FISH DISEASES

SIGNALS FOR A DISEASED ENVIRONMENT?

TABLE OF CONTENTS

ABSTRACT

In recent years, the subject of fish diseases in relation to pollution has received more and more attention in research on the quality of the North Sea environment. On the basis of laboratory experiments, there is reason to believe that the introduction of toxic substances actually does have a negative effect on the health of fish populations in the North Sea ecosystems. However, conclusive evidence from the field is not yet available. Methodological uncertainties and the difficulty of separating natural disease causing factors from pollutional ones form the greatest problems for research.

In general, the data base of fish disease occurrence in the North Sea is inadequate. Many of the investigations, in particular, are still incomplete because of the lack of chemical and microbiological parameters (thought to be) associated with the observed disease levels. Nevertheless, there are presently enough indications and circumstantial evidence to link some fish diseases with environmental deterioration in certain areas of the North Sea.

To illustrate this, the results of our investigations (of the Dutch situation) have been summarized. These findings support the case for a relationship between pollution and the prevalence of diseases in adult flatfish from the Dutch coast (flounder - Platichtys flesus and dab- Limanda limanda). The first results over a three-year period (1983-86) reveal the presence of epizootic liver neoplasms (tumours), and the greater prevalences of several viral skin diseases (lymphocystis and epidermal hyperplasia/papilloma) and bacterial skin diseases (ulcers and fin rot) in the two flatfish species from the contaminated areas. The presence of liver tumours may be directly related to specific environmental contaminants and, in the case of viral and bacterial skin diseases, there are strong suspicions that there is an (in)direct relationship with the total pollution load of the water. Our findings certainly suggest that there is real cause for concern, particularly in regard to the observed liver tumours.

It is concluded that the limited amount of knowledge about fish diseases doet not permit an adequate assessment of the current situation or future problems regarding the health of marine fish populations.

INTRODUCTION

One of the major issues within the discussion on the effects of pollution at present is the question whether pollutants affect the health of marine fish populations and, subsequently, whether fish diseases[1] can be used as signals for environmental deterioration.

1 The definition of disease is: 'a deviation from the state of complex physical or social well-being of an organism involving a well defined set of symptoms and aetiology and leading to an impairment of its normal functions' (ICES, 1985). For practical reasons, disease is used in the narrower sense as: 'any abnormality in the fish structure'.

To begin with, I would like to point out that several cases are known where anthropogenic toxicants have caused massive fish mortalities. A well-known example is the case of copper poisoning off the Dutch coast (Roskam, 1965). Nevertheless, such an occurrence is rare in the marine environment because of the likelihood of dilution and the fact that fish can usually flee from polluted waters (Möller, 1985). Far more attention should be paid, however, to the chronic pollution caused by heavy metals and persistent contaminants. These are harmful substances which are impossible to get rid of and which can slowly and insidiously contribute to the development of diseases. This is underlined by the fact that fish can take up pollutants directly from the water and, because toxic substances from their food intake can also build up.

STOCK-SPECIFIC PARAMETERS	ENVIRONMENTAL PARAMETERS
SPAWNING HABITS	ENVIRONMENTAL CONDITIONS DURING THE EGG AND LARVAL PHASES
POPULATION DENSITY	SALINITY CONDITIONS DURING THE ADULT PHASE
FISH MIGRATION	TEMPERATURE CONDITIONS DURING THE ADULT PHASE
FISH LENGTH (OR AGE)	SELECTION PRESSURE
	NUTRITIONAL CONDITION
	PARASITES
	FISHERIES
	PARASITES
	POLLUTANTS

TABLE 1:
Parameters that are suspected or have been proven to influence disease prevalence in free-living fish (from Möller and Anders 1986, Modified).

The relationship between fish diseases and pollution is, in most cases, not a clearly visible or straightforward one. Within the scientific community, it has become increasingly obvious that the relationship is even more complex than has been assumed until now (ICES, 1986). Pollution is only one factor in the eco-system that can cause diseases, infections and abnormalities to become more prevalent (table 1). The outbreak of many diseases in marine fish depend on the presence of pathogenic organisms, such as viruses or bacteria. In general, the outbreak of an infectious disease can be triggered off by pollution in two ways. First, pollutants which cause physiological stress in fish, thereby reducing disease resistance. Second, pollutants which contribute to increasing the activity and number of infectious organisms, causing a higher infection pressure. Pollution-induced stress, however, may cause damage of a non-infectious nature, such as certain types of tumours, liver or gill abnormalities, and skeletal deformities.

In this paper, I will briefly describe and evaluate the present situation of fish disease/pollution problems in the North Sea. In my opinion, the best way to illustrate some of the major problems is by summarizing recent Dutch experiences.

SOME POINTS FOR ORIENTATION

The following points are of general interest in the study of disease occurrence in relation to marine pollution.

- Effects of toxic substances on fish health

Laboratory experiments have clearly shown that heavy metals and a variety of organic substances are able to induce or trigger off the outbreak of different types of diseases (including tumours) in fish (Meyers and Hendricks, 1982; Couch and Harshbarger, 1985). Iron can play a role in reducing a fish's resistance (Weinberg, 1974); the presence of copper may induce a bacterial disease known as vibriosis (Roedsaether et al, 1977); toxic oil components may cause fin rot (Giles et al, 1978), ulcers (Balouet and Baudin-Laurencin, 1980) and/or tissue abnormalities in various organs (Malins and Hodgins, 1981); PCB's may contribute to the development of fin rot in fish (Sherwood, 1982), and, it has been shown that chromium can induce hyperplasia in the gills of rainbouw trout (Temmink et al, 1983), etc.

It has clearly been established in the field that concentrations of heavy metals and organic pollutants in the water and sediments of the southern North Sea and German Bight are relatively high. The chronic pollution caused by persistent contaminants in these areas, especially estuaries, is reflected in higher concentrations of these pollutants in the tissue of several marine organisms including fish (see de Jong, Volume 1, p. 43-47). The data of dutch computations suggest that the current levels of contamination in organisms often approach or even extend beyond levels which have sub-lethal effects according to laboratory experiments: the concentrations of cadmium, mercury, copper, lead and zinc appear generally to be above the 'no-effect' level, whereas the concentrations of iron and polychlorinated biphenyls (PCB's) are even above levels that are considered to be sub-lethal (Water-quality management plan, 1985).

o Effects of eutrophication on fish health

Concentrations of nutrients have increased considerably along the North Sea coastline. They have caused marked changes in the ecology of several areas. In the German Bight and along the danish west coast, recurring concentrations of low dissolved oxygen have been found, and the effects of eutrophication may have worsened the situation (see de Jong, Volume 1). Oxygen deficiency lowers the resistance of fish populations against diseases and, in extreme situations, can lead to acute fish mortality. In eutrophicated waters, it is quite likely that there will be favourable growth conditions for some pathogenic populations, which could cause infectious diseases to become more prevalent.

o Other effects of pollution on fish health

Thermal pollution and radioactive waste may have some impact on fish health, but they only play a minor role in the North Sea. There is not much data available on this subject. Theoretically, thermal pollution can lead to a rise of pathogenic micro-organisms and it has been associated locally with mass fish mortality (Thulin, 1985). Artificial radionucleids do not appear to have any effects on marine life, even on a local scale (near Sellafield, La Hague) (GESAMP, 1982). This statement, however, may require reappraisal as the use of nuclear energy increases. Finally, the introduction of pathogenic organisms via sewage effluents could also be considered as a potential threat to fish health. However, not enough is known yet about these effects.

SEARCHING FOR EVIDENCE IN THE FIELD

GENERAL DISEASE STUDIES AND PROBLEMS FOR RESEARCH

Among marine organisms, fish appear to be one of the most obvious victims of diseases and abnormalities. Numerous illnesses have been recorded in fish from the North Sea over the last hunderd years. The variety and kinds of diseases found to date in North Sea fish have been summarized by Möller and Anders (1986). Many of the recently noted diseases are also known from the past (ie. Johnstone, 1905), and therefore are probably not, or only indirectly, related to pollution.

Only a limited amount of knowledge is available about the natural background levels of diseases in marine fish. Consequently, the question whether fish disease prevalence in the southern North Sea has generally increased during the course of this century will remain unanswered.

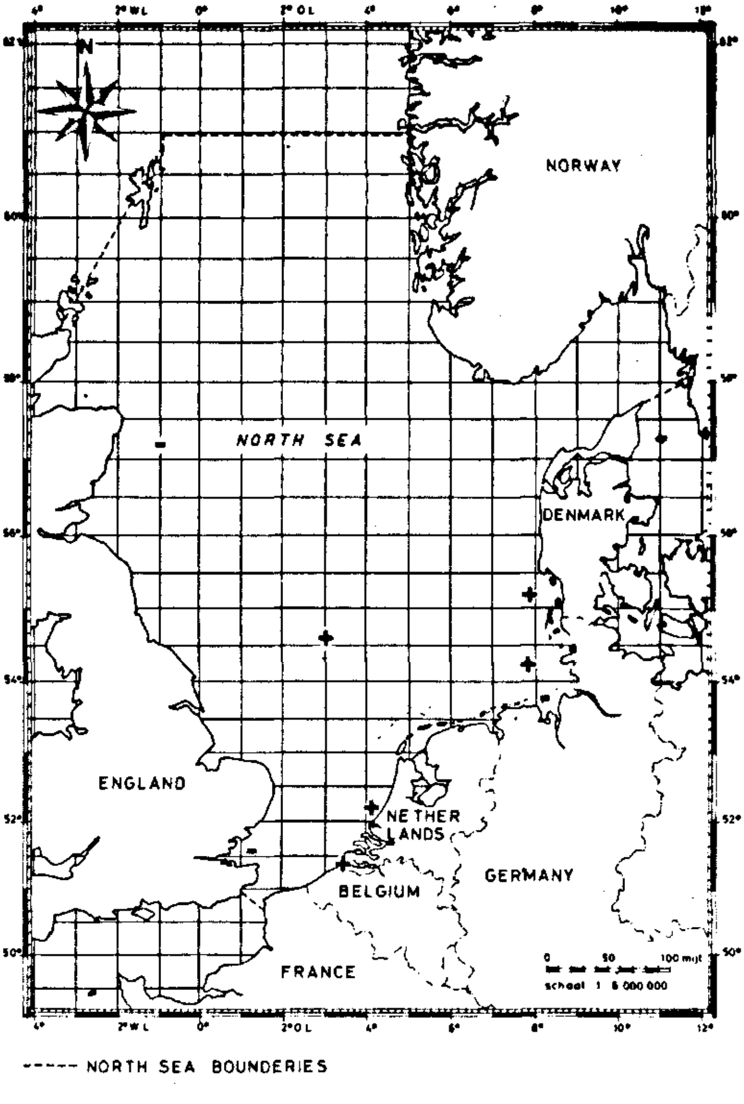
It is not an easy task to establish a baseline for discovering more about unnatural disease occurrences: most diseases show either great geographic and seasonal variations in occurrence and, differences amongst various species and populations are also known to exist (Banning and Warmerdam, 1986). Moreover, the gathering of accurate epidemiological data is still fraught with several uncertainties (Dethlefsen et al, 1984). Major handicaps in conducting field work are high running costs of research vessels and the lack of trained personnel. Another factor which complicates the issue when comparing regional disease rates is the fact that the disease frequency may differ according to age (length) or sex of the fish. Therefore, it is essential to ensure that the rates used are comparable. Finally, it is important to bear in mind that fish are mobile organisms. Fish can migrate and become diseased in other areas. One possible effect of this could be an apparent reduction in the prevalence of a disease in polluted areas. Consequently, it is essential to take into account the migrational patterns, if there are any, of the fish species that are being examined.

Despite all these problems, the seasonal and geographic distributions of some of the common diseases in fish in the North Sea are becoming better known (ie. Banning and Warmerdam, 1986).

SPECIFIC POLLUTION/DISEASE STUDIES

In his recent review on studies of pathology in relation to pollution, Dethlefsen (1986) uses various examples which clearly indicate the relationship between pollutants and diseases in certain areas. Among these are the occurrence of ulcerated fish in connection with the Amoco Cadiz wreckage; fin rot in flatfish in the New York Bight; fin erosion and liver conditions in fish from three regions in the United States; the ulcus syndrome in cod (Gadus morthua) in Danish coastal waters and liver tumours in bottom-dwelling fish in Pudget Sound, United States. But, these cases have not provided conclusive evidence for cause-and-effect relationships. The difficulty of providing statistical evidence for such cause-and-effect relationships is just one of the problems involved. The key difficulty, however, appears to be the differentiation between pollution and natural factors causing a regional or seasonal rise in the prevalence of a disease.

FIGURE 1
Map showing North Sea areas where fish disease surveys have produced positive (+) or negative (-) data indicating the involvement of pollution (based on a review by Dethlefsen, 1986).



----- NORTH SEA BOUNDERIES

In the North Sea, research on fish diseases and pollution is largely coordinated within the framework of the International Council for Exploration of the Sea (ICES). Figure 1 shows a map of the North Sea indicating the areas where fish disease surveys have been conducted with positive or negative data on a possible relationship with pollution. Scientists from Denmark, Germany, Belgium, and the Netherlands have provided a vast supply of data and circumstantial evidence that pollution is, in fact, involved in their coastal waters or areas beyond these. However, these studies are not yet complete owing, in part, to the involved nature of the problem. What is lacking is a sufficient number of investigations into chemical and/or microbiological parameters thought to be associated with the observed disease levels. Interestingly enough, a problem area has also been found near the Dogger Bank in the central North Sea (Dethlefsen, 1986), indicating that pollution/disease problems are not totally restricted to inshore areas. Conflicting results have been found in the German Bight and Elbe estuary, near the Thames estuary and east of Scotland (Möller, 1986 and Dethlefsen, 1986). The conflicting evidence indicates that disease trends related to pollution may differ in certain areas and, that caution is required in extrapolating findings from one area to another. It is quite possible that non-pollutional stress factors play an important part in complicating and obscuring the situation in some areas. From a hydrographical point of view, the German Bight, in particular, is known to be a problematic area (see Eisma, Volume 1, fig 4, 5 and 6). Furthermore, it must also be mentioned that the negative findings of English and Scottish scientists are based on a limited amount of information as they have not yet carried out any detailed studies (Dethlefsen, 1986). On the whole, however, at least four other extensive studies indicate that a relationship does actually exist between fish diseases and pollution in the North Sea.

THE DUTCH FIELD STUDIES AS AN ILLUSTRATION

Perhaps the best way to illustrate some of the current fish disease problems in the North Sea is by summarizing recent dutch experiences. The types of diseases discussed here largely cover those dealt with in other studies on this subject. The heavily polluted dutch coastal waters have been the site of an extensive fish disease survey since 1983. The multi-disciplinary project, commissioned by the Public Works Department (Rijkswaterstaat) and presently still underway, has already provided significant results supporting the case for a relationship between fish diseases and pollution (Vethaak, 1985a, 1985b).

The main contributors to the pollution of the dutch coastal waters are the Rhine, the Meuse and the Scheldt rivers. Dumping of contaminated harbour sludge takes place at several sites off the coast near these large water outlets. Sewage (from The Hague) is pumped directly into this coastal area. In addition, industrial waste from the titanium dioxide industry is still being dumped directly into the dutch sea. It will be difficult or even impossible to differentiate between the effects of the various pollution sources: synergetic or antagonistic effects will undoubtedly be found. Sampling areas are given in figure 2. They have been selected on criteria such as quality of the water (Rijkswaterstaat, 1983-1986), levels of contamination of various organisms: flounder, mussel and shrimp (received from the Joint Monitoring Group of ICES) and the occurrence of target fish species.

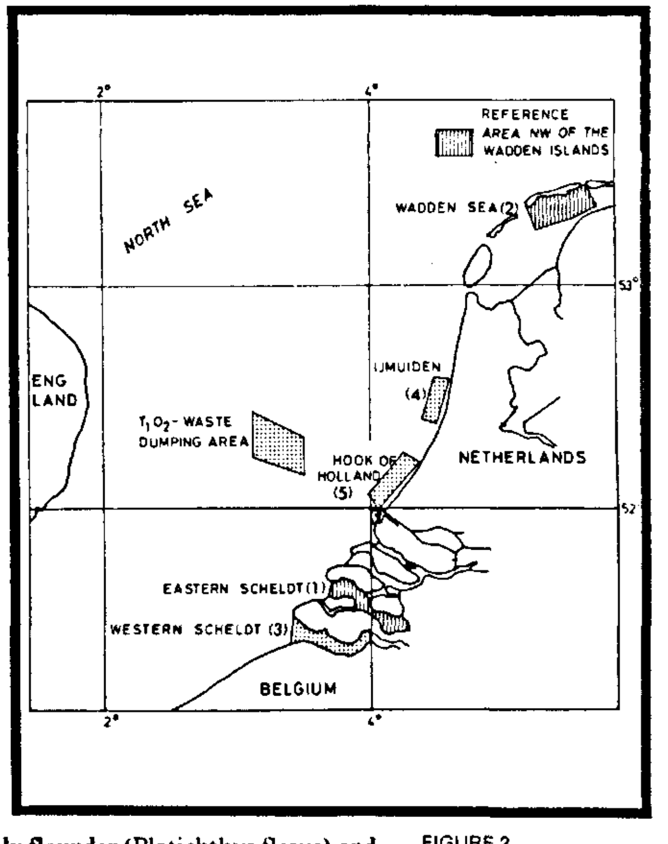


FIGURE 2
Map showing the geographic location of the sampling areas. Flounder was sampled in areas 1-5; dab in two off-shore areas.

In our study, we concentrated on two fish species, namely flounder (Platichthys flesus) and dab (Limanda limanda). Both are flatfish species and live in intimate contact with the sediments. Moreover, these species appear to be particularly sensitive to various diseases. Although flounder follows distinct migrational patterns, familiarity with these movements still enables it to be used as a local indicator species in estuaries and coastal zones. Dab is used as a general indicator species; it commonly occurs in the entire North Sea and shows only local migrations.

PRELIMINARY RESULTS AND CONCLUSIONS

By taking migration patterns and possible natural disease-causing factors into account, it was possible to indicate which abnormalities may result from pollution. Although no cause-and-effect relationship has been proven by this study, the following can be stated:

- the high frequency of liver tumours (neoplasms) observed in flounder and dab in dutch coastal waters is cause for major concern as it may be directly related to specific contaminants in the environment. This finding was the first to indicate a high prevalence of neoplastic liver lesions in North Sea fish.
- pollution was probably a contributing factor in at least three of the most common skin diseases found in flounder, which demonstrates an indirect effect of the general load of pollution. The identified diseases were: lymphocystis (a viral disease), ulcers and fin rot (bacteriological conditions). The observed levels of these external disease conditions in flounder in dutch coastal waters can (easily) be ranked among the highest levels found in the entire North Sea.
- preliminary data on the occurrence of papilloma (epidermal hyperplasia/papilloma, a viral skin disease) in dab in the dumping area of titanium dioxide waste point to the possibility that the associated waste contributed to the elevated disease levels found there.

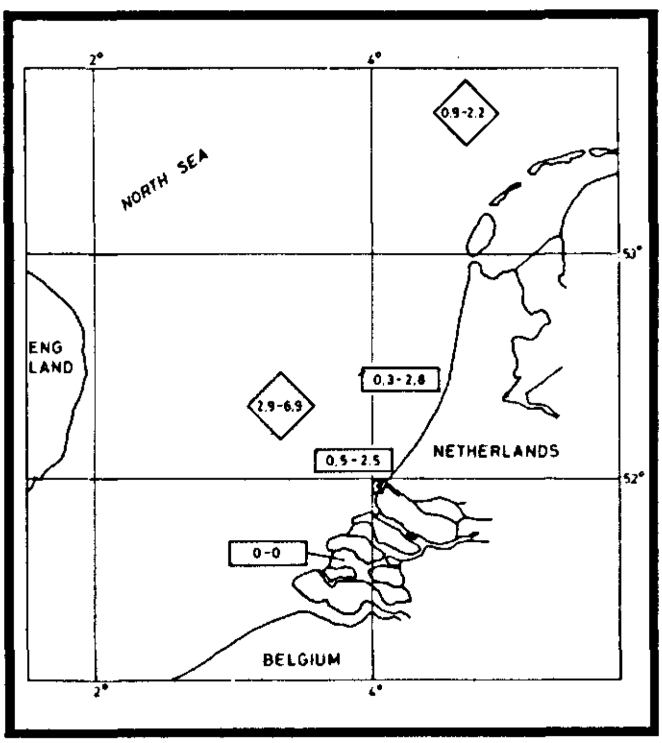
FIGURE 3
Prevalence (in percentage) of liver neoplasms in two flatfish species in different localities in Dutch coastal waters.

flounder; range of prevalence refers to samplings of fish larger than 25 cm during September '83, '84 and '85.

dab; range of prevalence refers to samplings of fish larger than 20 cm in March and May 1986.

MORE DETAILED DESCRIPTION OF THE EVIDENCE

In the following section, the specific diseases and their relationship with pollution are discussed in more detail.



Liver tumours in flounder and dab

This is probably the most relevant disease condition that can be linked to chemical pollutants. Liver neoplasms were observed in flounder and dab from various locations in dutch coastal waters (figure 3). These types of lesions have so far not been noted in flounder in the relatively clean reference area (Eastern Scheldt). A number of interesting remarks can be made in relation to this form of cancer[2]:

- the prevalence of clearly visible neoplasms increased with greater size or age. Its prevalence among fish older than three to four years was locally up to 40%. The total tumour prevalence will undoubtedly increase when inspections of microscopic lesions (presently being studied) are included.
- there is a higher prevalence of liver tumours among flounder and dab from polluted areas than those from less polluted regions.

2 Neoplasms with various degrees of malignancy.

Generally, neoplastic lesions in animals and humans have been recognized as potential long-term indicators of environmental change (as certain human neoplasms are thought to be induced by specific environmental contaminants). There is growing evidence that certain, as yet unidentified, toxic substances in the water and sediment are involved in the development of tumours in fish (Couch and Harshbarger, 1985). Furthermore, the prevalence of liver tumours in various fish species has been associated with PCB's and/or DDT (see Peters, 1984). American studies have been conducted on this problem and are particularly relevant to this discussion (Malins et al., 1984). These studies showed that statistically significant correlations existed between toxic chemicals (aromatic hydrocarbons) in the sediment and the prevalence of liver neoplasms in bottom-dwelling marine fish. The findings support an environmental aetiology of liver tumours in fish from contaminated areas. No evidence of a viral aetiology has as yet been found.

It is suggested therefore, that in the case of liver tumours in flatfish from dutch coastal waters, chemical contaminants may have acted as causative agents. Liver neoplasms were found in fish from the areas where the water and biota are known to contain many toxic chemicals including carcinogens, such as Polyaromatic Hydrocarbons (PAH's). From 1979-83, the highest PCB contents in the livers of flounder and mussels were detected along the Dutch coast, revealing the Rhine and Meuse rivers to be the main PCB sources (JMG-data-ICES). PAH concentrations in mussels from the Western Scheldt were shown to be about ten times higher than in other Dutch coastal areas (unpublished data RIKILT, Wageningen).

SKIN DISEASES IN FLOUNDER

(A compilation of the data of the analysis is presented in table 2.)

Lymphocystis disease

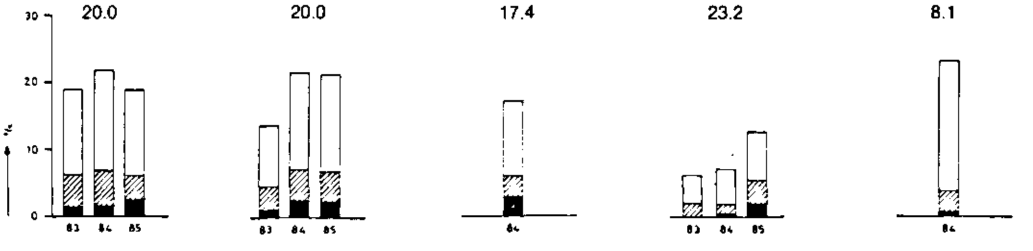
The symptoms are pearl- or tumour-like growths on the skin and fin. The disease is known to be caused by a contagious virus infection and is not necessarily lethal. The infection appeared to mainly spread among flounder during the spawning season, despite the fact that this occurs in deep and relatively clean water. In this season, the flounder is subjected to spawning stress and a high population density, which increase the risk of infection. It also hardly feeds in this period (low nutritional condition). After spawning, the flounder returns to its coastal and estuarine habitats (de Veen, 1971). There is growing evidence that pollution stress helps to activate latent virus infections in fish (Sindermann, 1983). This has most likely resulted in more frequent (2.1-2.5 times) and severe infections in the heavily polluted coastal waters (see histograms, table 2).

Ulcers and fin rot

Ulcers were mostly round, red and open wounds in the skin. Fin rot was characterized by tissue necrosis and – in severe cases – complete disappearance or erosion of the fin margin and fin rays, particularly of the caudal fin. The prevalence of ulcers and fin rot was highest in the most polluted areas, with clearly lower rates in less polluted regions (showing an increase of 4-5 and 11-15 times, respectively). It was found that various species of bacteria occurred in the blood of the flounder from severely polluted areas having one or both of these conditions. This is contrasted with the finding that there were no bacteria in the blood of flounder in the relatively unpolluted area. This has been interpreted as a possible indirect effect of pollution. The underlying assumption here is that bacteria grow faster in water with heavy organic pollution, thereby increasing the risk of infection.

It has been suggested that fin rot might be linked to chemical stress factors affecting the protective mucous layer of the fish. Such chemical stress may result from a low oxygen content combined with a high sulphide content in the aquatic environment. A secondary effect may be a bacterial invasion taking place in the affected spot (Sindermann, 1983).

TABLE 2
The case study of diseases in flounder in dutch coastal waters: compilation of analysis data.

DEGREE OF POLLUTION	heavy 5	4	3	moderate 2	minimal 1
SAMPLING AREA	Hook of Holland	IJmuiden	Western Scheldt (Mouth)	Wadden Sea near Terschelling	Eastern Scheldt (Mouth)
POLLUTION SOURCES	- the Rhine and Meuse rivers (port of Rotterdam approaches, the Haringvliet) - direct sewage effluents (from The Hague)	- North Sea Canal with Hoogovens industrial site	- river Scheldt - effluent discharges - dumping of gypsum	- influence of dutch coastal waters and the IJsselmeer; considerable sedimentation of contaminants	relatively minimal influence from outside sources
DISEASE RATES IN %					
(period '83-85; Sept.) No. of flounder exam. (> 20 cm)	1884	1576	465	909	1280
LYMPHOCYSTIS					
observed prevalence	20.6	21.7	16.1	22.6	4.6
expected prevalence[1]	20.0	20.0	17.4	23.2	8.1
expected prevalence and degrees of infection severity in different years □ STAGE 1 ▨ STAGE 2 ■ STAGE 3					
ratio*	2.5	2.5	2.1	2.7	1.0
ULCERS					
observed prevalence	3.9	4.4	2.4	1.1	0.9
ratio*	4.3	4.9	2.7	1.2	1.0
FIN ROT					
observed prevalence	1.3	1.1	1.5	0.1	0.1
ratio*	13	11	15	1	1
WATER TEMPERATURE[1] maximum (° C)	20	20	22	23	22
SALINITY[2] **FLUCTUATIONS (‰)**	24-30	26-30	17-30	28-32	27-30
CONDITION FACTOR[3]	96	100	87	84	86
POPULATION DENSITY[4]	16	11	36	100	65
FISHERY INTENSIVITY[5]	+++	+++	-/+	+	+

Stage I (mild): a few nodules occuring sporadically. **Stage II (moderate):** nodules and/or nodule clusters covering up to twice the area of the spread-out caudal fin **Stage III (severe):** nodules and/or nodule clusters covering an area larger than twice that of the spread out caudal fin.
* the prevalence of the disease of the Eastern Scheldt ('cleanest' area) is determined as 1.
1 calculated by indirect standardisation for length and sex of the fish. 2 data derived from Rijkswaterstaat, 1983-85.
3 condition factor - weight in mg x 100 / (lenght in mm)³ maximum value - 100 (September '83-'84); condition factor is used as measurement of nutritional condition. 4 maximum value - 100; based on total no. caught per hour (September '83-84 and '85). 5 roughly estimated; based on unpublished RIVO data.

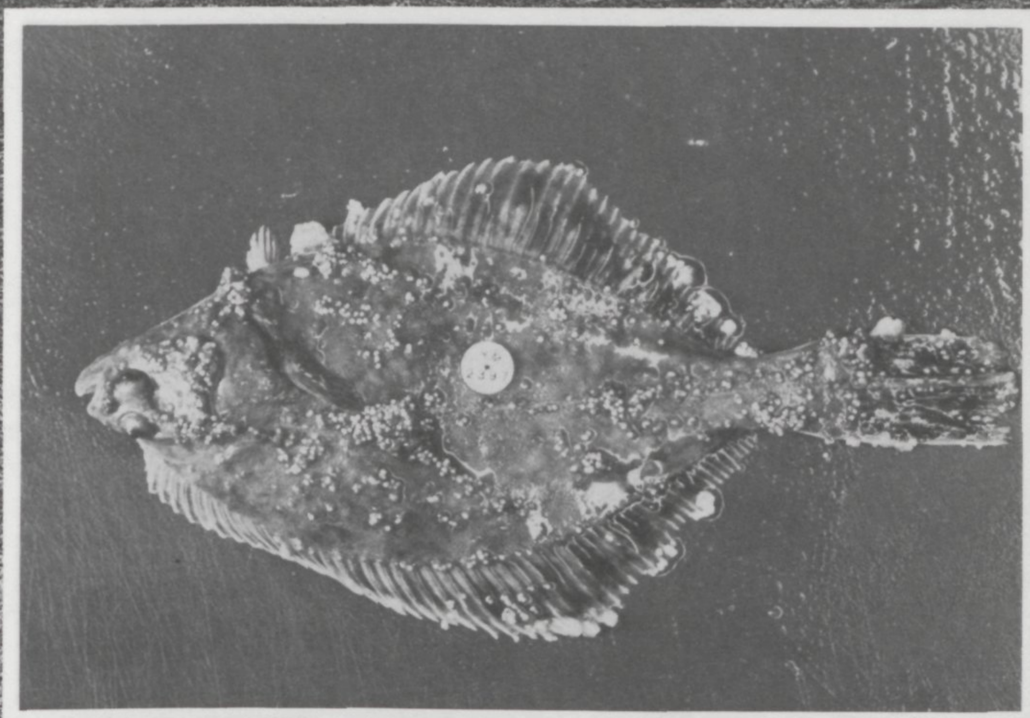


PLATE 1
Lymphocystis infection (flounder).

PLATE 2
Close-up of lymphocystis nodules (flounder).

PLATE 3
Lymphocystis nodules and pseudotumours (flounder).

PLATE 4
Liver tumours (neoplasms) (flounder).

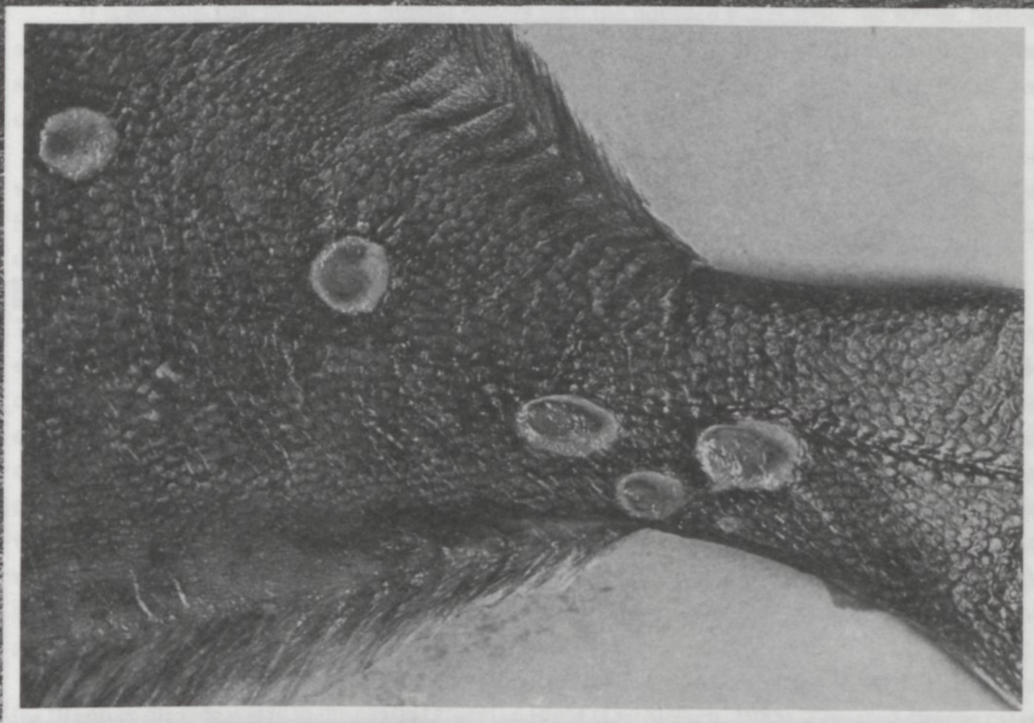


PLATE 5
Skin ulcers (flounder).

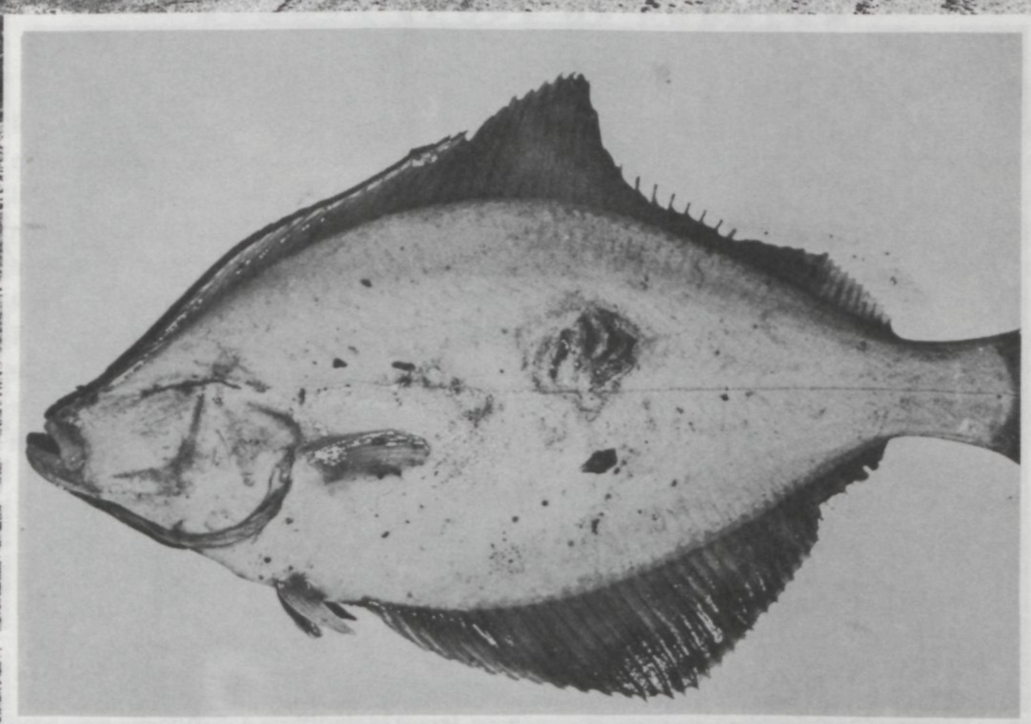
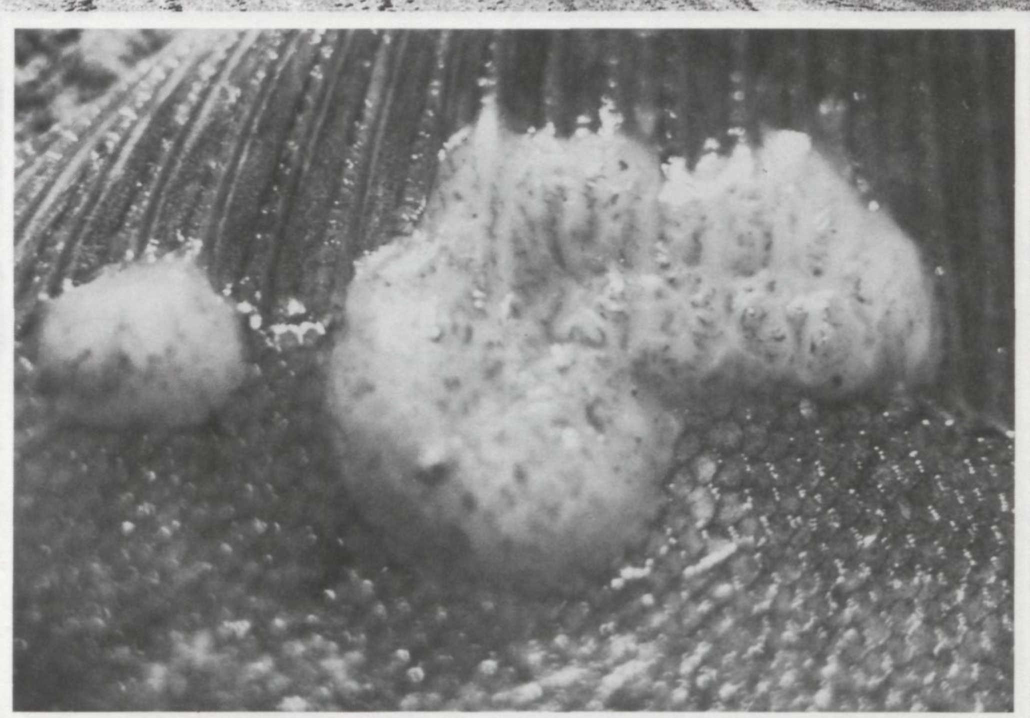


PLATE 6
Fin rot (flounder).

PLATE 7
Epidermal hyperplasia/ papilloma (dab).

PLATE 8
Close-up of epidermal hyperplasia/papilloma (dab).



(All photographs by the author, except plate 7 and 8 which have been provided by courtesy of P. van Banning, RIVO, IJmuiden).

It is obvious that the Dutch coastal waters with the polluted water from the Rhine, Meuse and Scheldt rivers are now heavily eutrophicated. Together with other pollution sources such as the sewage outfall near The Hague and the dumping areas of dredging spoil, situations which are conducive to the stimulation of ulcers and fin rot can result.

Another example in which an indirect relationship was found between bacterial diseases and water pollution was provided by a dutch-belgian study carried out in 1982-84 in the Western Scheldt estuary on a condition in eel called 'red disease' (Banning et al, 1984). However, this study did not find a direct relationship between the disease and contamination of the fish.

Papilloma in dab

This disease condition (epidermal hyperplasia/papilloma) is only found in dab, and just recently, evidence has been found to support a viral aetiology (Block et al, 1986). Symptoms are macroscopical jelly-like or whitish plaques or tumours (benign tumours) on the skin. Therefore, as in the case of lymphocystis disease in flounder, it is possible that papilloma in dab can also easily be triggered off by pollution stress, particularly during the winter fast and spawning season when the condition of the fish is poor. In both March and May 1986, the tumour prevalence in the titanium dioxide waste dumping area was if compared with the reference area, about a factor 1.5-2 higher. The values for March were 8.7 against 4.9%, and for May 4.0 against 2.8% (standardized for fish length). It should be added that natural disease-causing factors were more prevalent in the control area during that time (population density and condition factor).

The dutch results are consistent with those of german studies carried out in the dumping area for titanium dioxide waste in the central German Bight (Dethlefsen, 1985). Elevated disease rates of papilloma in dab in german and danish waters have also been linked to the recurring oxygen depletions in these waters (Block et al, 1986).

SCOPE OF CURRENT RESEARCH VERSUS SCOPE OF PROBLEM

This presentation has focussed on some obvious disease types in a number of adult fish only. But what about the effects during the early stages of fish? There is general agreement among experts that the embryonic and early stages are more sensitive to pollution than later stages during the fish's life cycle, but very little work has been done on this subject. In relation to this, the problem of the Wadden Sea pollution is particularly worrying (see paper by de Jong, p. 52) because of the importance of this region as a nursery area for young fish. In addition, studies should be concentrated on a larger number of fish species, preferably of a wide ecological variety. Finally, apart from obvious cases, it may not be possible to recognize all the effects of pollution by merely looking for readily visible lesions. No doubt, it will be more worthwhile to concentrate such studies on the presence of microscopic lesions in the sensitive and crucial fish organs (especially the liver).

THE ATTITUDE OF THE AUTHORITIES TOWARDS THE PROBLEM

It is a fact that interpretations concerning fish diseases in polluted waters have frequently been over-simplified. A multitude of social, economic and political factors have also played a part in complicating the issue. In most, if not all, countries along the North Sea, several different government departments are concerned with marine fish disease problems. In the dutch case, for example, those involved are the Ministry of Transport and Public Works for issues related to management of the quality of the water and the Ministry of Agriculture and Fisheries with respect to the management of fisheries and the quality of fish products. Anxiety that publications on fish diseases might unduly harm the fishing industry has certainly contributed to a very cautious attitude in these departments. The fishing industry is reluctant to sponsor research into this area for the same reason. Therefore, as far as the dutch situation is concerned, investigations into the potential relationship between marine pollution and fish diseases is seriously hampered by a widespread lack of enthousiasm. Fortunately, the Public Works Department (Rijkswaterstaat) is presently looking into whether fish disease research should become a permanent activity within its scope of work.

In order to clarify the present situation, the following remarks may be of some use:

- it is clear that the introduction of toxic pollutants into the sea is harmful for the state of health of marine life. Pollution-induced fish diseases could result in a depletion of the exploitable fish stocks. This may have serious ecological and economic consequences and, may even effect man via the food chain. Therefore, the study of fish diseases is not just motivated by a passing interest, but is rather a cornerstone in the protection of the marine environment.
- the present level of contamination has not been regarded as forming a health problem for human consumers of fish products, except in a few restricted coastal and estuarine areas (ie. Western Scheldt, Rhine, and Meuse rivers (Kerkhoff et al, 1981, RIVO, 1983)). Even if the degree of contamination is sufficient to cause obvious damage to the fish themselves, this certainly does not mean that human consumers will be harmed. Nevertheless, the presence of externally visible lesions will cause fishermen or market vendors to reject diseased fish. Therefore, from the point of view of commercial fisheries, the aesthetic and economic implications of fish diseases are more important than health problems.

CONCLUSIONS

- While an adequate data base of fish disease occurrence has not yet been sufficiently established, the general trend of linking fish diseases to marine pollution stems from laboratory experiments. The task now is to prove this relationship in the field (ie. at sea).
- There are enough indications and circumstantial evidence at present to link some fish diseases with the degree of water pollution in certain areas of the North Sea. These include:
  - liver tumours (neoplasms) in flatfish, which are possibly directly linked to specific toxic chemicals in the environment.
  - several viral and bacterial skin diseases of flatfish which are probably (in)directly related to the general state of pollution of the water.

It should be noted, however, that caution must still be used in interpreting the available data, due to the general lack of chemical and/or microbiological analyses.

- It must be recognized that, at present, the limited amount of knowledge about fish diseases – a relatively new field in fish biology – certainly does not permit an adequate assessment of the current situation or problems in the future in regard to the state of health of marine fish populations.

RECOMMENDATIONS FOR FUTURE RESEARCH

Here, I have followed closely the recommendations made by the special ICES Working Group held in Dublin, April 1986 (ICES, 1986), recommending that:

- information about background levels of diseases should be looked for in long-term (e.g. 5 years) baseline studies on a regular basis and in a broad area. Dedicated or combined cruises staffed by trained observers using internationally agreed approaches and methodology ought to be employed. Target organs should include skin, gills, fins and liver.
- specific investigations on diseases in relation to pollution should be carried out in hot-spot and reference areas.

The following recommendations are also made:

- a special study elaborating on the findings of liver tumours in flatfish along the dutch coast is highly desirable. The goal of such a study should be among others to gain a better insight into the nature and aetiology of this unusual disorder.
- one of the objectives of future research should be to find out more about the effect of pollutants during the most sensitive stages in a fish's life cycle, that is, the embryonic and early stages of life. This should definitely be applied to the fish species which find their main nurseries in the shallows of polluted coastal areas and estuaries (especially the Wadden Sea).
- it is necessary to approach the entire problem of fish diseases from as many perspectives as possible. Consequently, a multi-disciplinary approach within a broad ecological framework is one of the basic requirements.

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DISCUSSION

Mr. van der Voet opened the discussion with the remark that he had noted that Mr. Vethaak mentioned that the data base of fish diseases was not sufficiently established at present and that a lot of information was still needed. He then asked whether there were any indications of an increase or decrease of fish diseases over the last years.

Mr. Vethaak again stressed that it was essential to have a background of disease levels if you want to detect trends in disease occurrences. He could not even confirm whether disease occurrences had increased or not for the last decade; this may be explained by the fact that only a limited number of disease-surveys have been carried out and historical data are scarce or non-existent.

Another speaker from the floor asked what kind of data mr. Vethaak was referring to when he mentioned the desirability of microbiological and chemical data.

Mr. Vethaak answered that he, and any (other) researcher in this field, needed more specific microbiological and chemical data, (thought to be) associated with the observed disease levels or disease symptoms. In other words, data on the presence of persistent pollutants in normal and diseased fish tissues, on metabolic aspects of these pollutants, etc. The joint monitoring group of ICES is also carrying out some work which is relevant to this subject, but there is no specific research analysing residues of diseased fish in the North Sea. Dr. Dethlefsen's work in the Federal Republic of Germany may be the only exception. Again mr. Vethaak stressed that the lack of research capacity and available data were the main problems in drawing hard conclusions in regard to the relationship between pollution and fish diseases.

Mr. Lindeboom mentioned that ICES collects quite a large amount of data on pollutants in certain fish species and wondered whether mr. Vethaak had ever looked into correlations between the ICES data and his findings.

Mr. Vethaak confirmed he had done so. His choice of the various sampling areas had been based on ICES data using a pollution gradient. Consequently, there was certainly a solid basis from which it was possible to say that an increased disease level is prevalent in heavily polluted areas; there is background material on the chemical pollution in an area, as well as on the contamination of fish tissue in Vethaak's study.

Ms. Gubbay mentioned again the correlation between fish diseases and polluted areas and asked what definition of a polluted area mr. Vethaak used; was it based on heavy metals, bacteriological or other parameters?

Mr. Vethaak informed her that he had selected his polluted areas on criteria such as data from ICES and the chemical quality of the water.

Mr. Spaans referred back to the first question of this discussion by mr. Van der Voet and admitted that he was more or less confused by mr. Vethaak's answer. Did he understand correctly that fish diseases had been more or less constant over the last ten years which would mean that there was no problem?

The fact was, however, that no conclusion could be reached on whether disease levels had increased or decreased, and consequently whether they had been constant during the last decade, or not.

Mr. Spaans then declared that, it appeared unnatural to find approximately 40% tumors in dab.

Mr. Vethaak agreed that the observed high disease frequencies did not seem natural to him either and added that in regard to liver tumors, his findings of epizootic liver cancer in flatfish were the first to be observed in North Sea waters. He therefore considered this to be a highly suitable disease to indicate the effect of pollution. Still, he could not be completely sure, as he is one of the few scientists to have done any internal screening of fish organs and there is hardly any background information on internal diseases of marine wild fish stocks.

Mr. Spaans then asked how certain mr. Vethaak was about the causes of the disease.

Mr. Vethaak replied that he himself believed that the liver tumors were induced by pollution.

Another speaker from the floor noted that mr. Vethaak was very cautious about saying whether fish diseases have increased over the last years or not, while it is common knowledge that pollution in fact has increased. The speaker wondered whether it was possible to say that fish diseases had increased as well, provided that the correlation between pollution and diseases is accepted.

Mr. Vethaak added that it was important to take into account that a correlation does not necessarily mean a causal relationship. In order to establish a causal relationship more research is needed.

Further questions dealt with the relation between specific types of pollution (eutrophication, heavy metals, etc.) and fish diseases. The point was raised whether it was possible to find areas, with only eutrophication, or only polluted by specific substances, e.g. only heavy metals by using these areas, it would be possible to get more information on substances which induce the diseases.

Mr. Vethaak agreed. However, at present, the only possible relationship for which many indications exist is the relation with the general load in pollution of the water; in general, it is very difficult or even impossible to differentiate between the various kinds of pollution in the field. However, with regard to the liver cancers, it seems likely that specific contaminants, e.g. carcinogenic substances, are responsible.

Mr. Klatte then recalled mr. Vethaak had said that there were positive correlations between fish diseases and pollution along the coast of the continent, while on the other hand, he had mentioned U.K. scientists reporting negative correlations near the coast of the United Kingdom. Was there any explanation for these differences?

One of the explanations mr. Vethaak considered to be plausible was that non-pollutional factors could play a role in complicating and obscuring the situation in certain areas. He also noted that the policy and research effort of the UK is quite different from that of the Federal Republic of Germany and the Netherlands; there has only been limited research into this area in the U.K.