat and Skagerrak.

Fisheries

In general it must be said that it is not possible to make reliable estimates of stocks or resources in the Skagerrak/Kattegat area because of insufficient fishery investigations or the lack of investigations. Particularly for the Skagerrak area there is a very weak platform for estimating the resources. Nevertheless, stock estimations have been made on which the recommendations from ICES are based.

The reporting of the catches in the area, or lack of reporting, especially concerning herring, has resulted in an annual overfishing of 100 000 to 120 000 t over the recommended catch quantity. There are no special stock estimates for sprat and gadoid fishes in Skagerrak/Kattegat, and the resources are not included in the estimates for the North Sea. The same can be said for the industrial fishery and its by-catches. We have therefore no exact data for making conclusions on the exploitation of any of the fisheries resources.

The prawn fishery in the area has been increasing since 1975, but there is no reliable estimate of the stock at the moment.

4.3 Fishery resources

In this connection the Skagerrak-Kattegat area corresponds to the ICES division III a.

As an intermediate area between the North Sea and the Baltic Sea, the Skagerrak and Kattegat are of great importance to the biology of the fish and shellfish. The results of investigations, however, are often difficult to interpret as several species show a complex migration pattern, and exchange between the different areas occurs frequently. The scientific knowledge is nevertheless at a relatively low level, and is therefore not sufficient to give a satisfactory platform of knowledge for the generation of advice on fishery management.

The natural production capacity of the area is considered to be rather high. Information from different sources gives an average catch figure for fish of 40-55 kg/ha/year for coastal areas and 70 kg/ha/year for the open sea.

In the area we can find satisfactory conditions for spawning, nursery and feeding grounds for a diversity of species.

Fisheries

As mentioned it is a transition area between the North Sea with waters of high salinity and the Baltic Sea with waters of low salinity. Other typical features are a complicated current system and, in most of the area, a marked halocline and summer thermocline.

During the last decades the importance of the fishery has increased especially in Denmark and Sweden, and recently also in Norway. The fishery of other countries in the area is small.

Species

There are about 90 fish species in the Skagerrak. 10-15 other species may be found more or less regularly. About 30 species are of significant commercial value and another 20 species of a certain importance for the fishery.

There are 4 crustacean and 2 bivalve species of high value and, in addition, a few species of sharks, skates and squids of some commercial importance.

In the Kattegat the number of regular fish species is about 75. Another 10 or so occur with some regularity. About 25 fish species are of significant importance to the fishery and another 20 of a certain value. The number of sharks, skates, crustaceans, molluscs, etc. is very similar to that of the Skagerrak area, but the stocks are generally thinner, especially in the southern part.

In the south-western part of the Baltic Sea there are about 40 marine fish species. Of the other species mentioned above are only 5 left, none of them of commercial value.

There is thus a marked decrease in the number of species of fish and shellfish from the North Sea through the Skagerrak and the Kattegat to the Baltic Sea. This also applies to other forms of fauna and the flora and in both cases is due to the reduced salinity in the Baltic.

Many fish and shellfish species, as well as sharks and skates, are only found in deeper waters, especially in the Kattegat where the halocline is most pronounced.

Since the actual area is more open towards the North Sea the water and species exchange is more pronounced in that direction. For instance, some southern species more or less regularly enter the Skagerrak via the North Sea. A few of the species found in that sea area are also of northern origin.

The fishery

The commercially most important species in both the Skagerrak and the Kattegat are herring (*Clupea harengus*), sprat (*Sprattus sprattus*), salmon (*Salmo salar*), sea trout (*Salmo trutta*), eel (*Anguilla anguilla*), cod (*Gadus morhua*), whiting (*Merlangus merlangius*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius merluccius*), mackerel (*Scomber scombrus*), plaice (*Pleuronectes platessa*), dab (*Limanda limanda*), lobster (*Homarus gammarus*), Norway lobster (*Nephrops norvegicus*) and edible crab (*Cancer pagurus*). More important in the Skagerrak than in the Kattegat are, in addition, saithe (*Pollachius virens*), pollack (*Pollachius pollachius*), ling (*Molva molva*), halibut (*Hippoglossus hippoglossus*), witch (*Glyptocephalus cynoglossus*), spiny dogfish (*Squalus acanthias*), deep-sea shrimp (*Pandalus borealis*) and blue mussel (*Mytilus edulis*).

A number of species are more or less important as by-catch and in the industrial fishery, especially in the Skagerrak fishery, e.g. argentines (*Argentina sphyraena* and *A. silus*), blue whiting (*Micromesistius poutassou*), poor cod (*Trisopterus minutus*), Norway pout (*Trisopterus esmarkii*), sand dab (*Hippoglossoides platessoides*) and flounder (*Platichthys flesus*). Most of the by-catch species are used for industrial purposes or for animal feed. For the argentines there is sometimes also a direct fishery in Denmark and Norway.

Below are given some examples on the trends in the fishery for some of the most important species during the recent time. The figures are based on the findings of the ICES Advisory Committee on Fishery Management in 1984.

Fig. 18 shows the landings in the Skagerrak and the Kattegat of herring, which is the most important species. In the middle of the 1960's there was a considerable fishery (some years up to almost 400 000 tons), which took place mainly in the Skagerrak, but which rapidly decreased during the late 1960's. The decrease coincided with the well documented rapid decline in the North Sea herring fishery. After a slight recovery in the beginning of the 1970's, especially in the Kattegat, the decrease continued until the early 1980's when the curve turned upwards, and in 1983 the total catch approached 200 000 tonnes. The herring fishery is regulated between the countries, but the TACs are regularly grossly exceeded.

Fig. 19 shows the recent distribution of the sprat catches. The fishery was very important during the 1970's, but has shown a strong decline in the early 1980's, principally due to decreases in the stock size.

Fig. 20 shows the catches of cod. There is an upwards trend in the Skagerrak and a fairly constant catch in the Kattegat. Not apparent from the graph is the fact that there has been a recent decline in coastal cod stocks. This is particularly so in the eastern part of the area where the species has almost disappeared from parts of the Swedish coast; the reason for this disappearance is not known.

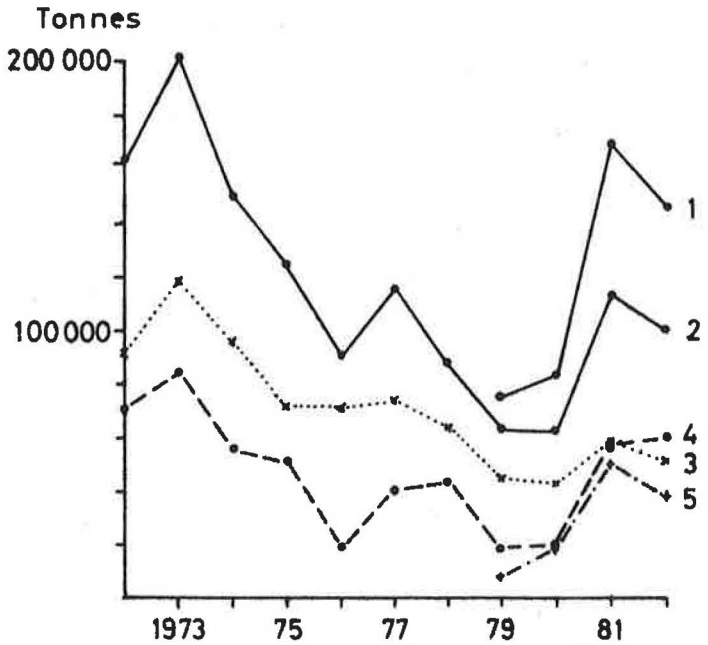

Fig. 18. The landings of herring in Skagerrak and Kattegat 1972-1982 according to official data. 1) Grand total, 2) Total, 3) Kattegat, 4) Skagerrak, 5) Unallocated catch.

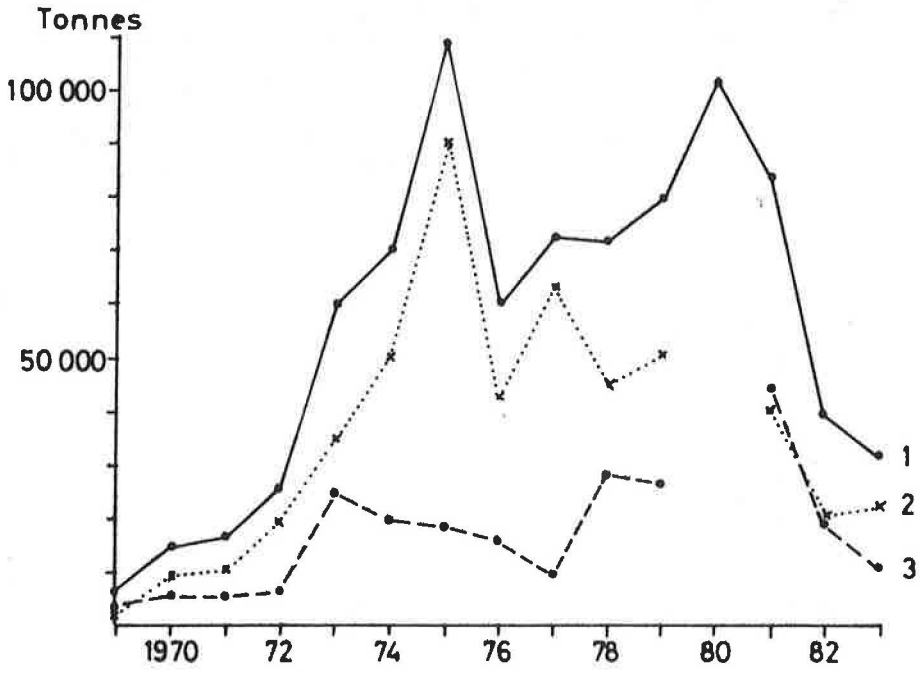

Fig. 19. The landings of sprat in Skagerrak and Kattegat 1969-83. 1) Total, 2) Kattegat, 3) Skagerrak.

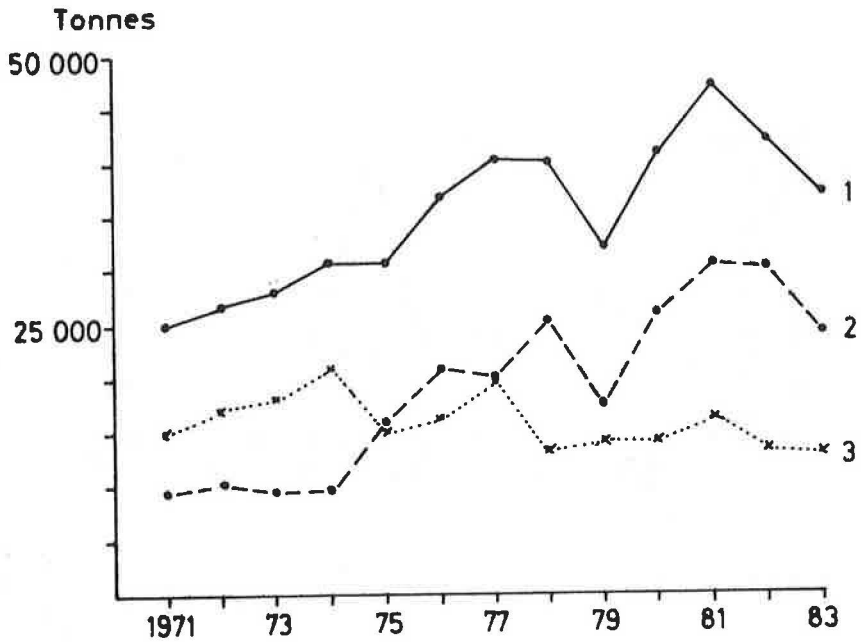

Fig. 20. Landings of cod in Skagerrak and Kattegat 1971-83. 1) Total, 2) Skagerrak, 3) Kattegat.

Catches of plaice (Fig. 21) show a peak especially in the Kattegat during the 1970's. After a decline up to the beginning of the 1980's there are now reports of a recovering stock.

The results of the fishery for whiting (Fig. 22) show a fairly constant fishery, except during 1978 when there was a peak.

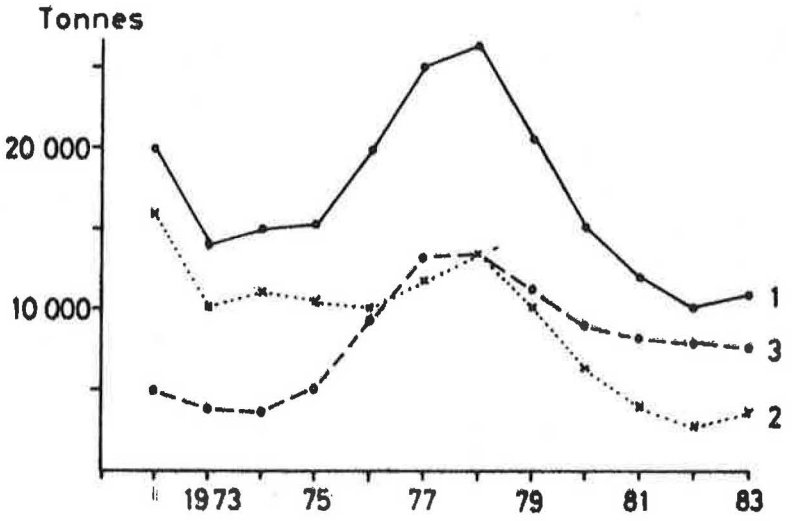

Fig. 21. Landings of plaice in Skagerrak and Kattegat 1972-83. 1) Total, 2) Kattegat, 3) Skagerrak.

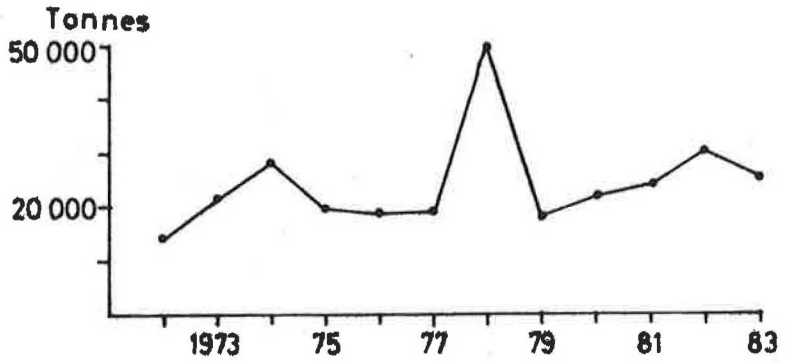

Fig. 22. Total landings of whiting in Skagerrak and Kattegat 1972-83.

In Fig. 23 the landings of the deep sea shrimp (almost all in the Skagerrak, but also some in the eastern part of the North Sea), are shown up to the early 1980's. The shrimp fishery was at its highest level in the early 1960's (not shown in the Figure), partly coinciding with the peak in the herring fishery, and with catches exceeding 7000 tonnes/year. After a strong decline around 1965, the shrimp fishery was relatively stable, but there has been an increase in the catches since early in the 1980's.

The landings of Norway lobster are variable (Fig. 24), but have generally been fairly stable. In the early 1980's there has been a significant increase in landings from the Skagerrak. In October/November 1985 mass mortality of Norway lobster was reported in the southeast Kattegat, most probably as a result of low oxygen concentrations.

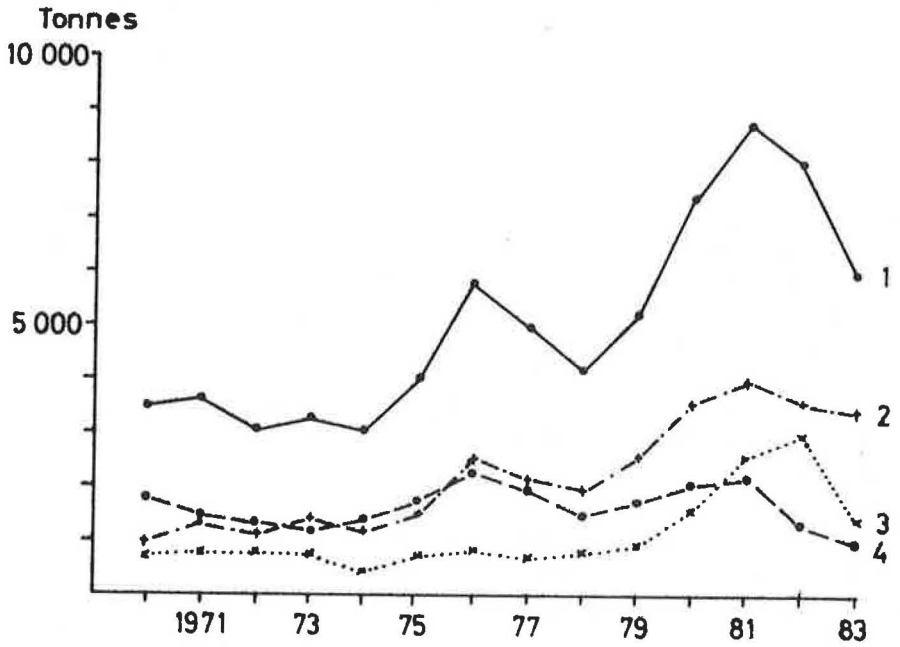

Fig. 23. Landings of deep sea shrimp in Skagerrak and Kattegat 1970-83. 1) Total, 2) Norway, 3) Denmark, 4) Sweden.

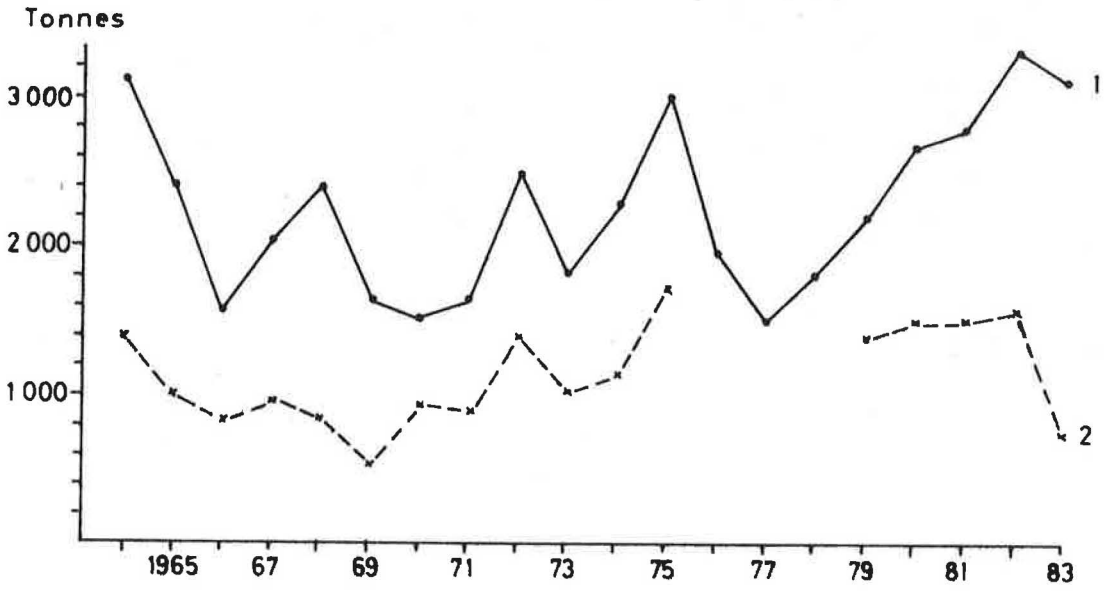

Fig. 24. Landings of Norway lobster i Skagerrak and Kattegat 1964-83. 1) Total catches, 2) Danish fishery in Kattegat.

The European lobster fishery has undergone a drastic decline since the 1950's and official landings have now decreased to less than 10%. Part of this decline, however, is misleading since a substantial number of lobsters are fished by people who do not sell their catches through official outlets and they do not therefore feature in official statistics.

There is, nontheless, agreement between scientists that part of this decline is due to a real decline of the lobster stock.

For other species than those mentioned here the trends of the landings may be positive or negative. Most of the fluctuations may be due to natural causes, but in some cases there might be other reasons.

Factors steering the trends in the fishery

As has been mentioned, the Skagerrak-Kattegat area is a transitional area between the North Sea and the Baltic Sea. The gradual decrease in salinity and the usually pronounced halocline influence the distribution of marine species, many of which are at the extreme of their distribution limits in the area and are thus very sensitive to changes in the environment.

Some species migrate in and out of the area and may be exposed to natural changes elsewhere.

During the last few decades, the fish and shellfish stocks have increasingly been fished in the Skagerrak and Kattegat at the same time as overfishing has occurred in the surrounding areas (herring and mackerel). The North Sea herring stocks are now recovering, but at the same time the sprat appears to be overfished. Increasing prices for some species, e.g. the Norwegian lobster, have increased the fishing effort for these species, and low prices and a lack of interest among the consumers have prevented a more intense fishery for other available stocks, e.g. the blue whiting. High fuel costs for fishing boats have in some cases caused fishermen to fish nearer to the coast than before. This, together with declining shrimp catches in their area (cf. Fig. 23, curve for Sweden), is one of the reasons why Swedish fishermen have switched from the shrimp fishery to a fishery for Norway lobster in the northern Skagerrak.

The variable environment makes it rather difficult to survey the fish and shellfish stocks in detail. To this must be added the fact that the knowledge of the natural requirements for many species is insufficient.

On the whole, it may be said that the most important fish and shellfish stocks at present probably are being exploited at their maximum sustainable yield or perhaps above it, e.g., the sprat. A slight increase in the fishery (e.g., for Norway lobster) or change in the environment (e.g., lower oxygen concentrations) may give rise to a negative trend as regards catches.

The fishery of some species is heavily regulated in the area, but some of the TACs are exceeded. For example, in 1983 the herring TAC was set at 57 000 tonnes, but the actual catch totalled about 200 000 tonnes.

Several sub-areas have been heavily contaminated during recent years. Such areas include some fjords and the sea areas outside several industrial sites in all three countries. There is also an inflow of pollutants and nutrients through rivers and directly from agricultural areas. Pollutants are regularly washed out into the Kattegat by the Baltic current from the Baltic Sea, through the Öresund and the Belts. Contaminants may also enter from the North Sea into the Skagerrak, for instance radionuclides.

There are signs of an increasing eutrophication of parts of the coastal areas, especially in the Kattegat, and also in some places along the coast of the Skagerrak. Local fishery and spawning and feeding grounds for important species have been adversely affected. Temporarily the oxygen content of the deeper water of SE Kattegat can be so low that bottom species are negatively influenced. They may be lethally affected or leave the area.

Up to now the influence of pollution (both excess nutrients and contaminants) on the fishery is local and mainly coastal, but fully evident.

In the open parts of Kattegat increased nutrient quantities may have been beneficial, especially for pelagic species. But the conditions may worsen and continuous watch must be kept on the situation in this sensitive and heavily exploited area.

Several indications that the coastal ecosystem is off balance have recently been presented (Rosenberg 1984). In the open sea, changes in the composition of the phytoplankton from a predominance of diatoms to flagellates have been observed (Vagn Hansen, pers. comm.). This may change the energy flow and have serious effects on the whole ecosystem.

To summarize, two major problems are apparent in the actual area: the threat of overfishing of some species, and the threat of pollution which may influence both fish and shellfish species directly and their food organisms. The interaction between these and/or other factors, such as changes caused by natural events, are not yet fully understood.

5. CONCLUSIONS ON MAN-MADE ECOLOCIAL EFFECTS

1) The input of nutrients (nitrogen and phosphorus) has been estimated to have increased several-fold to the Kattegat since the 1930's.

2) Significant increases in concentrations of total P and trends of increasing concentrations of inorganic N have been observed in the Kattegat. High concentrations of nutrients occur locally in some Skagerrak coastal areas.

3) Primary production has recently increased in some areas in the southern Kattegat and the Belts, but generally not in the open Kattegat (cf. Fig. 9). Accurate assessment of primary production over longer time periods is difficult, consequently temporal comparisons should be made with caution. The overall results point, however, towards increased primary production in some areas. High primary production has been recorded from some Skagerrak coastal areas.

4) Benthic animal communities have shown changes in composition and biomass during this century in the Kattegat and in some places in the Skagerrak. These changes suggest that large-scale changes have occurred in the Kattegat and perhaps in the Skagerrak. A decreased vertical distribution of several macroalgal communities has been observed in some Swedish coastal areas in the Skagerrak.

5) Catch statistics from the fisheries suggest that commercial species abundance fluctuate from time to time. These fluctuations are to a great extent due to fishery and recruitment success (year class stength). Effects of pollution have been observed in several coastal areas, and a recent mass mortality of Norway lobster in SE Kattegat is most probably connected to man-made inputs of nutrients ultimately resulting in oxygen deficiency.

6) Dinoflagellates have been recorded in high numbers in summer autumn in recent years in the area. The reason for this is unclear, but it could be a result of high nutrient concentrations in combination with specific hydrographic conditions. Some of the dinoflagellates are toxic and have killed fish and cultivated blue mussels as well as affected the marketability of mussels.

7) The main cause for the effects described above is most probably eutrophication of the Kattegat and some coastal areas of the Skagerrak. The effects of pollutants (e.g., heavy metals, organochlorines, radionuclides) are probably of minor importance except in local areas receiving waste discharges. Although certain changes due to altered climate have been observed, the effect of these climate changes alone is not considered significant.

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ANNEX 1

MEMBERS OF THE WORKING GROUP ON STUDIES RELATED TO POLLUTION RESEARCH IN THE SKAGERRAK-KATTEGAT AREA

The Group consisted of 9 members from Denmark, 8 from Sweden, 3 from Norway and 1 from the Federal Republic of Germany.

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ANNEX 2

TENTATIVE LIST OF TOXIC AND POTENTIALLY TOXIC SPECIES OF PLANKTON ALGAE IN THE SKAGERRAK-KATTEGAT AND ADJACENT WATERS

Species	Shellfish poisoning	Fish mortality
DINOFLAGELLATES		
Gonyaulax tamarensis	PSP	X
Gonyaulax catenella	PSP	
Gonyaulax spp.		
Dinophysis acuminata	DSP	
Dinophysis acuta	DSP	
Dinophysis norvegica	?	
Dinophysis fortii	DSP	
Dinophysis spp.		
Prorocentrum minimum	DSP	
Prorocentrum lima	DSP	
Prorocentrum balticum	?	
Prorocentrum micans	?	
Prorocentrum triestinum	?	
Prorocentrum spp.		
Gyrodinium aureolum		X
Gyrodinium breve	NSP	X
HAPTOPHYSEER		
Prymnesium parvum		X
YELLOW ALGAE		
Distephanus speculum		X
BLUEGREEN ALGAE		
Nodularia spumigena		

OOO

PSP = Paralytic shellfish poison

DSP = Diarrhoetic shellfish poison

NSP = Neurotoxic shellfish poison

ANNEX 3

RECOMMENDATIONS

1. There is evidence that the nutrient input to the area has increased over the last decades and also that the concentrations of nutrients have increased in the Kattegat and are locally elevated in some Skagerrak coastal areas. Several observations show that primary production has increased in some areas and others point towards large scale ecological changes in the Kattegat. There are also indications that the ecosystem, at least in some parts, is off-balance. It is therefore strongly recommended that immediate actions be taken towards reducing as far as possible the input of nutrients to the area.

2. It is evident that the scientific information especially on the open sea areas of the Kattegat and the Skagerrak is poor. As both these seas are of special interest, especially the Kattegat with its brackish surface water and halocline, more research is highly needed for the understanding of their ecosystem structure and function, and for the possibility to provide information to undertake the necessary precautions for their full conservation and, moreover, to be able to utilize their living resources in an ecologically sensible way. Among the most evident research needs, the following are proposed:

   a) In order to monitor the environmental changes and for an understanding of long-term natural fluctuations, long-term studies should be continued and implemented of, e.g. hard bottom algae and animals, soft bottom fauna, phytoplankton species composition and production.

   b) The pelagic system is insufficiently understood. Investigation of zooplankton (micro- and macroplankton including coelenterates) composition and its role in the ecosystem needs to be intensified in these open waters. The causes for the recently observed high numbers of dinoflagellates need to be investigated as well as the factors making some of these species toxic.

   c) Fishery investigations should be directed towards more ecologically orientated investigations and include the whole life cycle. Knowledge of the effects of the fishery on the various species as well as the effect of the rest of the ecosystem on the fishes is urgently needed in order to give accurate multispecies management advice.

   Regarding Norway lobster, immediate investigations of their population structure and recruitment processes should be started as the stock can be endangered due to overfishing and oxygen deficiency in some areas.

   d) It is of utmost importance that investigations should preferably be orientated towards functional aspects of the ecosystem. Cooperation between physical oceanographers and biologists is requisit. The cycling of nutrients, especi-

ally nitrogen, in the ecosystem is of special importance in this respect.

e) For rational investigation of the areas in the future it should be profitable to establish closer relationship between scientists and institutions bordering the Kattegat and Skagerrak. Joint expeditions on the research vessels should be implemented. The present Kattegat monitoring programme probably being well coordinated between Denmark and Sweden, it is recommended that efforts should be made to increase the measuring frequency in the present programmes and enlarge the scientific approach.

f) There is obviously a need for further organisation of both the ongoing and future studies in the Skagerrak and the Kattegat. Whoever takes the responsibility for the ongoing and future studies in the area, there is a need for cooperation concerning data acquisition, data banking, symposia, new techniques, etc. In order to obtain satisfactory collaboration, it is recommended that there should be created a permanent Skagerrak/Kattegat group, with members from Denmark, Norway and Sweden consisting of scientists actively working in the area, to coordinate studies in the area with both monitoring and scientific aspects. The group should be affiliated to ICES.

g) Special international programmes are occasionally organized to increase knowledge of an area and/or a specific problem. It is felt that investigations in the Skagerrak/Kattegat should be given higher priority.

It is recommended that the new group should consider whether it would be advantageous to organize a special scientific programme in Skagerrak/Kattegat within a 5-year period.

Finding the Skagerrak/Kattegat symposium in Göteborg 1976, at Lysebu 1980 and in Göteborg 1983 very stimulating, it is recommended that the new group consider a new symposium in 1987.

h) It is strongly recommended that the Assessment of the Environmental Conditions in the Skagerrak and the Kattegat be published in a Cooperative Research Report.

Indication of spine colours

Reports of the Advisory Committee on Fishery Management	Red
Reports of the Advisory Committee on Marine Pollution	Yellow
Fish Assessment Reports	Grey
Pollution Studies	Green
Others	Black

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