Odsmäl Kville sn, Bohuslän

Hällristning
Fiskare från
bronsåldern

Rock carving
Bronze age
fishermen

MEDDELANDE från
HAVSFISKELABORATORIET • LYSEKIL

nr 94

Hydrografiska avdelningen, Göteborg.

On Eutrophication and Pollution of Marine Areas

(Invited lecture at "The Ocean World" joint oceanographic Assembly 13-25 September 1970 in Tokyo)

by
Stig H. Fonselius

November 1970

On Eutrophication and Pollution of Marine Areas

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The pollution problem in the marine environment grows more and more serious in the whole world. A few months ago the famous Norwegian scientist Tor Heyerdal reported that during his voyage with the papyrus boat "Ra II" from Marocco to Barbados, he observed large amounts of all kind of garbage and oil lumps floating on the sea surface around the ship. Some days the whole sea surface was covered, so that it was almost impossible to dip a tooth brush in the water without getting it contaminated. Paper and cellulose rests, probably originating from hygienic tissues were floating all around the ship.

Such a large scale contamination of the open sea is a serious warning to all of us that there are limit for how much the ocean can stand without damage to biological life.

Fig. 1 shows a map of the most contaminated areas of the world ocean published in FAO:s journal "Ceres" by Waldichuk and Andrén. The contaminated areas are exagerated on the map in order to make them better visible, but we can, however, see that some semienclosed bays the large shipping routes and the large permanent surface current areas are worst contaminated. It can also be seen that Heyerdal sailed along a severely contaminated route.

On the map the Baltic is shown to be the worst contaminated sea area in the world. Because I happen to work in that area, it is natural that I mostly will refer to the conditions in the Baltic area in my talk.

It has been estimated that some 20 million passengers every year travel by ship across the Öresund between Sweden and Denmark. During the summer season some 500 passenger ships cruise in the Baltic area. This traffic yields between 250 to 400 m^3 of garbage every day. Most of it is dumped in the sea. The regular ferry routes claim that dumping from the ferries is forbidden, but I have personally seen it happen several times.

The garbage dumping causes difficulties for fishing trawlers, which are reluctant to cross ferry routes when trawling because of the risk to get the trawl clogges up with empty bottles, beer cans, paper and plastic items.

Areas with stagnant or partly stagnant conditions are especially sensitive to pollution due to the slow water exchange. Such areas have generally a positive water balance, which causes formation of a light surface water layer which isolates the heavier deep water from contact with the atmosphere. A shallow sill at the entrance to such a basin restricts the horisontal water exchange. Examples are fiords in Norway, Greenland, Canada, the Black Sea, the Baltic etc. Stagnant basins act as nutrient traps. Nutrients are removed from the surface water through uptake by microorganisms. When these organisms die they or parts of them sink through the halocline into the deep water. Through bacterial oxidation processes the nutrients of these organisms are transformed back into inorganic form and are dissolved in the water. Due to the slow water exchange through the halocline large amounts of nutrient salts are accumulated in the deep water of the basin. In spite of this high nutrient concentration in the deep water, the surface water may be on the starving limit regarding nutrient salts. Fig. 2 shows the vertical distribution of total P, inorg. P and org. P in the Baltic. This distribution is typical for stagnant basins (Fonselius 1969).

There is of course always a certain exchange of water through the halocline and therefore nutrient rich water is mixed up into the surface water. This amount is, however, small. If the nutrient concentration of the deep water is increased, the amount of nutrients brought up into the surface water will also increase. Especially if the deep water is regularily or occasionally renewed through inflows of new heavy salt water over the entrance sill, large amounts of nutrients will be mixed up into the surface water "fertilizing" it.

The discharge of organic wastes from communities and industries will cause an oxygen reduction process in the water. Oxygen is utilized for oxidation of the organic matter and nutrients bound in the matter will be released. This process will cause an increase of the primary plankton production in the area. This again will increase the oxygen utilization. A secondary oxygen reduction process will begin, where the new organic matter is oxidized. This secondary oxygen reduction may require 2 to 5 times more oxygen than the primary process. This secondary process is not accounted for in the conventional BOD techniques.

In coastal areas with restricted water exchange e.g. in archipelagos, gulfs and bays this discharge may cause eutrophication of the water. The primary production increases until the light penetration limits it. A thick layer of green algae is formed along the shores and in the surface water. Everybody who has had an aquarium has certainly experienced this. Signs of such an eutrophication can be observed in the Baltic area around all large cities, especially around Stockholm and Helsinki with their large archipelagos. Many fresh water lakes in industrial areas show signs of eutrophication e.g. the Boden See in Central Europe, Mälaren, Vänern and Vättern in

Sweden, Baikal in the USSR and the Great Lakes in the USA.

In sea areas with a low nutrient content a release of organic wastes may cause eutrophication of the surface water in the whole area. The increased biological production may be beneficial to the surface water by increasing the fish yield, but it can have serious effects on the conditions in the deep water. The increased amount of decaying organic matter may there lead to total oxygen deficiency. Hydrogen sulfide will be formed and the area will then be transformed into a dead oceanic desert. The bottom fauna will be completely destroyed. When hydrogen sulfide is formed, the environment changes from oxidizing to reducing. During reducing conditions nutrient salts will be dissolved from the bottom sediments, increasing the high nutrient concentration of the stagnant water still more.

If the nutrient content of the deep water in a stagnant area has been increased e.g. through dissolution of nutrients from the bottom sediments, a "fertilization" of the surface water through a renewal of the deep water may cause an enormous plankton bloom. This may start an "evil circle" of fertilizations. During every fertilization large amounts of organic matter are produced. Therefore more organic matter is brought down into the deep water. The oxygen there will fast be utilized, hydrogen sulfide will again be formed and more nutrients will be released from the sediments. The next renewal will again cause a large plankton bloom, producing new organic matter which will sink down into the deep water etc. It seems to be very difficult for Nature to restore oxidizing conditions when such a fertilization cycle has started.

The Baltic is an example of such a partly stagnant basin. Its surface water has a very low nutrient content and large amounts of nutrients are accumulated in the deep water. Phosphorus is considered to be the limiting nutrient for the primary production in the Baltic. As long as oxygen measurements have been carried out the deep water has had a low oxygen concentration. Hydrogen sulfide formation has occasionally occured in some isolated deep areas. The long series of oxygen measurements carried out since the 1890:s (fig 3) on the international deep stations show that the oxygen concentration of the deep water during the present century has decreased from about 3 ml/l to values close to zero. Hydrogen sulfide has several times appeared in the bottom water of the central basin. Every time larger areas have been poisoned. The last stagnation period produced hydrogen sulfide in the whole deep area of the Baltic proper. The deep water was renewed in 1969 and all hydrogen sulfide had disappeared in the winter 1969-1970. Recent measurements show, however, that the oxygen values are again fast decreasing and that hydrogen sulfide formation has again begun in the northern parts of the central basin (fig. 4).

It is known from sediment cores that stagnation periods have occured earlier in the geological history of the Baltic. It is also known that natural factors as e.g. increased salinity and temperature may have diminished the water exchange and increased the oxygen utilization, but it is quite obvious that the enormous load of urban and industrial waste water, discharged into the Baltic, has enforced the oxygen utilization.

An international working group established by the ICES has published a report on the pollution of the Baltic. In that report it is estimated that organic matter equal to a biological oxygen demand (BOD_5) of 1.2 million tons per year is discharged into the Baltic by industries and in sewage water. The basic assumption was that the organic load of discharged sewage is equivalent to 25 kg O_2 /person/year. Fig. 5 shows some results of the report. It was agreed that BOD_5 values is not a good way to express oxygen demand, but that it was difficult to find a generally acceptable better way to express it. Swedish investigations have actually shown that BOD_5 is only about 1/3 of the total BOD, being lower for industrial wastes and higher for e.g. ensilage juice from silo machineries in agriculture. When multiplying the BOD_5 value 1.2 million tons by 3 and considering that the total volume of the Baltic is about 22,000 km^3 we get a total BOD of 0.45 mg O_2/m^3/day. The oxidation of this material causes as I mentioned earlier a secondary oxygen demand which is 2 to 5 times the primary demand. Therefore the actual oxygen demand caused by this waste discharge may be 1 to 2 mg O_2/m^3/day. This is true only if the wastes were evenly distributed in the whole water mass. All waste discharge is made at the shores and therefore the actual oxygen demand in the neighborhood of large cities and industries may be several times higher.

The working group also estimated that about 14,000 tons of phosphorus are annually discharged into the Baltic, most of it originating from sewage water. The basic assumption was that sewage water contains 1 kg P/person/year. Swedish investigations have shown that the phosphorus concentration in sewage water has increased from 1.5 g/person/day to more than 4 g/person/day during the last 15 years. This phosphorus increase originates mainly from the increasing use of synthetic detergents in households and laundries. Several of the most popular washing powders contain more than 30 % phosphate. Fig.6.

Most of this phosphate is certainly removed from the water through bilogical filtering in shallow water close to the discharge area, but there is, however evidence that the phosphate concentration has increased in the Baltic during the last 15 years, both in the surface water and the deep water. Fig. 7 shows the phosphate increase in the surface water. All phosphate measurements carried out in the central Baltic between 0 and 10 m from 1951 to 1970 are plotted in the figure. It can be seen that the phophate values due to the biological production every summer decrease down to values close to zero, but that there is a clear tendency for the surface values to increase from year to year. Several "fertilizations" of the surface water can be seen in the figure.

Fig. 8 shows the phosphate increase in the deep water from 1954 to 1970. The tendency is here much clearer due to the absence of primary production. The hydrogen sulfide formation causes dissolution of phosphate from the sediments but there must of course be an increasing supply of phosphorus from the surface water in order to supply phosphates to the sediments during oxidation periods. The increasing fertilization of the surface water increases primary production there and also the oxygen utilization in the deep water. Fig. 9 shows the alternating oxygen and hydrogen sulfide periods in the central Baltic (Fonselius and Rattanasen 1970).

This increase of the phosphorus is better understood if it is considered that the residence time of the water in the Baltic as an average is 24 years. The actual exchange rate is of course faster in the surface water and slower in the deep water and such a value is a very rough simplification. One third of the water flowing out from the Baltic returns with the inflowing deep water. Therefore only about 2.85 % of e.g. a tracer will annually be removed from the Baltic. This means that an accumulation of 35 times the annually discharged amount will occur. Such an accumulation may happen only if an ideal tracer is used which does not decompose, sediment or participate in the biological life cycle.

Ordinary sewage waste will therefore not accumulate in such a degree, but there are some compounds which are only slowly decomposed e.g. pesticides as DDT and some industrial products as PCB (poly-chlorinated biphenyles) which is used in paints, transformer oils etc. PCB is almost understructible and a Swedish investigation has shown that DDT and PCB accumulate in marine organisms and that the concentration in marine species from the Baltic may contain up to 100 times more of these products than species from the Swedish west coast or the North Sea. Fig. 10 shows some of these results, from a work by Jensen, Johnels, Olsson and Otterlind. The concentrations are expressed as mg/kg fatty tissues. Analyses of tissues of marine organisms, e.g. mussels, herring, plaice, picked dogfish, cod, salmon, grey seal, ringed seal, guillemot, white tailed eagle and heron have shown that organisms from the Baltic contain about 8-10 times higher concentrations of PCB and DDT than organisms from the Swedish west coast (Kattegat) or from England or Canada. The eagles (all found dead) contained 100 times higher concentrations of these compounds than eagles catched in Northern Sweden (Lappland). These latter eagles generally build their nests at the Norwegian north coast at the Atlantic. The investigation in the Baltic shows that the concentration of DDT and PCB increases in the food chain so that the animals on the top of it have the highest concentrations. Since many of the investigated animals were caught in the open sea, there must be a transport of pesticides and other toxic substances from land to the open sea. The concentration of chlorinated hydrocarbons seems to be 10 times higher in the Baltic than in the Kattegat and Skagerrak. The reason for this is obviously the restricted water exchange in the Baltic.

DDT is probably the most used pesticide in the world. Many investigations have shown the dangers of the use of DDT in large amounts. DDT is found in the air and DDT has been reported in fatty tissues of pingvins in the Antarctic, far away from all DDT sources. The thin surface film on natural waters consists mainly of fats and fatty decomposition products from dead plankton organisms. DDT dissolves in this film and is therefore enriched there. Through wave action and turbulence it is spred downwards in the water. It may affect primary production by inhibiting the assimilation process of phytoplankton. Phytoplankton is one of the first links in the food chain in the sea and the annihilation or even a considerable decrease of phytoplankton in the sea may have very serious effects on marine life and may ultimately be a danger for Mankind by decreasing the amount of food in the oceans.

Much of the mercury found in marine environment is spred with the air. Mercury is brought to the air with smoke and fumes from factories and by burning of paper in garbage destruction plats. Mercury may also be added to the water through direct discharge from factories, e.g. paper and pulp industry, chlor-alkali plants, tooth clinics and through leaking out from soil in agricultural areas where mercury compounds are used as seed disinfectants. In the paper and pulp industry and in agriculture organic mercury compounds are used. The pulp industry in Sweden has recently replaced marcury compounds used as slimecides and fungicides with another, unfortunately very poisonous compound, penta-chlor-phenol.

Metallic mercury has generally a low toxicity as has also the inorganic mercury ion, if used inlow concentrations. Mercury ions and fumes may cause mercury poisoning, which injures skin and mucous membranes and may accumulate in the kidneys injuring these. Inorganic mercury compounds are, however, removed from the body by help of the kidneys and the victim recovers if the exposure ceases.

Organic mercury compounds are considerable more dangerous. Organic mercury is accumulated in the body and attacks the nerve system. The organic part of the molecule, to which the mercury is attached, makes it easily soluble in fats. Therefore it may dissolve in the thin fat layer surrounding the nerve cords. When symptoms of poisoning by organic mercury compounds are observed there is no recovery and severe cases may lead to death as happened in Japan some years ago.

There seems to be large differences in the toxicity of organic mercury compounds. The most dangerous compounds are the alkyl mercury compounds, e.g. methyl-mercury-dicyan-diamine. It is believed that less poisonous organic mercury compounds may be transferred into alkyl-mercury compounds e.g. in the bottom sediments.

No fatal case of mercury poisoning, caused by high mercury content of fish or meat is known to have happened in Sweden. It has, however, been found that fish from certain areas along the Swedish coast and especially from inland waters may contain up to 5 mg mercury/kg fish meat. It has also been found that mercury concentrates in the food chain so that the animals on the top of it have the highest concentrations. The high concentrations seem to be locally restricted and e.g. cod catched in the open Baltic has according to german investigations a normal mercury concentration. Fig. 11.

In the most contamined areas commercial fishing is now probihited. An economically damaging effect for the fishermen is the panic such reports raise through TV, radio and newspaper. In Sweden fishermen have encountered difficulties to sell uncontaminated fish catched in the open sea far away from contaminated areas. During the first months after the publishing of the prohibitions the fish market in Gothenburg decreased by more then 20 %. Most of the fish marketed in Gothenburg is catched far out in the Skagerrak and the North Sea. The customers did obviously not know the difference between salt water fish and fresh water fish.

The size of oil tankers has increased enormously during the last years. In the Baltic the 17 m deep entrance sill at Darss puts an upper limit of some 120,000 tons to the size of the tankers. The controll of such large ships is rigorous in the Baltic and there is no risk for oil dumping from them. Accidents may, however, happen. The handling of such ships in narrow waters is difficult and the North Sea and the Baltic are not free from mines outside the narrow swept channels. If a full loaded tanker of 100,000 tons is blown up in the Baltic, enormous damage may be caused to marine life and beaches.

Oil dumping from smaller ships, e.g. small tankers, cargo ships and trawlers occurs almost daily and even if the dumped amount may be small, the total amount may be considerable and is certainly a heavier treat to marine life and beaches. Almost every week drifting oil belts are reported in the Baltic and in Kattegat. Most of these originate from illegal flushing of tanks in the open sea. In 1968 125 discharges of oil from ships are known to have occured in coastal areas of Sweden.

The situation is especially serious in the Baltic with its slow water exchange. Some countries in the Baltic area have a shortage of fresh water and plans are made to distill or dialyze Baltic sea water which is especially suitable for such puposes due to its low salinity. If the water is contaminated by oil, difficulties may arise in preparation of drinking water.

The effect of oil on marine life has earlier not been considered to be serious except in the case of sea birds. These can not survive even a light contamination. The formation of an oil film on the sea surface may enhance gas exchange between air and sea and may effect plankton. Marine algae have been shown to be very sensitive to oil and oil products according to an investigation by Mirnov and Lanskaya (1966). It was found that algae died and that retardation in cell division occured. Developing eggs of Rhombus maeoticus were found to be very sensitive to oil derivates. Fish flesh may be tainted by oil products. According to Kühnold (1969) fertilized cod and herring eggs are seriously influenced by crude oil in the water.

The most serious damage by oil accidents is caused by the solvent detergents used for destruction or sinking of the oil. The oil compound may sink to the bottom and destroy fishing grounds and eventually it will float up to the surface again. The solvent part of the detergent may destroy marine life. Only mechanical methods should be used to remove the oil from sea surface, but considering the heavy damage of crude oil on beaches, most authorities prefer the use of detergents.

Oil films are broken down through wave action and they are also attacked by bacteria. Thick oil lumps are formed, which float on the surface. Such black lumps are difficult to remove from beaches and also from clothes and skin.

Oil may be harmful to phytoplankton and therefore there is a risk that the increasing oil contamination of the sea may lead to same kinds of effects as was mentioned in the case of DDT.

The Baltic, as all seas has been polluted by radioactive fallout. Radioactive wastes have been dumped there, but nowadays the control is rigorous. The construction of nuclear power plants going on or planned in the Baltic area will cause the release of small additional amounts of radioactive matter. Control measures will, of course, be very stringent but it has to be remembered that leakages may accidentally occur even if authorities do not admit to such possibilities. Nuclear ships, both submarines and surface vessels may be a potential danger. If a large leakage occurs in the Baltic, marine life may be demaged for several decades. Pollution by cooling water from nuclear power plants or from power plants using fossil fuels may cause unpredictable damages, e.g. by increasing the oxidation rate of organic matter which may cause oxygen deficiency.

There has been a lot of discussion in the newspapers about the recent dumping of nerve gas containers into the deep water of the Atlantic. In the Baltic area the danger of dumped war gases is a reality. The dumping has occured in relatively shallow water (maximum 100 m) and therefore this material is a serious treat to fishermen and also to people bathing in the sea or children playing on the beaches.

Dumping of german war material including phosphorus bombs and war gases was carried out on several places in the southern Baltic area in 1946-47 under the supervision of the allied occupation forces. Several accidents with mustard gas happened during the years after these dumpings but the whole matter was almost forgotten until recently when several new accidents happened. Polish, german, danish and swedish fishermen have been reported to have been injured by mustard gas from corroded gas containers catched in their trawls. Recently the newspapers told about a small boy who got severely burned by some liquid, probably mustard gas, when playing with sea weed on the beach.

Mustard gas should according to experts be destroyed in few hours when in contact with water. Mustard gas is, however, a heavy liquid, not soluble in water. It is quite obvious that the oxidation of a big lump of such a heavy insoluble liquid will take much longer time. It is now believed that the gas, produced during this oxidation, may lift the container to the surface and that it in that manner may drift into shallow water.

Recently there has been discussions on the possibility to remove the old war material from the dumping areas and destroy it. Unfortunately it seems to be very difficult to get exact informations about the dumping areas. The responsible authorities are reluctant to admit the dumping and because it happened long time ago it is difficult to trace the participants in the work. Most of them are not in service any more and many are dead. Nobody seems to know exactly the places where the dumping occured, how much was dumped or what kind of material it was. The removal of these containers will certainly not be an easy task. Extensive research is necessary in order to know the effects of war gases in the water. One has e.g. to know the maximum concentrations for under water work etc.

The pollution of air and water has during recent years grown so serious that it has alarmed scientists over the whole world. The goverments in the worst contaminated areas have begun to try to stop or limit the pollution. Steps by single nations is not sufficient in the present situation. It is now necessary to take up the problem, which concerns all of us on an international level, e.g. in the United Nations. We need international pollution laws and an international control of the pollution before it is too late.

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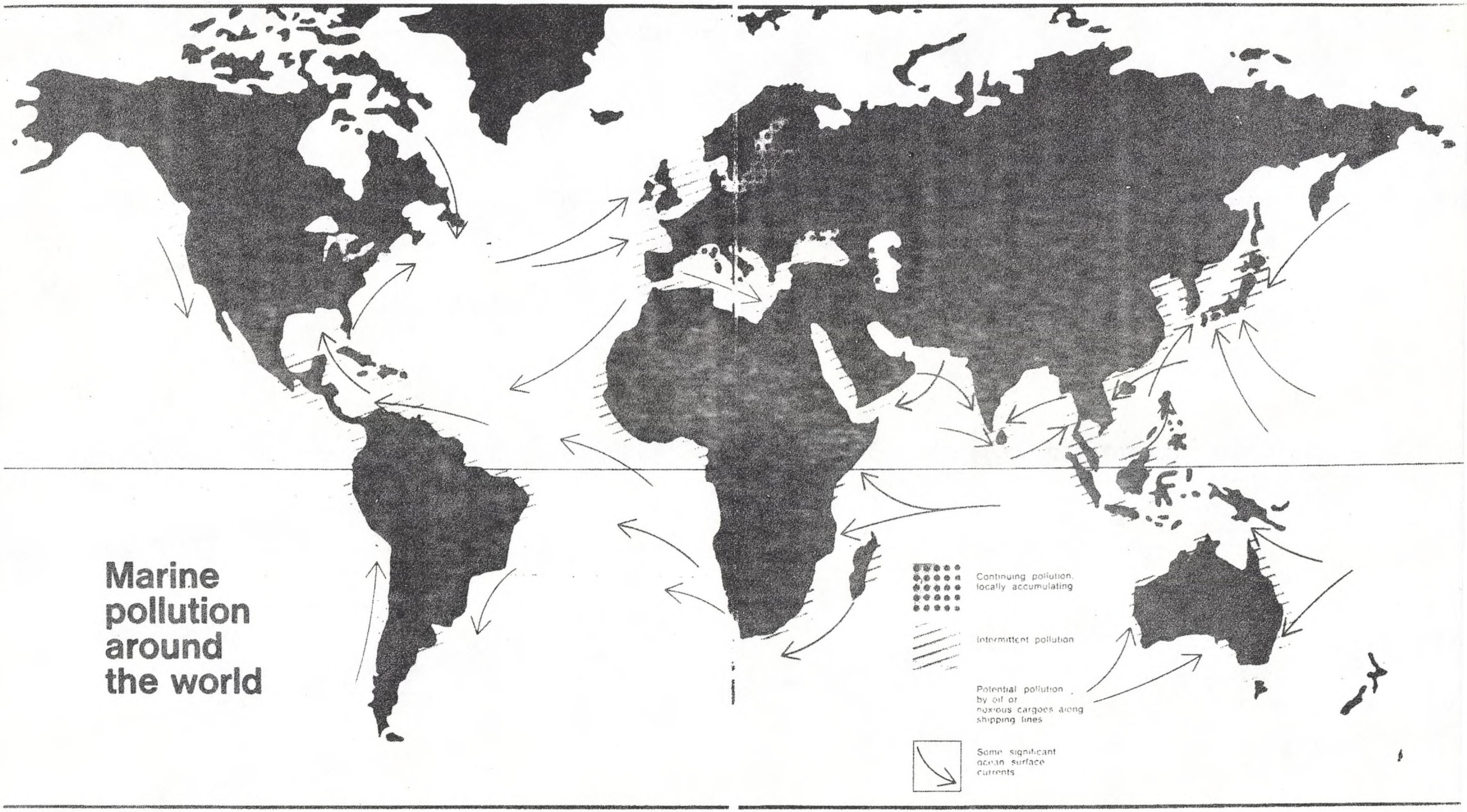

Marine pollution around the world
Continuing pollution, locally accumulating
Intermittent pollution
Potential pollution by oil or noxious cargoes along shipping lines
Some significant ocean surface currents

Fig. 1

Fig. 2

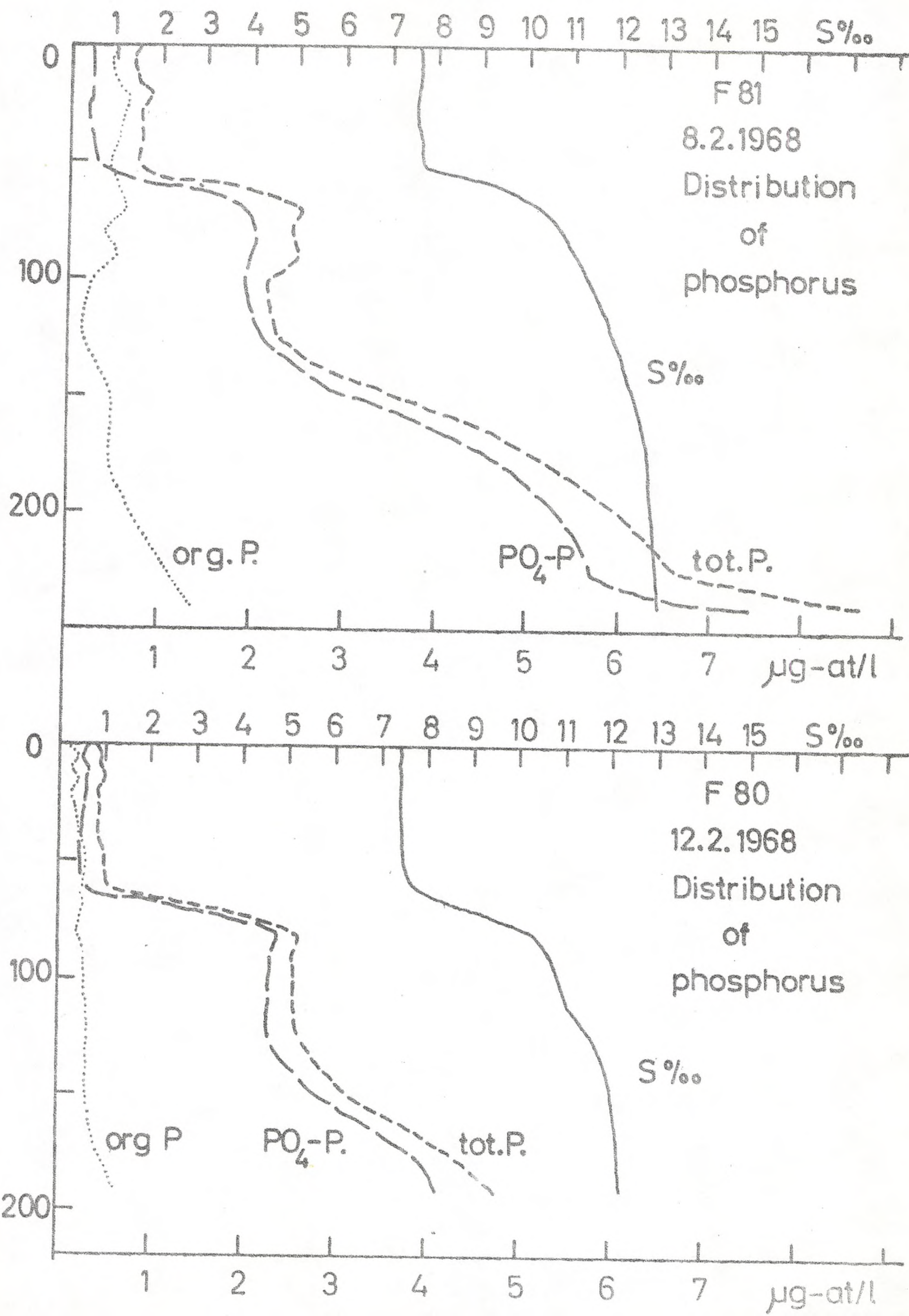

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 S‰
0
100
200
F 81
8.2.1968
Distribution
of
phosphorus
S‰
org. P.
PO_4-P
tot. P.
1 2 3 4 5 6 7 µg-at/l
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 S‰
0
100
200
F 80
12.2.1968
Distribution
of
phosphorus
S‰
org P
PO_4-P.
tot. P.
1 2 3 4 5 6 7 µg-at/l

Fig. 3

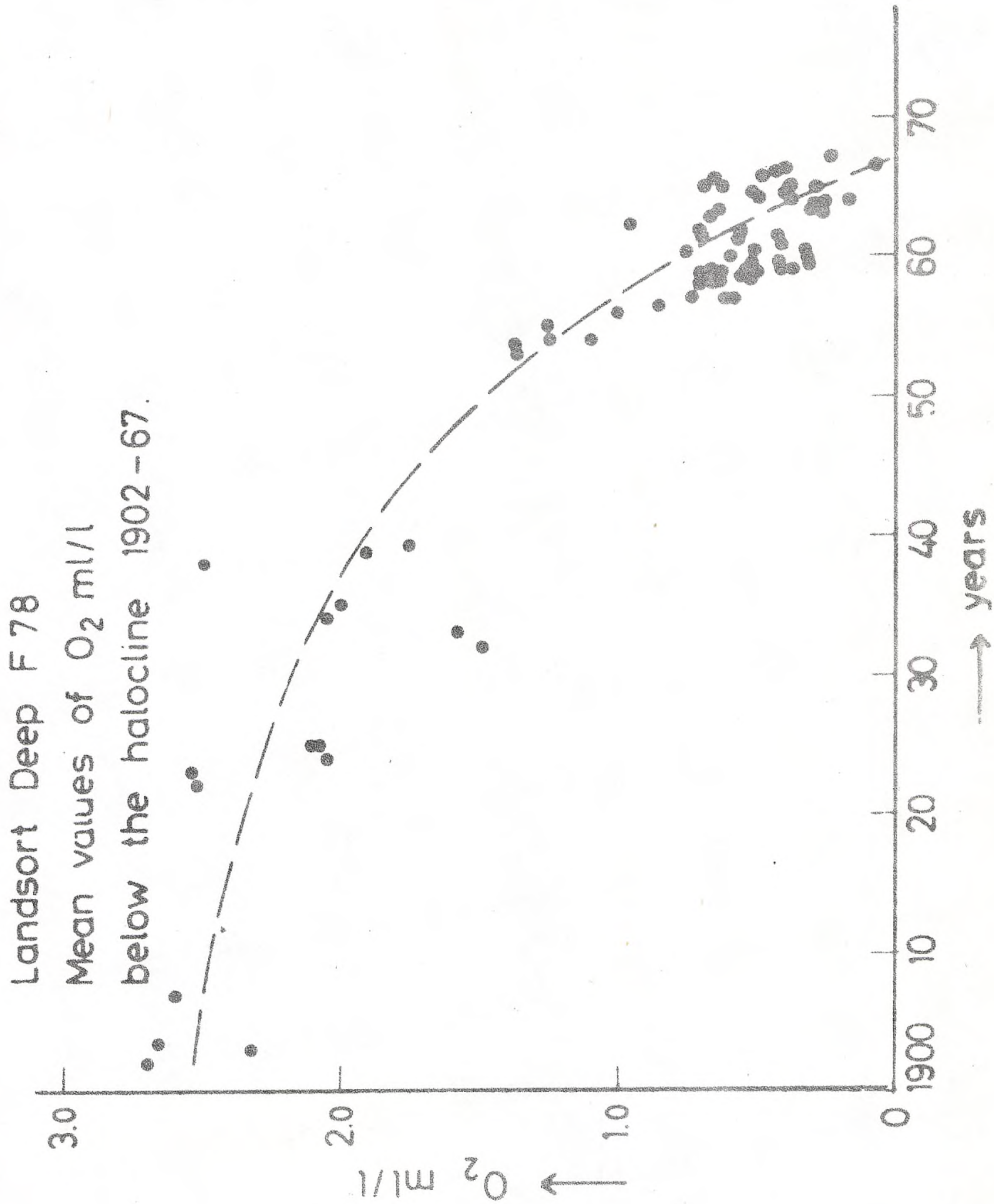
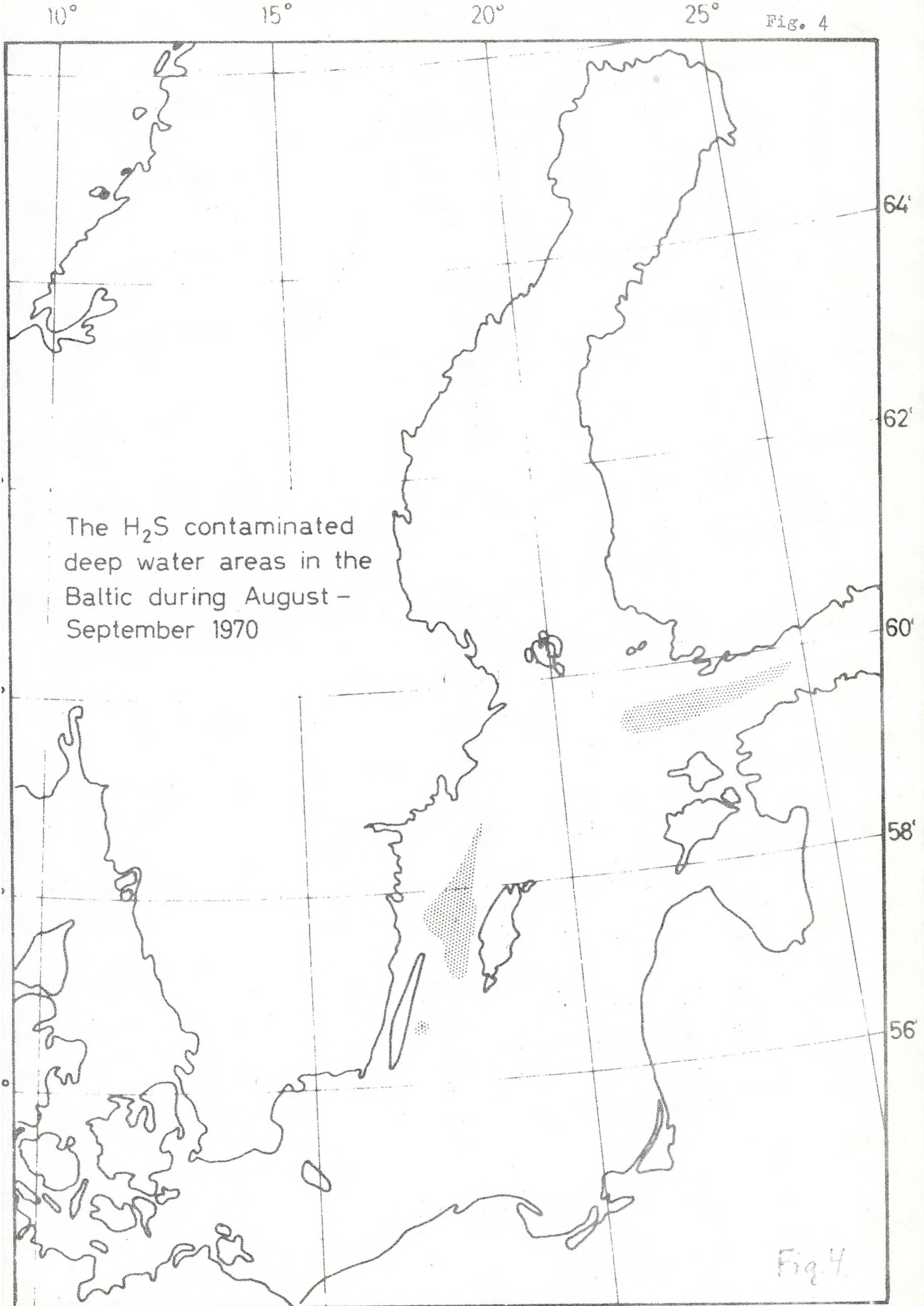

Landsort Deep F 78
Mean values of O_2 ml/l
below the halocline 1902 - 67.
3.0
2.0
1.0
0
O_2 ml/l
1900
10
20
30
40
50
60
70
years

Fig. 4


10°
15°
20°
25°
64°
62°
60°
58°
56°
The H_2S contaminated deep water areas in the Baltic during August - September 1970
Fig. 4

Dybern et al.
ICES, Coop. Res.
Rep. Ser. A. No 15.

Waste discharge expressed as BOD_5 in different areas of the Baltic. Some figures rounded off.

Area	Millions inhabitants		Sewage discharge BOD_5 tons/year		Industrial discharge BOD_5 tons/year	BOD_5 tons/year totally for every area (approxim.)
	Direct.	Indirect	Direct.	Indirect	Direct.+Indirect.	
Bothnian Bay	0.230	0.167	5,600	4,500	159,000	169,000
Bothnian Sea	0.565	0.495	13,600	12,200	384,000	410,000
Gulf of Finland	4.868	0.797	121,400	19,200	115,000	256,000
Baltic proper	3.335	2.065	60,900	30,000	~110,000	~ 200,000
Baltic Sea	8.998	3.524	201,500	65,900	~760,000	~ 1,025,000
Belt Sea	1.195	2.600	40,100	21,000	< 10,000	70,000
Öresund	1.770	0.310	40,600	2,600	< 10,000	53,000
Kattegat	0.625	0.360	16,000	5,000	~ 25,000	46,000
Totally	12.588	6.794	298,200	94,500	~800,000	~ 1,200,000

Wastes from sewage and industry discharges expressed as tons of BOD_5/year

Area	Denmark	Finland	Poland	USSR	Sweden	FRG	GDR
Bothnian Bay		148,000			21,000		
Bothnian Sea		50,000			361,000		
Gulf of Finland		83,000		170,000			
Baltic proper	> 2,000		10,000	96,000	79,000		>10,000
Baltic Sea	> 2,000	281,000	10,000	266,000	461,000		>10,000
Belt Sea	> 45,000					10,000	>10,000
Öresund	> 40,000				6,000		
Kattegat	> 6,000				37,000		
Totally	> 93,000	281,000	10,000	266,000	503,000	10,000	>20,000

Fig. 6

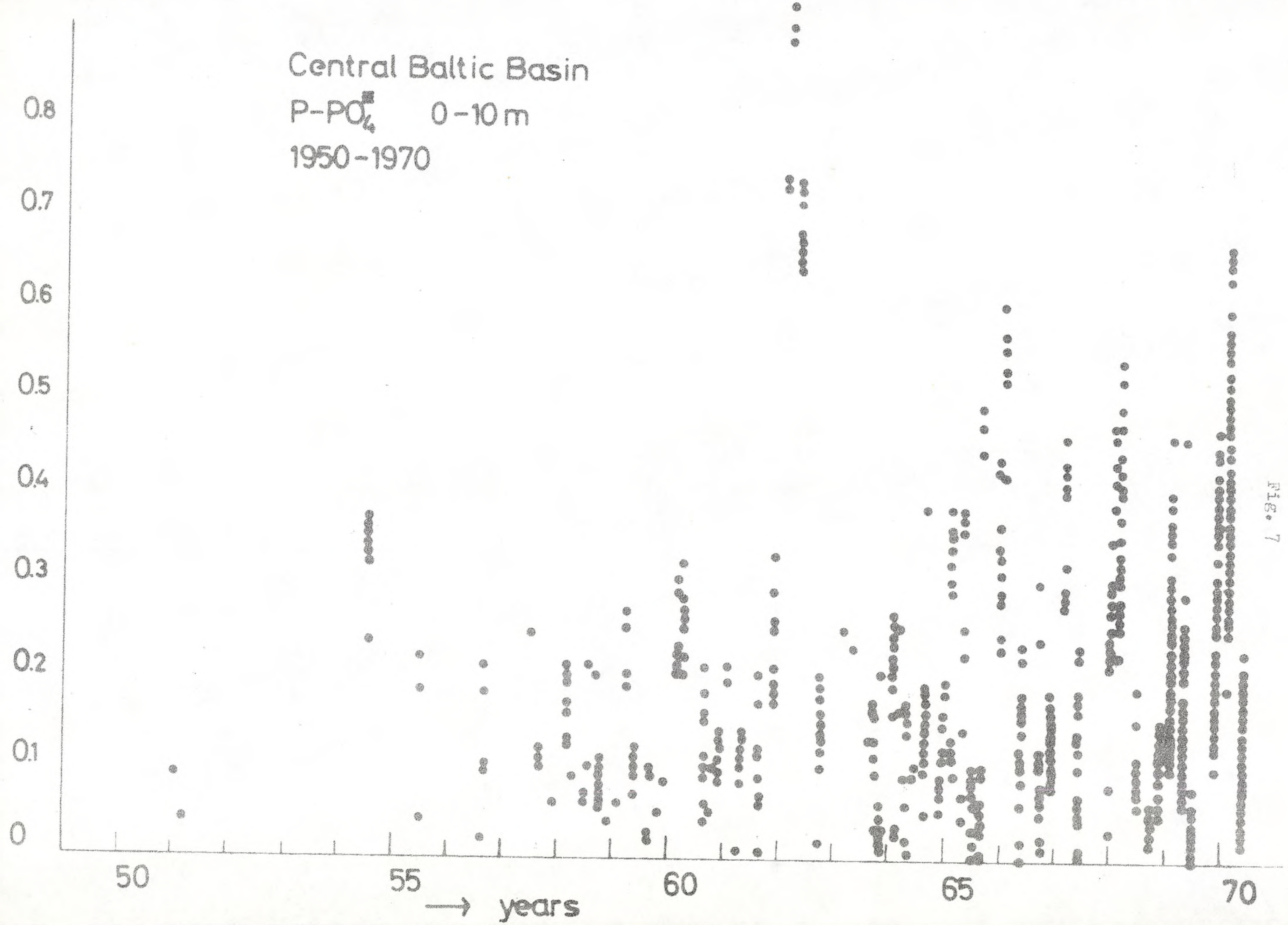
Estimated amount of phosphorus in discharged wastes
Tons P/year

Area	Direct.	Indirect.	Totally
Bothnian Bay	290	220	510
Bothnian Sea	780	600	1,380
Gulf of Finland	5,050	870	5,920
Baltic proper	3,880	2,370	6,250
Baltic Sea	10,000	4,060	14,060
Belt Sea	1,240	2,800	4,040
Öresund	1,960	350	2,310
Kattegat	890	400	1,290
Totally	14,090	7,610	21,700

Estimated amount of phosphorus discharged in wastes by different countries. Tons P/year

Area	Finland	USSR	Sweden	Others
Bothnian Bay	280		230	
Bothnian Sea	800		580	
Gulf of Finland	1,470	4,550		
Baltic proper		1,840	2,700	1,700
Totally	2,550	6,390	3,510	1,700

Fig. 7



Central Baltic Basin
P-PO4 0-10 m
1950-1970
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50
55
60
65
70
→ years

Fig. 8

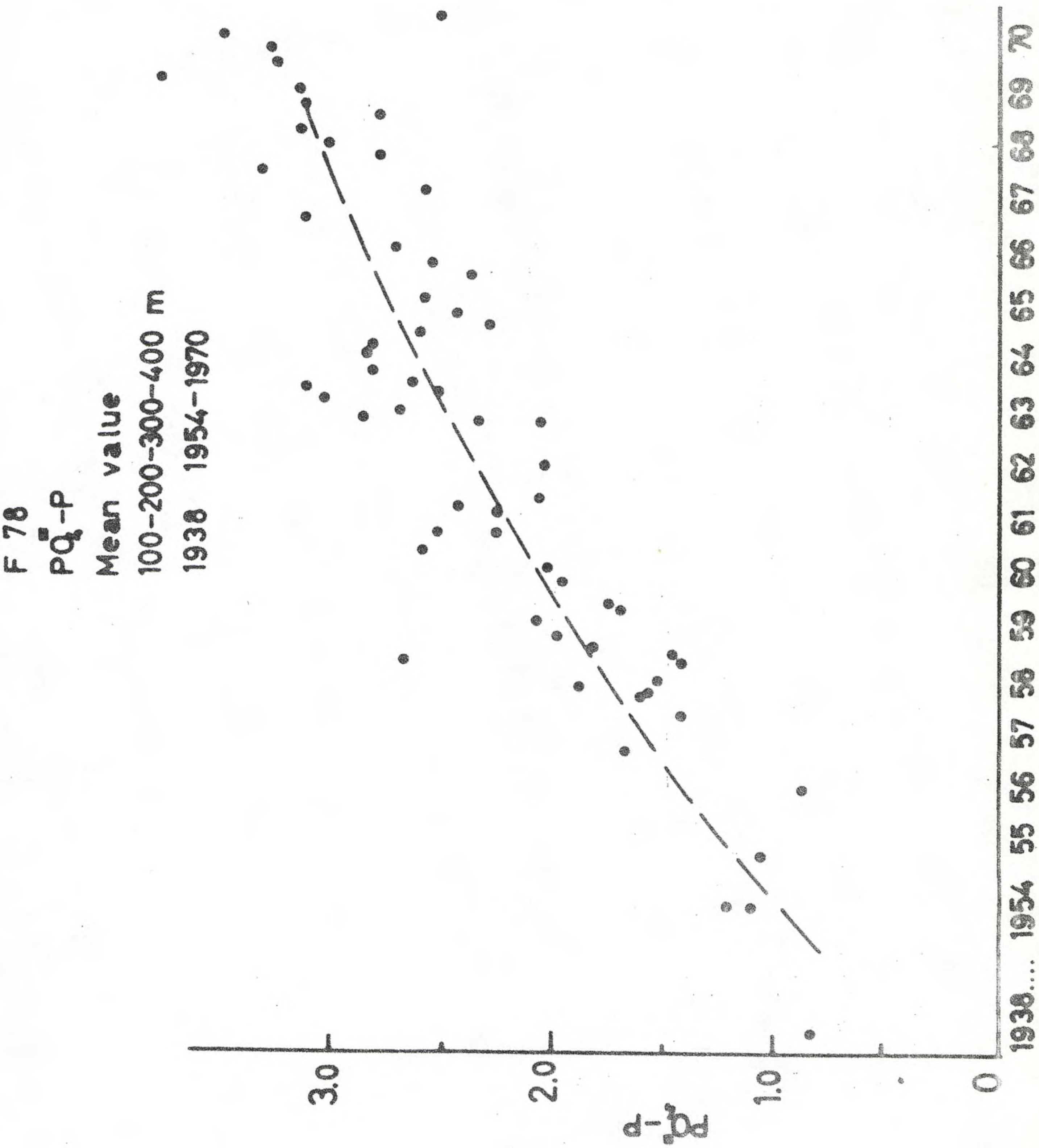
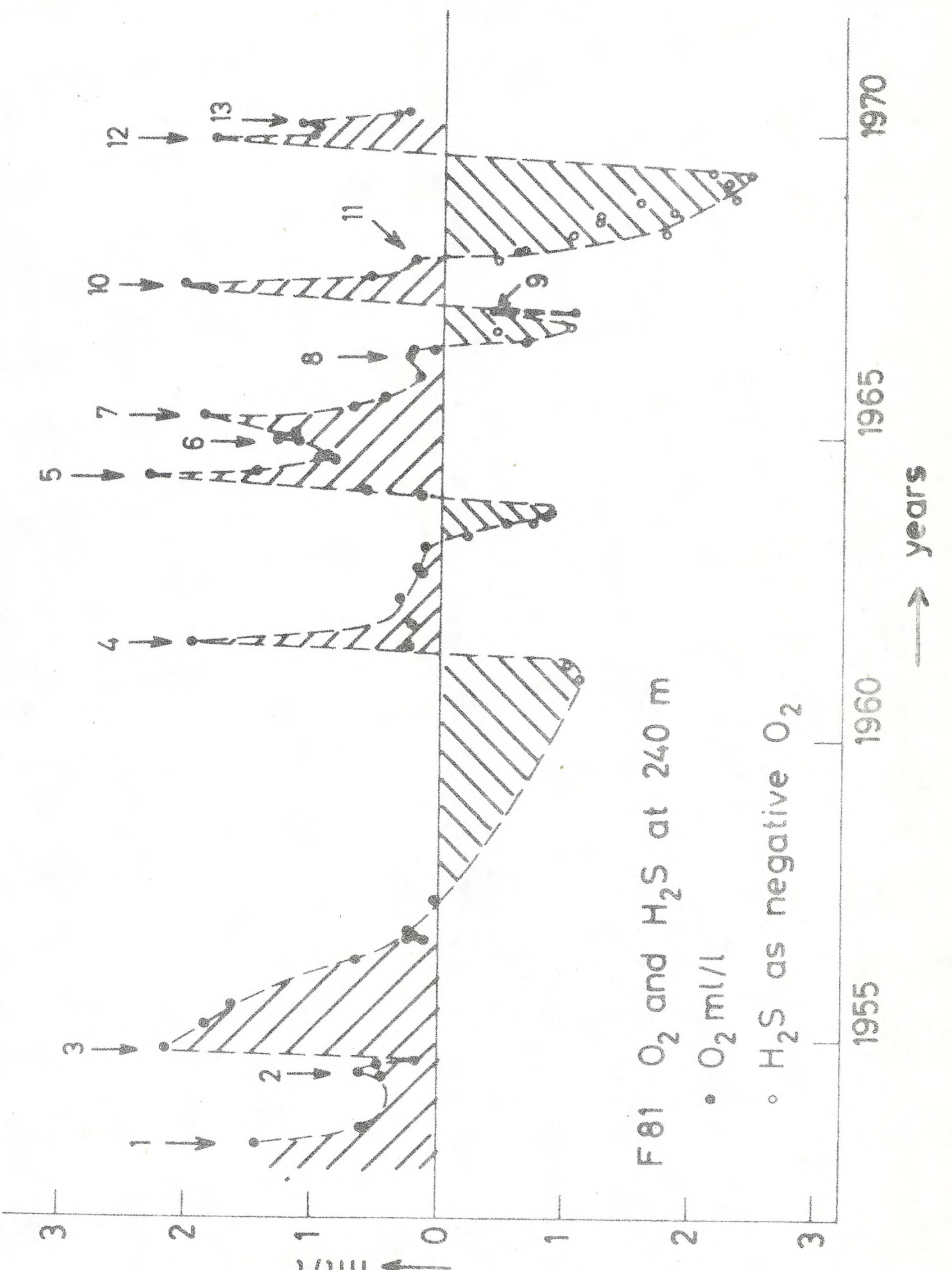
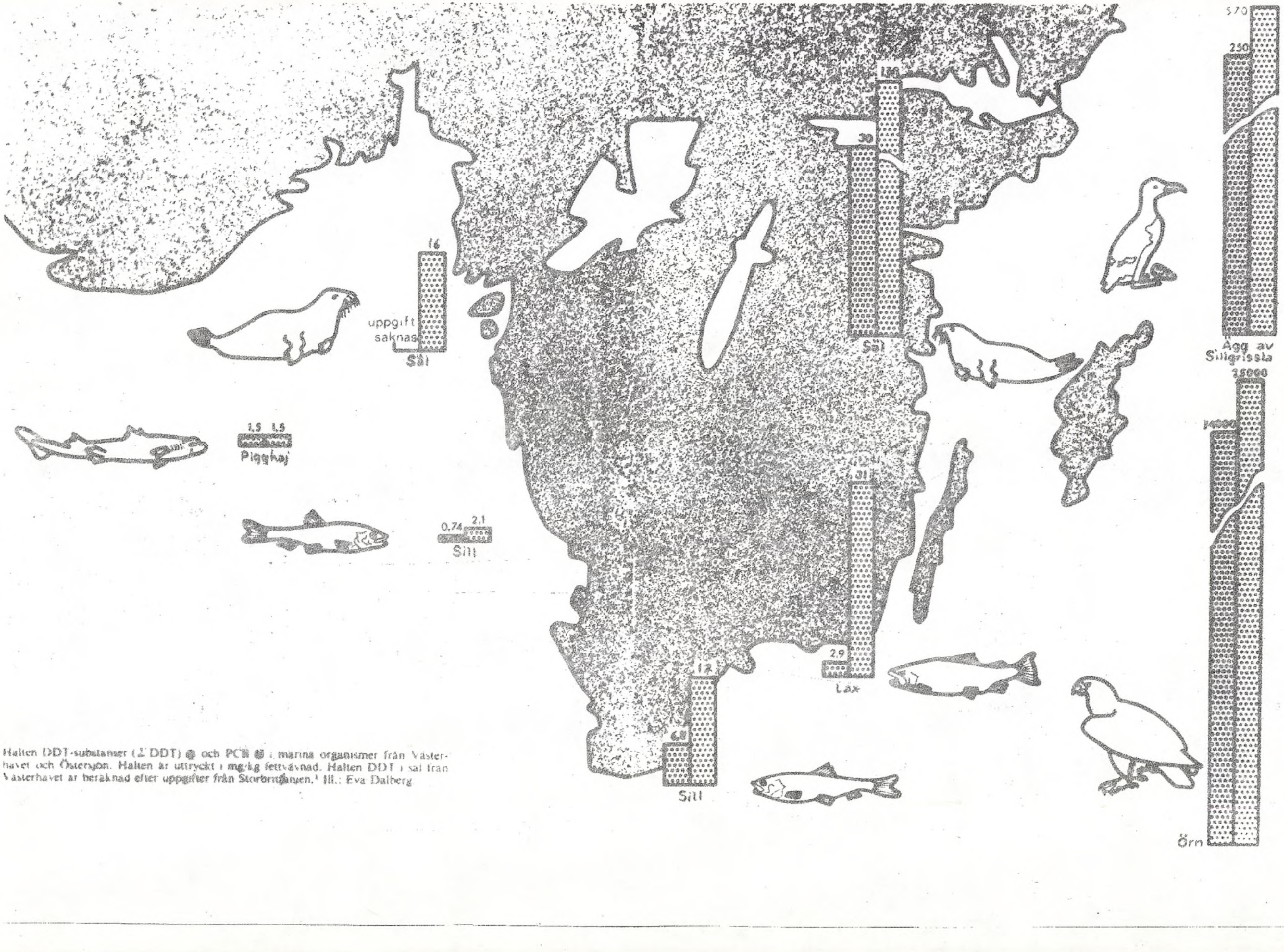

F 78
PO_4-P
Mean value
100-200-300-400 m
1938 1954-1970
3.0
2.0
1.0
0
PO_4-P
1938.... 1954 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70

Fig. 9



F 81 O_2 and H_2S at 240 m
• O_2 ml/l
∘ H_2S as negative O_2
ml/l
3
2
1
0
1
2
3
1955
1960
1965
1970
years
1
2
3
4
5
6
7
8
9
10
11
12
13

Fig. 10



Halten DDT-substanser (Σ DDT) ● och PCB ● i marina organismer från Västerhavet och Östersjön. Halten är uttryckt i mg/kg fettvävnad. Halten DDT i säl från Västerhavet är beräknad efter uppgifter från Storbritannien.[1] Ill.: Eva Dalberg

Fig. 11

Analysis of fish for Mercury by Folkhälsoinstitutet. Vår Föda 1967:1

Area	Concentrations of Mercury/kg ranged	Mean value	Type of fish
Certain lakes and coastal areas	0.13-3.95	1.30	Perch
	0.15-5.20	1.09	Pike
	0.17-2.55	1.00	Pike-perch
	0.12-1.40	0.36	Vendace

Mercury contents in fish (muscles). Läkartidningen 64 (37). 1967

Area	Range of Hg concentration mg Hg/kg	Type of fish
The West Coast	0.03-0.2	Pike, perch, pike-perch, vendace
The Baltic	0.02-2.5	" " " "
Lakes	0.05-10.0	Only pike
Off the coast in the Baltic and the Atlantic	0.016-0.110	Various salt water fishes