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MINISTRY OF AGRICULTURE, FISHERIES AND FOOD
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The field assessment of effects of dumping wastes at sea : II Epidermal lesions and abnormalities of fish in the outer Thames Estuary

D.BUCKE, M.G.NORTON and M.S.ROLFE

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1. Introduction

The Ministry of Agriculture, Fisheries and Food (MAFF) is responsible under the Dumping at Sea (DAS) Act 1974 (Great Britain – Parliament, 1974) for the control in England of waste disposal from vessels at sea. As part of the Ministry's responsibility under this Act to protect fisheries and the marine environment generally, periodic monitoring surveys are undertaken in waste disposal areas to determine the effect that dumping may have on the receiving area and its biota.

The Ministry's policy and approach to the monitoring of dumping grounds has been described earlier in this series of reports (Norton and Rolfe, 1978) and subsequent reports have described the results of surveys made in several areas to determine the physical, chemical and biological effects of dumping, with particular attention to sediments and the benthic fauna. In the case of the area of the outer Thames Estuary where $5 \times 10^6 t\ a^{-1}$ of sewage sludge are dumped, intensive surveys to quantify the effects of dumping in the water column and at the sea bed were conducted in 1972 and 1977/78 (Talbot *et al.*, 1982; Norton *et al.*, 1981). The results of monitoring the concentrations of contaminants in fish and shellfish from the general area have also been reviewed (Murray and Norton, 1983).

The detailed surveys described above are based on the premise that the direct biological effects of dumping are most likely to be revealed by investigating the benthic fauna (Norton and Rolfe, 1978). Monitoring of the abundance or health of fish populations was not included because fishing activity and the natural spatial and temporal variability of fish would make data very difficult to interpret. Furthermore, no direct effects on fish populations were anticipated, in view of the low toxicity of the sewage sludges dumped. In recent years, however, a number of workers (Mahoney *et al.*, 1973; Perkins *et al.*, 1972; Shelton and Wilson, 1973a, b; Mearns and Sherwood, 1974; Newell *et al.*, 1979; Dethlefsen, 1980; Nounou *et al.*, 1981) have considered the possibility that various diseases and abnormal conditions in fish had a causative association with some form of pollution. Much of this work has been reviewed by Sindermann (1979) and in most cases any association remains speculative and is supported by only circumstantial or inconclusive evidence. It has been suggested, however, that both fin rot in flatfish (Sherwood and Mearns, 1977) and shell disease in Crustacea (Young and Pearce, 1975) could be induced by contact with sediments contaminated with sewage sludge. In both cases the disease symptoms were more prevalent in contaminated areas and could be induced in the laboratory by exposure to contaminated sediments. In the most exhaustive work (Sherwood and Mearns, 1977) fin rot in the Pacific Dover sole *(Microstomus pacificus)* could be induced after 13 months of exposure in the laboratory to bed sediments contaminated with sewage sludge, and it was suggested that contamination by PCBs was possibly a causative factor. Those authors also reported the results of an intensive study of Pacific Dover sole off the Palos Verdes peninsula of southern California, where an examination of nearly 30 000 fish revealed a greatly increased incidence of fin rot in areas of fine sediments containing high levels of chemical contaminants derived from nearby sewage sludge discharge sites. Murchelano and Ziskowski (1979) suggested that fin rot was "a sentinel of environmental stress", and although the exact aetiology of the disease remained unknown they found a higher incidence of this condition in the winter flounder, *Pseudopleuronectes americanus*, in the polluted waters of the New York Bight than elsewhere.

In a more recent review of the incidence of fish disease in the North-east Atlantic, Möller (1979) concluded that, although most diseases could not be readily linked to contaminated areas, an increased incidence of fin rot in the German Bight might be associated with the dumping of sewage sludge. He also suggested that increased numbers of ulcerated cod in parts of the Danish Belt Sea might reflect the presence of discharges from sugar and cellulose industries.

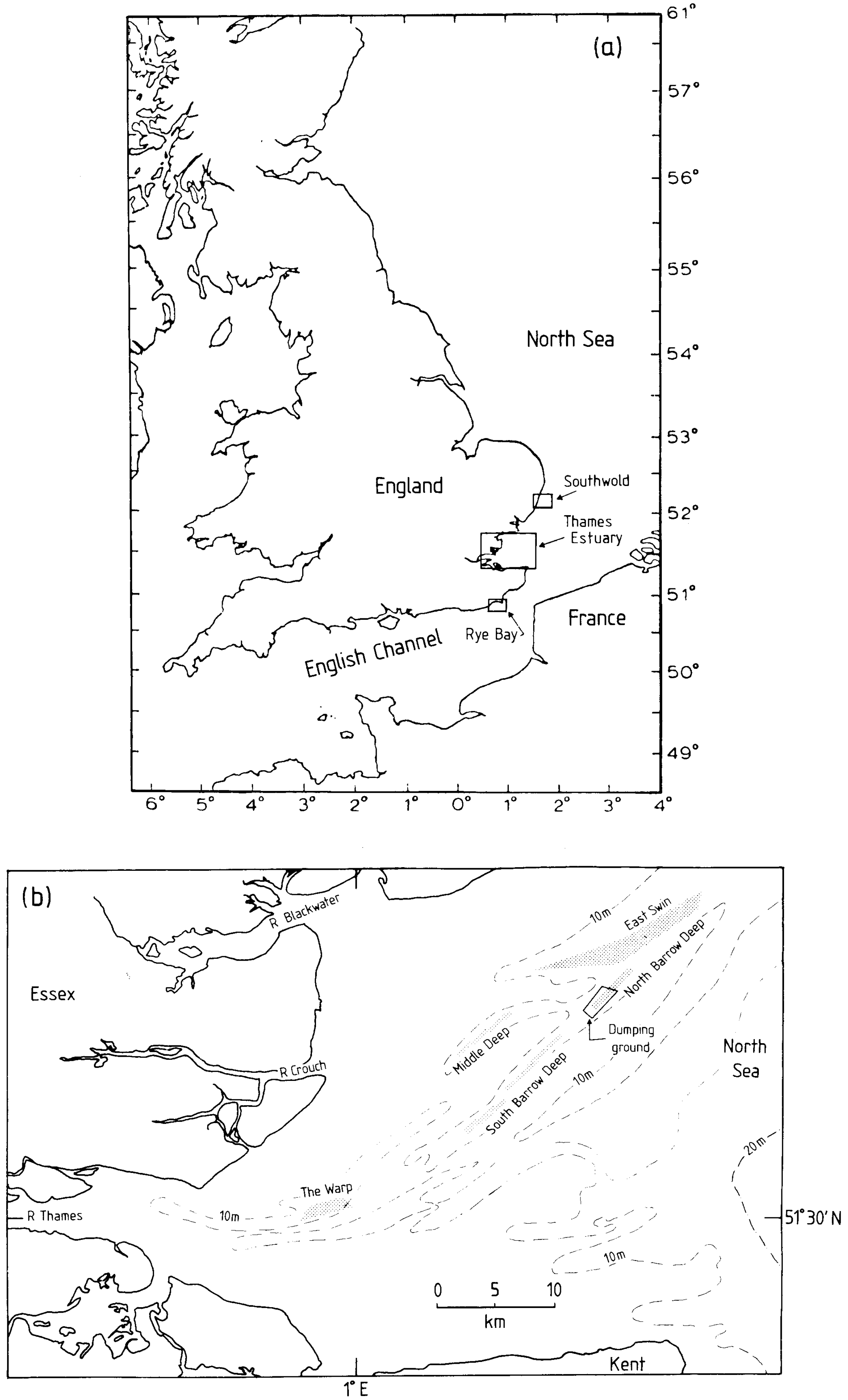
In view of the suggestion that fin rot and other diseases might be induced by exposure to sediments contaminated by discharges including those of sewage sludge, it was decided to investigate the incidence of fish diseases and other abnormalities in the vicinity of the UK's largest sewage sludge dumping operation in the outer Thames Estuary. The sampling and experimental programme was designed a) to establish the level of incidence of fish diseases in the Thames Estuary for comparison with the results of other studies; b) to enable any spatial trends within the estuary to be identified; and c) to compare the incidence of fish disease with that in fish populations sampled in other areas off England more remote from discharges.

The results of surveys carried out during spring 1980 are presented in this report. Results of the 1977/78 studies defined the extent of the influence of sludge dumping on the water column and in the sediments (Norton *et al.*, 1981).

2. Methods

2.1 Species of fish sampled

In the USA, considerable work has been carried out on fin erosion of the Pacific Dover sole *(Microstomus pacificus)* (Sherwood and Mearns, 1977) and other demersal species. However, recent European surveys have been widened to include other diseases and abnormalities in several species of fish (Dethlefsen, 1980; Möller, 1979, 1981 a, b). All demersal species of commercial importance caught were sampled in the present survey, including Dover sole, lemon sole, dab flounder, plaice and cod (full specific names are given in Table 1). Special consideration was given to Dover sole which ecologically (although not phylogenetically) resembles the Pacific Dover sole in having a stronger preference for soft sediments than the other species listed. (The Pacific Dover sole is more closely related to the lemon sole



(a)
North Sea
England
Southwold
Thames Estuary
Rye Bay
France
English Channel
61°
57°
56°
55°
54°
53°
52°
51°
50°
49°
6°
5°
4°
3°
2°
1°
0°
1°
2°
3°
4°
(b)
Essex
R Blackwater
R Crouch
R Thames
10m
East Swin
North Barrow Deep
Dumping ground
Middle Deep
South Barrow Deep
The Warp
North Sea
20m
51°30′N
0 5 10
km
Kent
1° E

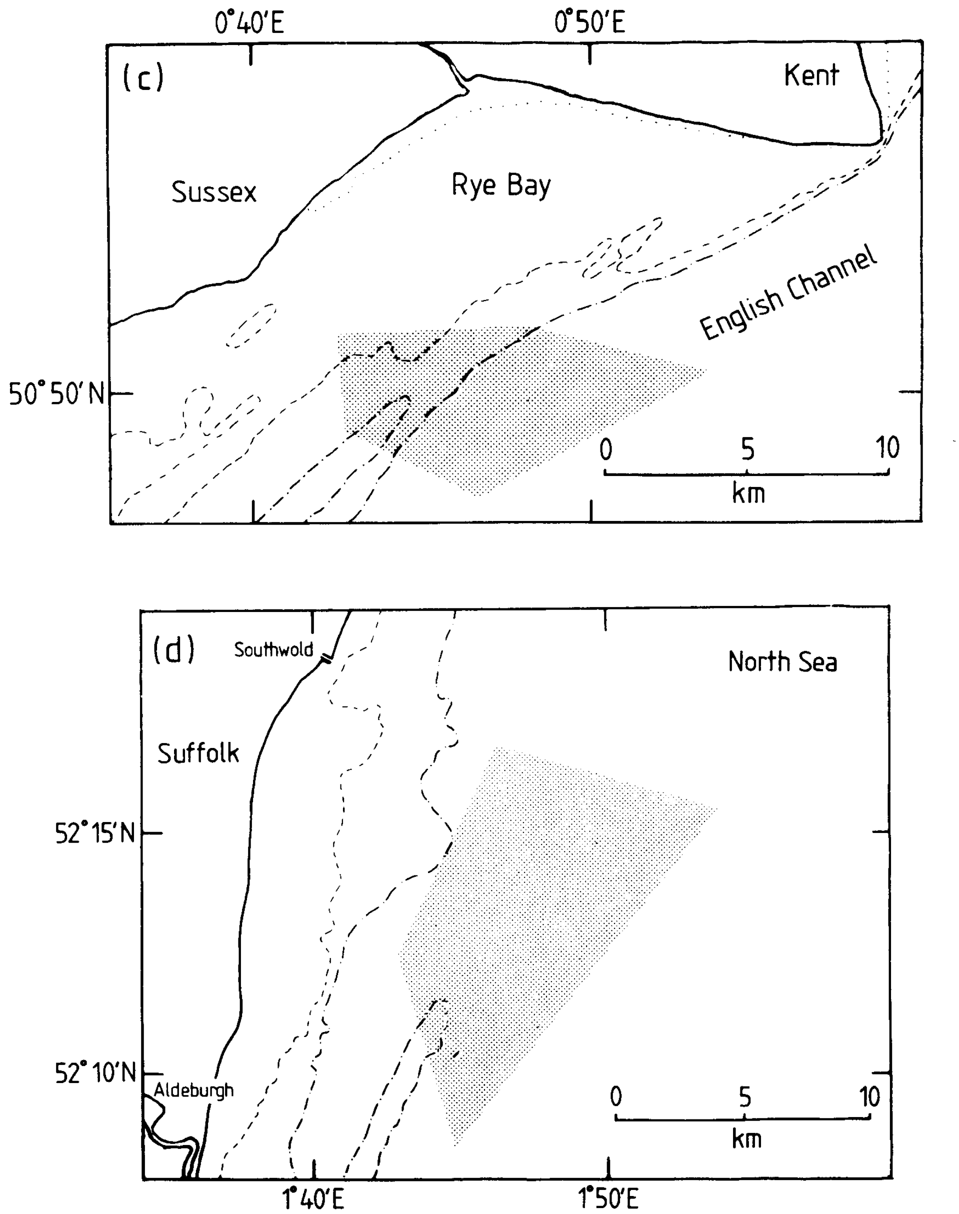


Figure 1 Areas sampled in the present study: (a) location of areas; (b) the outer Thames Estuary, showing the area used for the dumping of sewage sludge; (c) Rye Bay; (d) off Southwold. [shaded] trawling sites.

Table 1 Specific names of fish examined for abnormality

Gadus morhua Linnaeus, 1758	Cod
Limanda limanda (Linnaeus, 1758)	Dab
Microstomus kitt (Walbaum, 1792)	Lemon sole
Platichthys flesus (Linnaeus, 1758)	Flounder
Pleuronectes platessa Linnaeus, 1758	Plaice
Solea solea (Linnaeus, 1758)	Dover sole

which is generally associated with coarser offshore substrates). The survey was carried out in spring when adult Dover sole move inshore to spawn, thus increasing the numbers in the inshore areas covered by the survey.

2.2 Areas selected for study

Within the outer Thames Estuary (Figure 1) sewage sludge is dumped at the northern end of the Barrow Deep. Trawlable grounds in that vicinity are limited by the complex topography to the East Swin, Middle Deep, Barrow Deep and The Warp (Figure 1b). Earlier studies (Norton *et al.*, 1981) showed that sediments in the Barrow and Middle Deeps were contaminated with sludge particles but that the East Swin was outside the main area of settlement of dumped sludge. The areas of The Warp and West Swin further up the estuary contained sediments affected more by estuarine and river discharges. The area sampled thus offered a gradient from the offshore waters unaffected by sludge settlement, through areas known to be affected by sludge settlement, to areas subject to contamination from several sources. Fish sampled in each of these discrete trawling areas were inspected to determine whether any spatial trends were evident, although the mobility of the fish may result in their being influenced by conditions in the estuary as a whole rather than by local conditions.

Two other areas were also selected to provide controls against which the results of the Thames Estuary survey could be assessed. In view of the possibility of trawl damage being confused with fin 'rot', control areas were sought which would be subject to a similar fishing intensity while being remote from the influence of sewage and other discharges. Rye Bay was selected as one control area (Figure 1c) since it was known to be a sole ground supporting a different stock from that populating the outer Thames Estuary; it had also been used as a control area by Shelton and Wilson (1973 a, b) in their studies of disease in Liverpool Bay fisheries. The second control area was a sole ground off Southwold (Figure 1d) which, although more distant from sewage and other discharges, probably contained sole from the same stock as the Thames Estuary.

2.3 Sampling

Trawling was conducted from the MAFF Research Vessel CORELLA between 29 April and 12 May 1980 and also from a local fishing vessel, the MV MAAGEN, on 23 June, 3 and 7 July 1980. Four separate areas (East Swin, The Warp, Middle Deep and north-east of the dumping ground) in the outer Thames Estuary were worked by RV CORELLA, trawling being restricted to daylight hours for navigational reasons and being further limited by inclement weather to the more protected sites. Subsequent trawling by MV MAAGEN enabled the narrower parts of the Barrow Deep south-west of the dumping ground to be sampled.

The fish from each haul were separated into species, individually measured and carefully examined for any disease or abnormality under the headings of fin rot, fin damage, ulcers, haemorrhaging (both as petechiae and bleeding wounds), nodules and tumours, lymphocystis, skeletal deformities, and other anomalies. Pigment variations were also recorded, except for flounders for which only gross changes were noted (non-melanised patches are so common in this species that they cannot be regarded as abnormalities). A selection of abnormal fish was photographed at sea and most were deep frozen for subsequent re-examination. Samples of abnormal epidermal tissues, livers and spleens from diseased fish, random samples of visceral organs from apparently healthy fish, and any fish exhibiting vertebral anomalies were preserved in 10% formal saline for subsequent histological examination.

2.4 Diagnosis of abnormalities

2.4.1. *Differentiation between fin rot and fin damage*

Many workers refer to the difficulty of distinguishing fin rot from damage caused, for example, by trawling. Sindermann *et al.* (1978) in their field guide do not attempt to define precisely the symptoms of fin rot although they mention the possibility of blackening and opacity of tissues at the base of the eroded area, formation of scar tissue and also the collapse and resorption of fin rays. They do, however, list the general characteristics of fin *damage* as 'a) active haemorrhaging of fin tissue, b) many red spots or 'petechiae' on the body of the fish, c) exposed fin rays and splitting of fin membranes, and d) absence of melanized or darkened tissue at erosion sites'. They also state that 'other forms of rough handling of catches may also produce superficial abrasions that may be confused with fin erosion'.

Difficulties in identification may still arise, however, when fin rot and damage are present together. In practice, the most significant distinguishing feature was taken to be the state of the fin rays which, according to Sindermann, should in fin rot be eroded to the same level as the membranes. But this characteristic could not be taken as the single distinguishing feature because in some cases loss of fin rays as well as membrane could be clearly attributed to physical damage, especially when associated with haemorrhaging or physical damage on other parts of the fish. Melanized tissue at the edge or eroded fins (referred to by Sindermann and others as an indication of fin rot) was not always observed in the present study and was not assumed to be necessary for the diagnosis of fin rot, particularly since melanization can be difficult to see in naturally dark-skinned fish.

The procedures used in this study to describe fin rot and fin damage comprised an initial subjective classification at sea followed by a more objective analysis of the lesions in the laboratory. In the latter examination both the extent of the rot along and into the fin were categorised as slight, moderate or sever according to the criteria shown in Appendix 1. Although it is recognised that the distinction between each category of fin rot is arbitrary, the use of a consistent method of classification assists further discussion and the comparison of results from different laboratories.

We have thus described these classification procedures in some detail in Appendix 1 so that the scheme could, if required, be used in future studies to ensure the use of consistent terminology.

In some cases fish fins were damaged during deep freezing and subsequent handling, making the re-assessment of fin damage at the laboratory impossible; in these cases reliance had to be placed on the original assessment made at sea.

2.4.2. *Histological examination*

Samples were prepared for histological examination by embedding in paraffin wax and staining 6 μm sections of the embedded tissues with haematoxylin and eosin (HE) according to Bucke (1972). In addition, certain samples were stained for: a) micro-organisms, using Giemsa, Gram-Twort, Lendrum's phloxine-tartrazine, and Ziehl-Neelsen (ZN) techniques; b) morphological details using van Gieson stain, Martius-scarlet-blue (MSB) and periodic-acid-Schiff (PAS). All methods are described by Disbrey and Rack (1970).

3. Results and discussion

3.1 Overall incidence of abnormalities

A total of 7 448 fish (2 344 Dover sole, 971 cod, 978 flounder, 1 484 dab, 1 597 plaice, 74 lemon sole) were examined of which 554 (8.0%) had some visible (i.e. external) abnormality. The full results are presented in Table 2 which lists the abnormalities found for each species in each of the areas sampled: only the presence of an abnormality is indicated, not the degree of severity. The data in Table 2 are based on the visual assessment made at sea, but some pathological diagnoses were also based on histological examination of selected examples of abnormality.

Photographs of many of the abnormalities are included in Plates 1-8: the photographs of other than histological sections each bear a scale marking representing 1 cm length.

3.2 Fin rot

A total of 110 fish showed some degree of fin rot (1.5% of the total sampled). The frequency of fin rot encountered in the three main areas is shown in Table 3 and some typical examples of fin rot are shown in Plates 1 and 2. Due to the small size of some samples, caution is required in making direct comparisons between areas. However, there did appear to be a slightly greater incidence of fin rot in the outer Thames Estuary than in Rye Bay for those species for which comparative data exist (flounder, dab, plaice). On the other hand, three of the species collected at Southwold (Dover sole, flounder and dab) had a greater incidence of fin rot than those from the Thames, although cod taken at Southwold were completely free of fin rot.

When the results of the two control areas are combined the incidence of fin rot in cod, flounder, plaice and dab appears to be slightly higher in the Thames area. The t test shows these differences to be of only limited statistical significance ($P < 2.5\%$) and when the uncertainties inherent in the diagnosis are considered it is doubtful whether real differences in the incidence of fin rot between areas have been detected.

Comparing the levels of incidence found in the Thames Estuary (0-3.8% according to species) with those reported by other workers, it can be seen that the levels in this study are generally in the lower part of the reported range. For instance the incidence of fin rot in Pacific Dover sole off southern California (Sherwood and Mearns, 1977) ranged from 0.7 to 3.9% while the incidence in other species of sole ranged from 0.4 to 13%. Mahoney *et al.* (1973) reported the incidence of fin rot in winter flounder and summer flounder to be 2-55% in the Raritan Bay area, and Ziskowski and Murchelano (1975) found that between 3.9 and 16.3% of winter flounder had some degree of fin rot in the New York Bight Apex, while outside this area the incidence was 0-2.3%.

The incidence of fin rot in dab in the North Sea was found by Möller (1979) to be 0.2-0.3%, while Dethlefsen (1978) found that the average incidence offshore was 1.6%, rising to a maximum of 13.9% in one sample in the region of the sewage sludge dumping site in the German Bight. The rate of incidence in dab taken on our survey of the Thames Estuary (2.2%) was roughly the same as Dethlefsen found for the German Bight as a whole (2.1%).

Only few data are available for cod: Dethlefsen reported an incidence ranging from zero offshore to a maximum of 1.4% (mean of 0.7%) in the German Bight sewage sludge dumping area, and the incidence found in the Thames Estuary (0.8%) is comparable with the levels found in his studies.

The above comparisons should perhaps be regarded with caution in view of the different methods employed for classifying fin rot as well as for differentiating it from fin damage. This can be seen from the attempt in our study to grade the severity of fin rot as slight, moderate or severe. Using the scheme described in Appendix 1, 65% of our cases of fin rot have been classified as slight, with only 6% in the severe category (Table 4). There is thus considerable scope for different results depending on how 'fin rot' is defined by the investigators. The few photographs of fin rot published hitherto show a degree of fin rot which we would place into our 'severe' category (see Sindermann *et al.*, 1978; Sherwood, 1978). If only severe infections such as those illustrated are taken as indicative of fin rot, then it is clear that the incidence of fin rot in our study would be extremely low by comparison.

The data in Table 2 have also been reviewed in relation to a number of other factors such as position of capture within the Thames Estuary, size of fish, location of the fin rot on the fish, and possible association of fin rot with fin damage. No consistent spatial trends were apparent in any of the species sampled, which is not unexpected in view of the limited size of the sampling area and the mobility of the fish. The size distribution of all fish caught is compared with that of fish with fin rot in Figure 2. There is some indication that larger flounders, plaice and dabs in the Thames Estuary are more likely to have fin rot than smaller ones, but such an interpretation cannot be statistically substantiated as the size composition data of the affected fish based on small numbers.

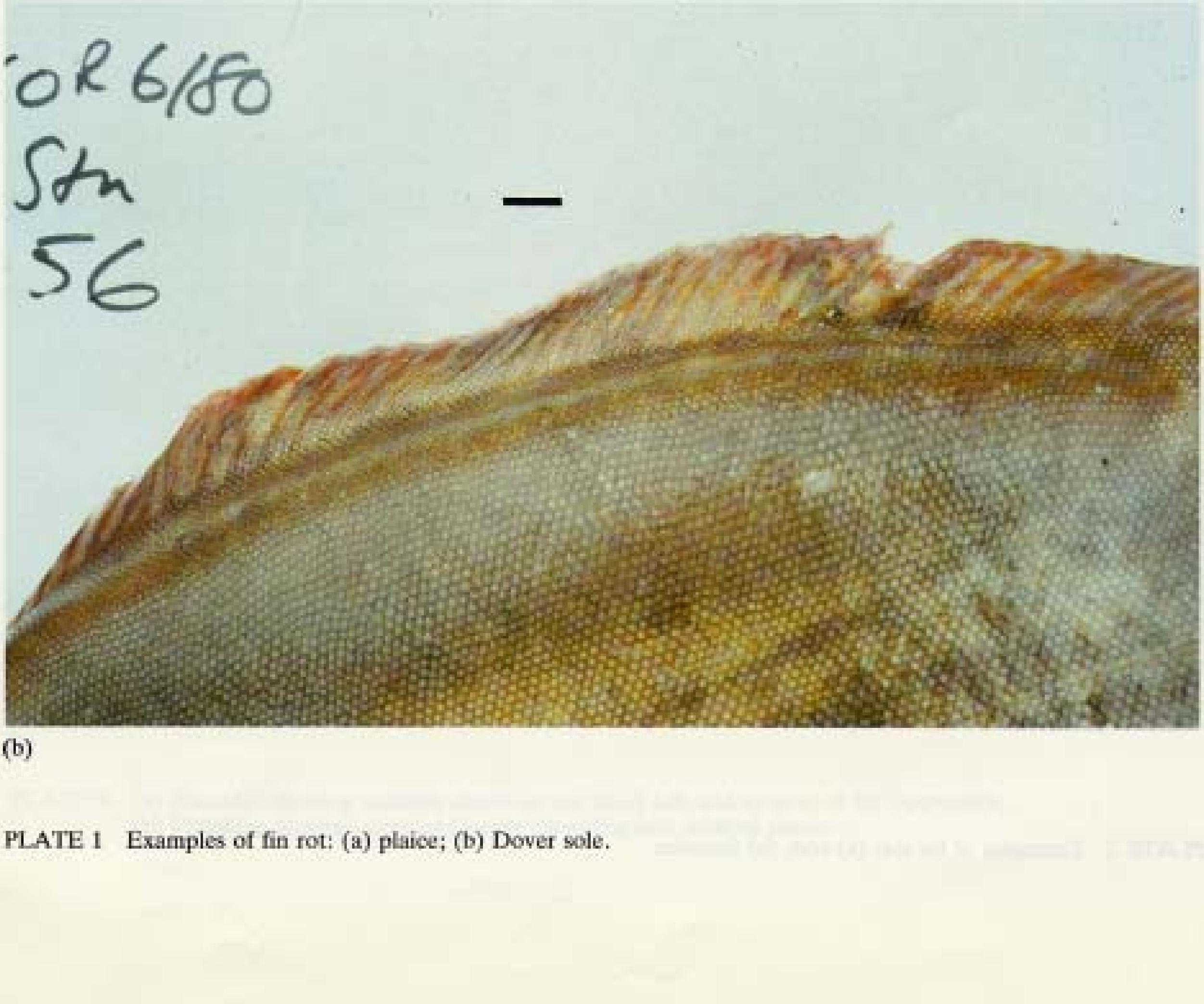
The site and severity of the fin rot on each affected fish is given in Table 4. The most common sites of the lesions varied between species, e.g. 65% of all cases of fin rot observed on Dover sole occurred on the caudal fin, whereas this was the site for only 37% of the cases in flounders. In the remaining cases, fin rot was restricted to the dorsal or ventral fin, apart from one case of erosion of a pectoral fin.

Table 2 Abnormalities in examined fish

Species	Area	Total number caught	Abnormalities (Percentage of total number of each species caught in each area)									
			All† abnorm-alities	Fin rot	Fin damage	Ulcers	Haemor-rhages	Pigment abnor-alities	Nodules	Lympho-cystis	Deform-itites	Others
Sole	East Swin	432	4.6	0.9	0.7	0.5	2.1	1.1	0.2	0	0	0.2
	Warp	480	17.3	1.7	2.7	2.3	5.6	5.2	1.1	0	0.8	0.6
	Barrow (N)≠	556	2.6	0.4	0.5	0.2	1.1	0.5	0.2	0	0	0.2
	Barrow (S) *	56	1.7	1.7	7.1	0	0	0	0	0	0	0
	Middle Deep	118	4.1	0	0	1.6	1.6	0.9	0	0	0	0
	Thames (total)	1 742	7.6	0.9	1.4	1.0	2.7	2.1	0.4	0	0.2	0.3
	Rye Bay	61	4.8	0	3.2	0	0	0	0	0	3.2	1.6
	Southwold	541	3.9	1.6	1.1	0.4	0.2	0.2	0.4	0	0.9	0.2
Cod	East Swin	99	3.0	2.0	45.5**	0	1.0	0	0	0	0	0
	Warp	159	3.6	0.6	3.8	0.6	0.6	0	0.6	0	0.6	0.6
	Barrow (N)	401	1.3	0.8	0	0	0	0	0	0	0	0.5
	Barrow (S)	0	0	0	0	0	0	0	0	0	0	0
	Middle Deep	67	1.5	0	0	1.5	0	0	0	0	0	0
	Thames (total)	726	2.0	0.8	NR	0.3	0.3	0	0.1	0	0.1	0.4
	Rye Bay	88	1.1	0	1.1	0	0	0	0	0	0	0
	Southwold	157	1.8	0	0.64	0	0	0	0	0	1.2	0.6
Flounder	East Swin	37	32.3	13.5	13.5	5.4	0	2.7	10.8	0	0	0
	Warp	58	20.9	1.7	5.2	3.5	3.5	3.5	0	0	5.2	3.5
	Barrow (N)	12	8.3	0	0	0	0	0	0	8.3	0	0
	Barrow (S)	161	5.4	3.0	5.0	0.6	0	0	0	0.6	1.2	0
	Middle Deep	233	8.9	3.0	4.3	1.2	0	0	0	2.6	0.9	1.2
	Thames (total)	501	11.2	3.8	5.4	1.6	0.4	0.6	0.8	1.6	1.4	1.0
	Rye Bay	454	11.3	2.9	1.3	1.5	1.1	0.7	1.1	3.1	0.2	0.7
	Southwold	23	12.9	4.3	0	0	0	0	0	8.6	0	0
Dab	East Swin	15	0	0	0	0	0	0	0	0	0	0
	Warp	17	0	0	0	0	0	0	0	0	0	0
	Barrow (N)	42	2.4	2.4	2.4	0	0	0	0	0	0	0
	Barrow (S)	282	5.0	2.5	4.6	1.8	0	0.7	0	0	0	0
	Middle Deep	7	0	0	14.3	0	0	0	0	0	0	0
	Thames (total)	363	4.2	2.2	4.1	1.4	0	0.6	0	0	0	0
	Rye Bay	983	3.4	0.9	0.7	1.6	0.3	0.4	0	0.2	0	0
	Southwold	138	8.6	4.3	0.72	1.4	0	0	0	2.2	0.7	0
Plaice	East Swin	19	0	0	0	0	0	0	0	0	0	0
	Warp	47	16.9	2.1	10.6	2.1	6.4	2.1	0	0	4.2	0
	Barrow (N)	17	11.8	0	5.9	0	11.8	0	0	0	0	0
	Barrow (S)	935	2.1	1.5	5.8	0.2	0.1	0.2	0	0	0.1	0
	Middle Deep	7	0	0	0	0	0	0	0	0	0	0
	Thames (total)	1 025	3.0	1.5	6.0	0.3	0.6	0.3	0	0	0.3	0
	Rye Bay	561	4.0	1.4	1.2	0.2	1.1	1.1	0.2	0	0	0
	Southwold	11	0	0	0	0	0	0	0	0	0	0
Lemon Sole	East Swin	0	0	0	0	0	0	0	0	0	0	0
	Warp	1	0	0	100	0	0	0	0	0	0	0
	Barrow (N)	47	0	0	0	0	0	0	0	0	0	0
	Barrow (S)	0	0	0	0	0	0	0	0	0	0	0
	Middle Deep	0	0	0	0	0	0	0	0	0	0	0
	Thames (total)	48	2.1	0	2.1	0	0	0	0	0	0	2.1
	Rye Bay	26	7.6	3.8	0	0	3.8	0	0	0	0	0
	Southwold	0	0	0	0	0	0	0	0	0	0	0

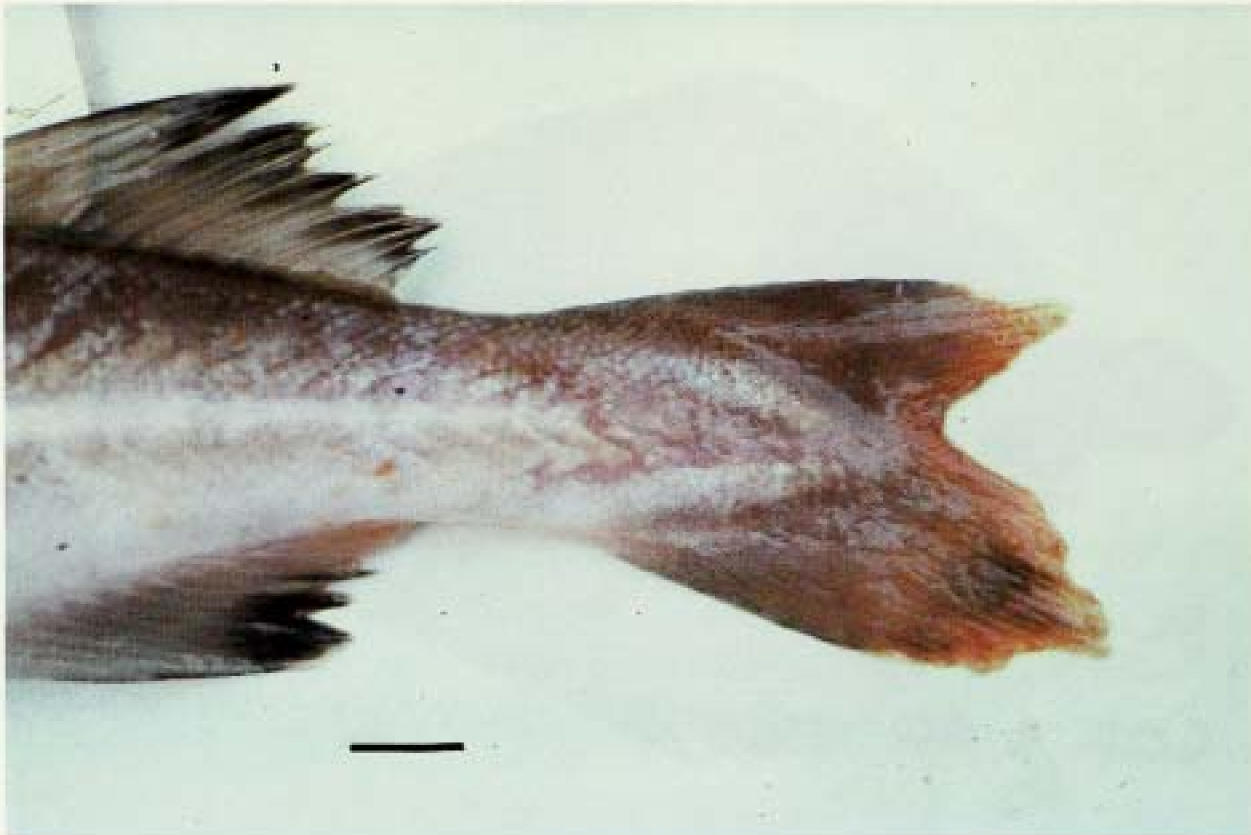
† Excluding fin damage
≠ Near dumping ground
* South of dumping ground
** Included recording of minimal fin damage found on nearly all small (<30 cm) cod. Subsequent stations recorded only on larger (>30 cm) fish
NR Not recorded

(a)

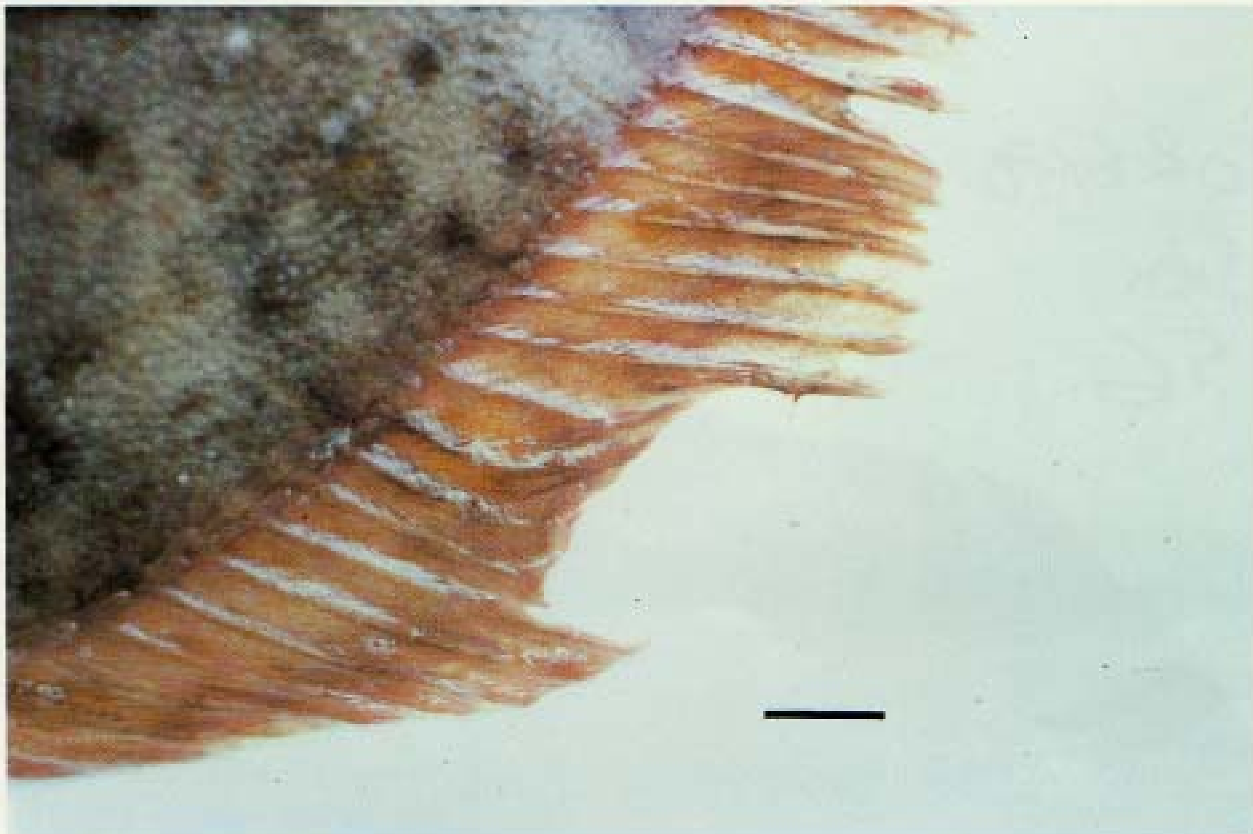


(b)

PLATE 1 Examples of fin rot: (a) plaice; (b) Dover sole.

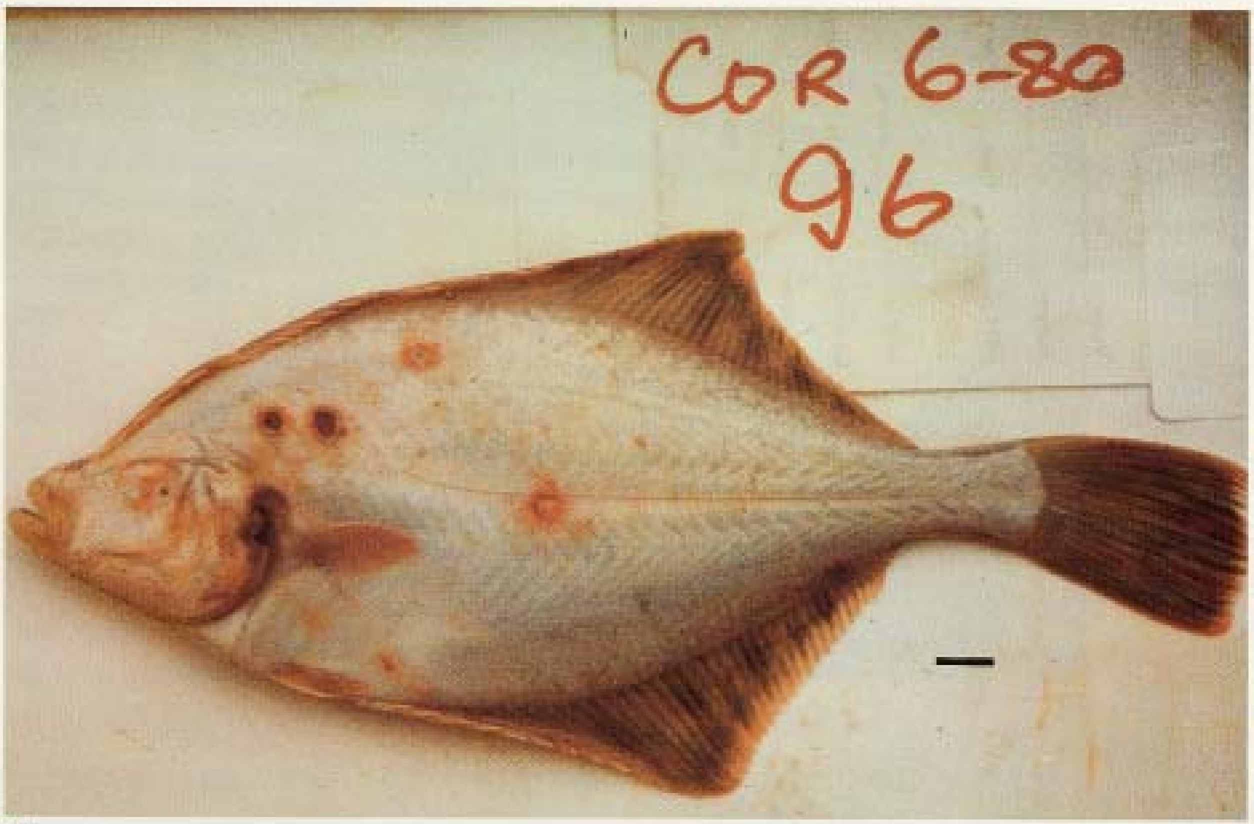


(a)



(b)

PLATE 2 Examples of fin rot: (a) cod; (b) flounder.



(a)


(b)

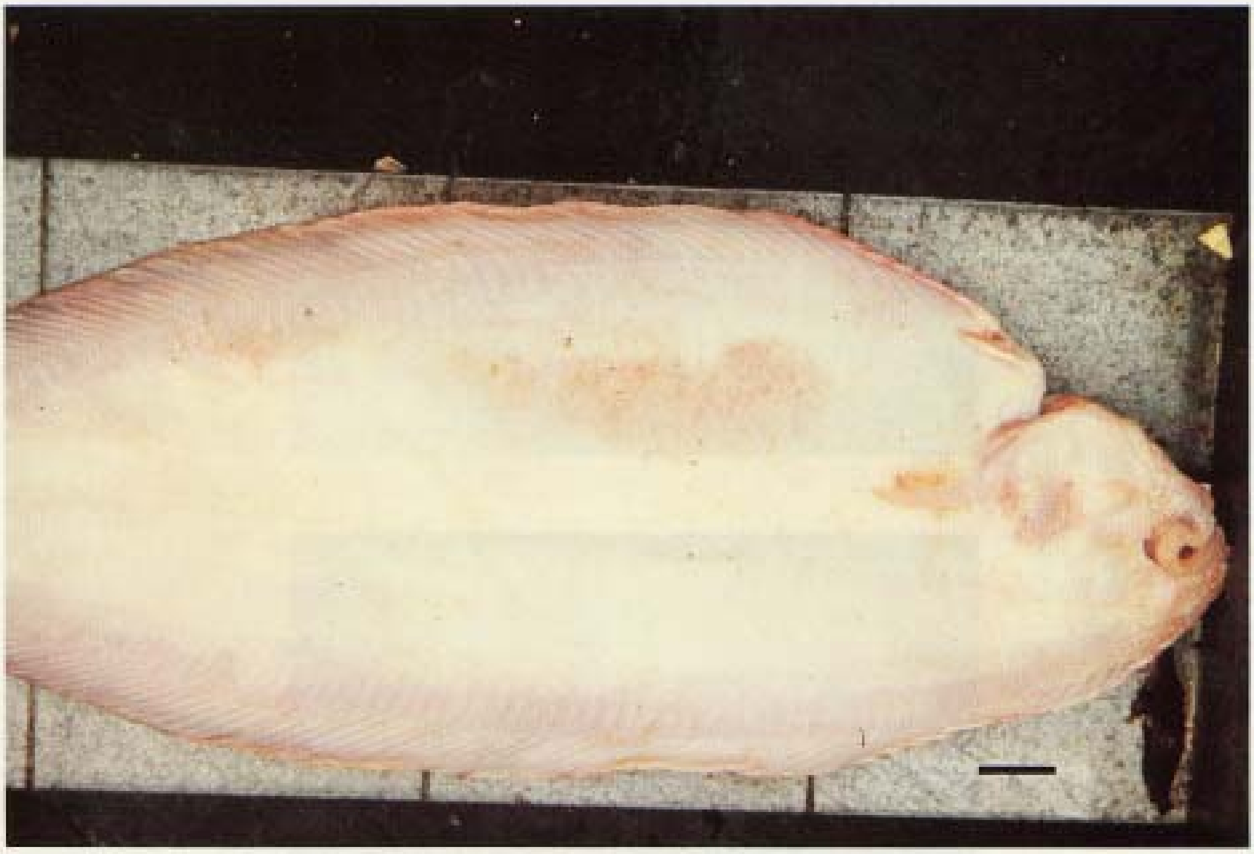
PLATE 3 (a) Flounder showing multiple ulcers on the blind side and erosion of the operculum.
(b) Flounder showing ulcerated lesion extending into osseous tissue.

(a)

(b)

(c)

PLATE 4 (a) Dover sole showing a single ulcer on the blind side.
(b) Section of ulcer in Dover sole, showing loss of epidermis (arrowed), hyaline tissue (H), phagocytic cells (P), fibrous tissue (F) and skeletal muscle (M). (HE stain, magnification x 50.)
(c) Section of ulcer in cod, showing cellular infiltration and muscle necrosis. (HE stain, magnification x 175.)



(a)

(b)

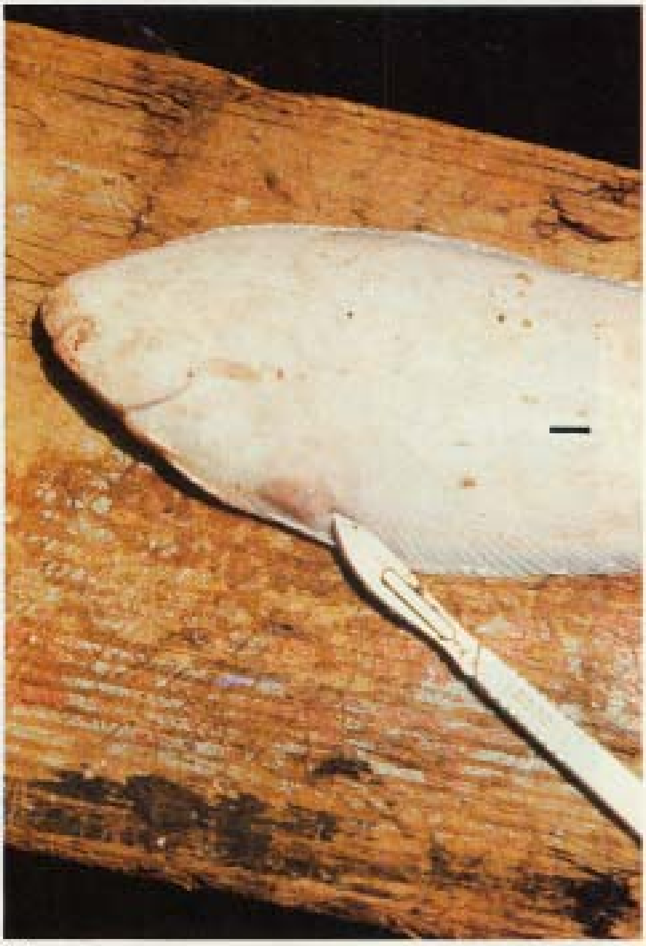
PLATE 5 (a) Haemorrhagic area on the blind side of a Dover sole.
(b) Flounder showing loss of pigmentation on the caudal peduncle.

(a)

(b)

(c)

PLATE 6 (a) and (b) Nodule on the operculum of a flounder, viewed (a) from above, (b) from side.
(c) Transverse section of a nodule – an inflamatory lesion involving the fin-ray – on the caudal fin of a Dover sole, showing epidermis (E), disintegrated bone (B) and inflammatory cells (I). (HE stain, magnification x 50.)

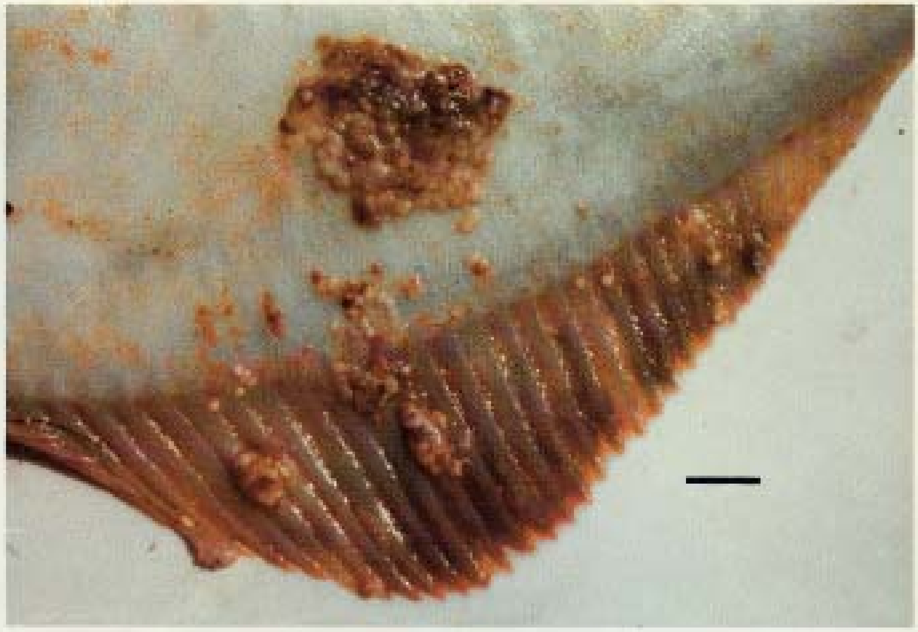


(a)

(b)

PLATE 7 (a) Tumour on the blind side of a Dover sole (the scalpel points to the lesion).
(b) Section of a Dover sole 'tumour', showing the epidermis (E) and multiple thickened fibrous walls (F) forming a capsule containing necrotic cells (N). Cellular infiltration of the muscle (M) is also evident. (HE stain, magnification x 50.)

(a) Lymphocystis nodules on the blind side of a flounder.



(b) Deformity (compression) in cod.

(c) Spinal scoliosis in dab.

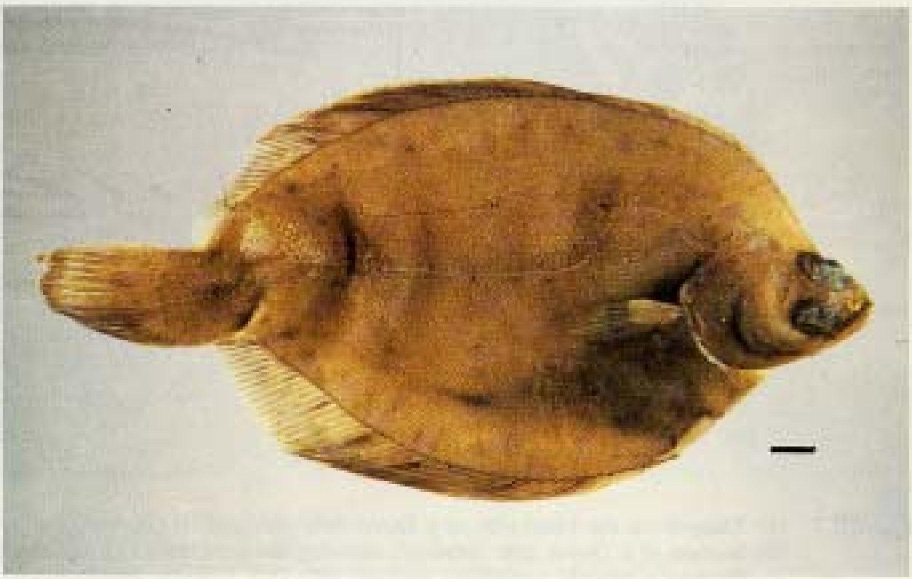


PLATE 8

Table 3 Percentage occurrence of fin rot in main sampling areas (Data exclude samples containing < 10 fish)

Species	Thames	Rye Bay	Southwold	Southwold and Rye Bay combined
Dover sole	0.9	0*	1.6	1.3
Cod	0.8	0*	0	0
Flounder	3.8	2.9	4.3*	2.9
Dab	2.2	0.9	4.3	1.3
Plaice	1.5	1.4	0*	1.4
Lemon sole	0	3.8*	ID	3.8*

ID = Insufficient data
* Sample size 10-100 fish

Table 4 Site and severity of cases of fin rot found in fish

Species	Area	Instances on dorsal or ventral fin				Instances on caudal fin				Instances on pectoral fin	Total No. of fish with fin rot		
		Slight	Moderate	Severe	Total	Slight	Moderate	Severe	Total		Slight	Moderate	Severe
Dover sole	Thames	4	0	0	4	10	1	0	11	0	14	1	0
	Rye Bay	0	0	0	0	0	0	0	0	0	0	0	0
	Southwold	4	1	0	5	5	1	0	6	0	7	2	0
Cod	Thames	2	1	0	3	1	1	1	3	0	3	2	1
	Rye Bay	0	0	0	0	0	0	0	0	0	0	0	0
	Southwold	0	0	0	0	0	0	0	0	0	0	0	0
Flounder	Thames	11	3	0	14	5	2	0	7	1*	12	7	0
	Rye Bay	5	3	0	8	4	3	0	7	0	7	6	0
	Southwold	1	0	0	1	0	0	0	0	0	1	0	0
Plaice	Thames	4	3	0	7	6	2	1	9	0	10	3	2
	Rye Bay	3	2	0	6	1	2	2	5	0	4	2	2
	Southwold	0	0	0	0	0	0	0	0	0	0	0	0
Dab	Thames	5	0	0	5	1	1	1	3	0	6	1	1
	Rye Bay	2	1	1	4	2	4	0	6	0	3	5	1
	Southwold	4	1	0	5	1	1	0	2	0	4	2	0
Lemon sole	Thames	0	0	0	0	0	0	0	0	0	0	0	0
	Rye Bay	1	0	0	1	0	0	0	0	0	1	0	0
	Southwold	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL		46	15	1	62	36	18	5	59	1	72	31	7

*Moderate

Seven 'severe' cases of fin rot were found out of the 110 affected, all but one occurring on the caudal fin (or caudal fin and peduncle). Since the location and the severity of the fin rot have not been included in other published results it is not possible to compare these findings with other studies.

Fin damage (as opposed to fin rot) was generally in the form of torn or broken fin rays and/or membranes. The degree of fin damage varied between species and areas, the greatest numbers of damaged fish being found in the Thames area where it is probable that relatively more fishing activity occurs. It was not possible to identify the origin of damage in many cases, and a significant proportion may have occurred during capture in the survey itself. It is noteworthy that a very high percentage of fin damage in cod occurred in small fish, possible due to escape through the meshes during previous encounters with fishing gear. The characteristics used to differentiate fin rot from fin damage allow the more severe cases to be identified with confidence, but where slight fin rot or damage occurred

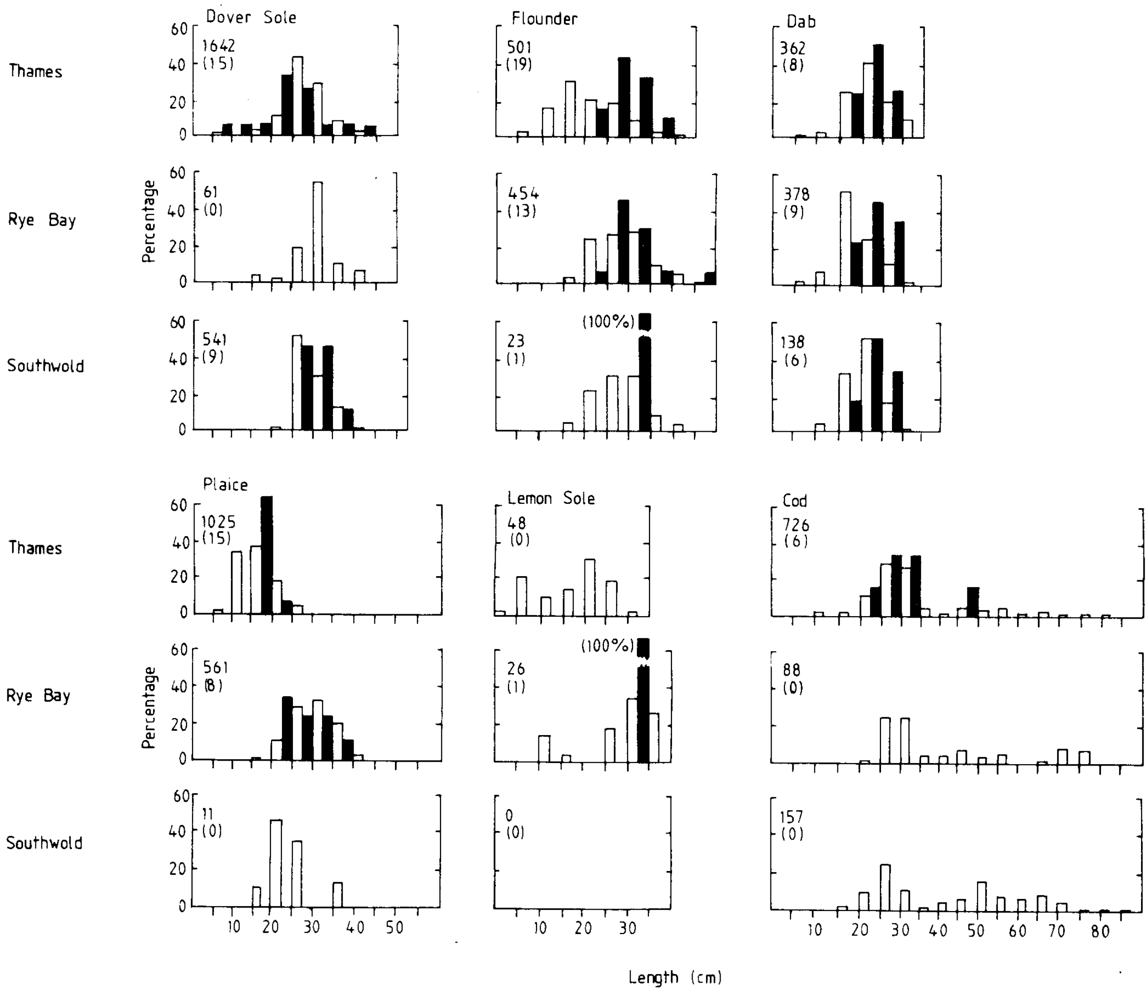


Figure 2 Size distribution of fish with fin rot compared with those of all fish caught in each area.

■ with fin rot; □ all fish; 1 642(15) total number of fish (number with fin rot)

there was more scope for error in the subjective assignment of individual cases to the rot or damage categories. In view of these uncertainties, caution should be exercised in making comparisons between the results of different workers.

An examination of fish affected by fin rot showed that early lesions could be identified by a loss of epidermis and superficial haemorrhaging, and in a few samples there was evidence of bacterial involvement. The more established lesions showed a range of pathological changes which included areas of fibrosis and cellular activity. A more critical examination revealed granulomatous foci, some with necrotic centres, set between phagocytic and multinucleated cells, particularly where degenerating osseous tissue (fin-rays) was found. Reparation was indicated in some lesions by the presence of amorphous acidophilic material on their outer edges.

It was difficult to distinguish early stages of fin-rot lesions from trauma, and further work would be required to quantify the proportion of fin-rot cases in each category of severity. However, it was evident that, although there were considerable variations in the pathological changes involved in these lesions, most cases examined were chronic and proliferating. Murchelano and Ziskowski (1977) considered that pathological variations of fin-rot lesions had an association with the seasonal behaviour of the summer flounder *(Paralychthys dentatus)* and showed those lesions to have a different morphology from fin rot in the winter flounder *(Pseudopleuronectes americanus)*. These workers suggested that fin rot in summer flounder was acute or 'non-proliferating' and associated with bacterial infection, whereas that in winter flounder was chronic or 'proliferative'.

Fin-rot lesions should perhaps be regarded as a special manifestation of epidermal ulcers (Section 3.3) and therefore both could be regarded as a single type of abnormality. However, in view of the small number of ulcerated fish which were examined histologically, any association between these two abnormalities must remain tentative. So here numerical treatments of the two symptoms have been kept separate. It is of interest, however, that grouping ulcers with fin rot would not radically change the conclusions drawn from Table 3, and does not affect the statistical significance of the difference between the number of fish affected in the Thames Estuary and the Rye Bay/Southwold areas.

3.3 Ulcers

In the flatfish the ulcers varied from small (5 mm diameter) red superficial lesions to large (several cm) eroded areas involving the sub-dermal tissues and extending into the bony structures of the operculum (Plates 3 and 4). Histological examination showed varying stages of inflammation and repair but more usually ulceration resulted in an area devoid of epidermis and perhaps also of dermis. The affected tissues consisted of granulomatous areas, some of which had necrotic centres made up of serous material and phagocytic cells. Often there was extensive fibrous connective tissue extending into the skeletal muscle and along the sub-dermal connective tissue layers (Plate 4). In some instances the skeletal muscle tissues showed evidence of Zenker's necrosis and even a breakdown of osseous tissue. The healing ulcers showed well organised fibrous and vascular elements which sometimes involved the subcutaneous fatty tissues. The outer edges of these ulcers were often bounded by amorphous hyaline material or newly established epithelium. Ulcers in the gadoids revealed the oedematous changes in the sub-dermal connective tissues and marked muscle necrosis (Plate 4).

Where more than 100 fish of a given species were taken, ulceration was most prevalent in flounders and dabs in the Thames Estuary and Rye Bay, where the incidences were in the range 1.4-1.6% (Table 2). These were well below those recorded in the central and eastern parts of the North Sea (Möller, 1979, 1981 a, b). The incidence of ulceration in Thames Estuary cod was low at 0.3%, and below that found elsewhere in the North Sea (Dethlefsen, 1980; Möller, 1981 a, b). Some spatial trends were apparent, the incidence of ulcers being higher in the inner Thames Estuary (The Warp area) where it was 2% compared with 0.5% in the other four areas of the Thames Estuary, 1% in Rye Bay and 0.4% off Southwold.

Most of the ulcerated tissues examined histologically exhibited chronic symptoms, and the histopathological changes observed resembled those associated with fin rot, i.e. loss of epidermis accompanied by dermal fibrosis often extending into the musculature, hyperaemia, necrosis, and sometimes haemorrhage. Where these symptoms were absent, only superficial epidermal changes were observed, occasionally associated with bacterial action.

Sindermann (1979) extensively reviewed the subject of epidermal ulceration in fish, and stated that, after fin rot, it was the next most commonly reported anomaly of fish from polluted waters. His review revealed that 'ulceration of bacterial aetiology' was the most likely cause of these epidermal lesions, although he recognised other causes such as trauma, predator attacks and parasitic infections. Perkins *et al.* (1972) suggested that the ulcers in dabs, plaice and flounders caught from the north-eastern Irish Sea did not have the typical appearance of ulcers caused by bacteria, but they did not suggest a cause. In studies on epizootics in perch, *Perca fluviatilis*, where extensive epidermal ulceration was a common characteristic, the primary cause was initially considered to be unknown (Bucke *et al.*, 1979) although further studies have suggested bacterial aetiology (Bucke, 1979). Similarly, carp erythrodermatitis, an ulcerative condition in cyprinids which for many years was of unknown aetiology (Fijan, 1972; Bucke *et al.*, 1975), is now accepted as a bacterial disease (Bootsma *et al.*, 1977). Therefore, a bacterial aetiology of the ulcerous, and perhaps fin rot, lesions in the fish sampled in our study should be considered, but such epizootics are seldom spontaneous, and the interaction of several environmental conditions including temperature, salinity, nutritional deficiencies, and stress from pollution, as well as overcrowding, are probably associated with an infectious disease process. In particular, *Vibrio* spp are known to be present and pathogenic to fish and shellfish in estuarine waters of low salinity.

3.4 Haemorrhages

These included petachiae (small blood spots just below the skin surface), bleeding and healed wounds and were generally superficial (Plate 5). Histological examination showed only minimal dilation of the dermal blood vessels, with no gross changes. Although wounds obviously caused by trawling were not included, it is likely that past fishing activity or bruising during the landing of each haul could account for some of the haemorrhages, so a relationship between the occurrence of haemorrhages and fin damage might be expected. Haemorrhages were most common in fish taken from The Warp where the incidences in Dover sole, flounder and plaice were 5.6, 3.5 and 6.4% respectively; fin damage was also common in these cases. However, a high incidence of haemorrhage (11.8%) also occurred in plaice near the Thames dumping ground where no fin damage was observed. No simple relationship exists between fin damage and haemorrhage, as is shown by the lack of any statistical correlation between these factors, either within each species or area.

Few comparative data for haemorrhages exist as most workers recognise the difficulties of distinguishing disease and injury. However, Dethlefsen (1980) found a positive correlation between the incidence of haemorrhages and of ulceration in cod, plaice, dab and flounder. No statistically significant relationship was apparent in the present study for these species; the only correlation that existed ($P \pm 5\%$) between haemorrhages and ulcers was for Dover sole.

3.5 Pigment abnormalities

Excepting flounder, in which a degree of pigment variability must be regarded as normal, (e.g. Plate 5) most pigment abnormalities were seen in Dover sole, mainly in the form of lighter areas on the upper surface or orange patches on the underside. No histological changes were associated with these variations. As with haemorrhages, the highest occurrence was in Dover sole, flounder and plaice from the Warp area.

3.6 Nodules and tumours

Nodules consisting of small, raised, and often hard lumps were most prevalent in flounder and Dover sole. Nodules which occurred on flounders were generally associated with fin-rays, gill opercula or other bony structures of the head (Plate 6) and could be readily distinguished from the small knobs and roughened areas normally found near the lateral line on the upper side of flounders. In many instances the nodules were red, especially in Dover sole, where they were less than 1 mm in diameter and associated only with fin rays. Occasionally there were multiple nodules on one specimen.

Initial histological examination showed that some nodules were formed by early lymphocystis affected cells, but these were seen in only flounders and plaice. A single nodule found on a cod was identified as a tissue response to a parasite situated in the sub-dermis. The small nodules in the fins of Dover sole and flounder consisted largely of inflammatory cells, with evidence of tissue, including bone, disintegration (Plate 6). Other nodules also showed inflammatory processes, and in some instances where larger nodules or tumours were present (Plate 7) there were fibromatous infiltrations involving sub-cutaneous and muscle tissue. In one instance a 5 mm diameter tumour situated on the caudal peduncle of a Dover sole revealed histological changes including an infiltrating fibrous mass which involved even the vertebrae. In another instance, again in a Dover sole, a sectioned 20 x 10 mm tumour showed multiple thickened fibrous walls surrounding cavernous areas lined by reticulo-endothelial cells; there was little tissue structure within the fibrous capsules, only a few groups of necrotic cells (Plate 7).

Fin-ray nodules similar to those found in this study have been described by Wellings (1969) as 'angioepithelial nodules', and he considered them precursors of epidermal papillomas. In our study, epidermal papillomas (McCain *et al.*, 1978) showing the characteristic X cells were not observed, neither were pseudobranchial tumours of cod (Alpers *et al.*, 1977; McCain *et al.*, 1979; Dethlefsen, 1980) or epidermal hyperplasias of dab (Dethlefsen and Watermann, 1980). In the tumour-like nodules on Dover sole the epidermis was intact, but the dermis looked 'spongy'. Th appearance was due to a network of vascular sinuses, fat cells and hyperaemia. Hard *et al.*, (1979) described similar tumours in *Atopomycterus nichthermerus* (spiky globe-fish) and tentatively suggested that, in the absence of any positive findings of bacteria, fungi or other infectious agents, the lesions represented an inflammatory granulomatous response generated by a superficial parasitic infection. No parasites or other infectious organisms were detected in our study. Some sole were infested with the parasitic copepod *Lepeophthirus* spp, but there did not appear to be any connection between these infestations and the incidence of tumours.

3.7 Lymphocystis

The presence of lymphocystis was indicated either by multiples of rounded nodules or as only one or two small (2 mm diameter), whitish nodules. The multiple forms were especially prevalent on the fins and bodies of flounders (Plate 8). Sites of infection are often seen where previous injuries have occurred and therefore lymphocystis is considered a highly infectious disease (Sindermann, 1979) in which localised skin cells become greatly enlarged by the action of a virus. Histologically these cells were shown to contain basophilic cytoplasm, convoluted cell walls and enlarged nuclei. As has been mentioned already, histological examination showed that some abnormalities first classified as 'nodules' were actually early stages of lymphocystis. The data in Table 2 (based on a visual diagnosis) are thus incomplete, but since only a sub-sample of nodule cases was examined histologically a quantitative reassignment of all nodule cases is not possible.

Lymphocystis was limited to two species, flounder and dab. The most common occurrence was in flounders which had an incidence of 3.1%, 1.6% and 8.6% in Rye Bay, the Thames Estuary and at Southwold respectively. Among dabs, a rate of lymphocystis infection of 2.2% was found at Southwold (which is similar to Möller's (1979) record of 2.5% lymphocystis in dabs taken in the North Sea in 1978), but only 0.2% were affected in Rye Bay and none in the Thames Estuary. These levels are all below those found by Shelton and Wilson (1973 a, b) who reported that in 1972 14.6% of the flounders they caught in Liverpool Bay and 8.8% of those from Rye Bay were infected. Dethlefsen (1980) found that the incidence of lymphocystis in flounders caught in the German Bight in summer ranged from 2.1 to 5.4% and decreased in offshore waters. In addition there is evidence that the disease is more prevalent in estuarine conditions (Brinkmann, 1962).

The large variations in the incidence of lymphocystis found in our study and in those cited above would be consistent with the view often expressed that lymphocystis is an infectious disease whose causes do not appear to bear any relation to pollutant sources. The absence of lymphocystis in species other than those mentioned is in general agreement with the findings of other workers.

3.8 Deformities

Deformities which were found included one specimen of 'compressed' cod and a case of spinal scoliosis in dab

(Plate 8). Most of the other deformities involved abnormally shaped fins, probably attributable to some previous trauma.

Sindermann (1980) suggested that skeletal anomalies may result from genetic damage to eggs, embryos or larvae, or to cytotoxic effects on developmental stages of fish, and in an earlier review (Sindermann, 1979) he quoted several authors who considered there was a causal relationship between skeletal anomalies and environmental conditions. The number of abnormalities found in the current study is too low to allow any comment on the possible causes.

3.9 Other abnormalities

Other abnormalities noted were occasional incisions on the non-pigmented surface in flat-fish, haemorrhagic, oedematous areas affecting the epithelium of eyes in cod (2), and a 30 x 20 mm dark-coloured, epidermal cyst in a lemon sole. The incidence of these abnormalities was too low to warrant further discussion.

4. Conclusions

This survey of diseases and abnormalities in demersal species of fish has allowed the incidence of fin rot, ulcers, haemorrhages, pigment abnormalities, nodules, lymphocystis and other abnormalities to be determined in areas of the outer Thames Estuary and in areas in Rye Bay and off Southwold.

Of the 7 345 fish sampled, 398 (5.4%) had some visible (i.e. external) abnormality (excluding fin damage). Of these, 110 (1.5% of total) showed some degree of fin rot. Using the classification system described, most cases of fin rot were defined as 'slight' and only 7 were considered 'severe'.

The incidence of fin rot was generally lower than that reported by other workers in New York Bight and off the southern California sludge outfalls, but it was similar to that found in the German Bight. There were no clear spatial trends in the occurrence of fin rot. Its incidence in cod, flounder and dab from the Thames area may have been slightly higher than in the reference areas, but the uncertainties inherent in the diagnosis of fin rot, particularly in the early stages, render any firm conclusions liable to some doubt.

Fish taken from those parts of the Thames Estuary where sediments are known to be contaminated from the dumping of sewage sludge showed no evidence of an increased frequency of occurrence of the diseases or abnormalities studied. Nor was there any increase in the outer Thames Estuary generally, although there was some evidence that the incidence of ulcers, haemorrhages and pigment abnormalities was highest in The Warp, the sampling area furthest into the estuary. This area is the furthest from the sludge dumping site and previous studies had suggested that sediments there were more affected by river and estuarine discharges. Histopathological examination did not provide any definite explanation of the cause of these anomalies, except that most ulcerative lesions examined revealed chronic, invasive changes which may have been associated with earlier bacterial infections, especially *Vibrio* spp, some of which are known to be present and pathogenic to fish and shellfish in estuarine waters of low salinity. Haemorrhages are often caused by the impact of fishing gear or subsequent handling, but there did not appear to be a simple association between disease and injury. Pigment anomalies in fish are a relatively common occurrence, especially in flounders, as was evident in this survey, but they have no commercial significance and apparently no pathological effect on the fish.

The incidence of nodules and tumours was low and showed no clear spatial distribution. Histological examination revealed these anomalies to be mostly invasive, proliferating lesions typical of inflammatory responses to protozoal or other parasitic infections, rather than neoplastic conditions. This suggests that more detailed studies of nodular lesions, particularly early lesions in Dover sole, should be made to check for parasites. In addition, the internal organs and tissues of any affected fish should be screened for parasites and compared with organs from unaffected fish.

The incidence of lymphocystis was highly variable and most common in flounder, with the highest incidence in one of the control areas. The results of this study are consistent with those of other workers which show wide variations in the rate of incidence, consistent with lymphocystis being an infectious disease.

The original motive for this study was to determine any effects which the dumping of 5 million t a^{-1} of sewage sludge might have had on the health of fish populations in the outer Thames Estuary. The results provide no evidence that dumping has significantly affected the incidence of fish diseases and abnormalities in the outer Estuary.

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Appendix 1

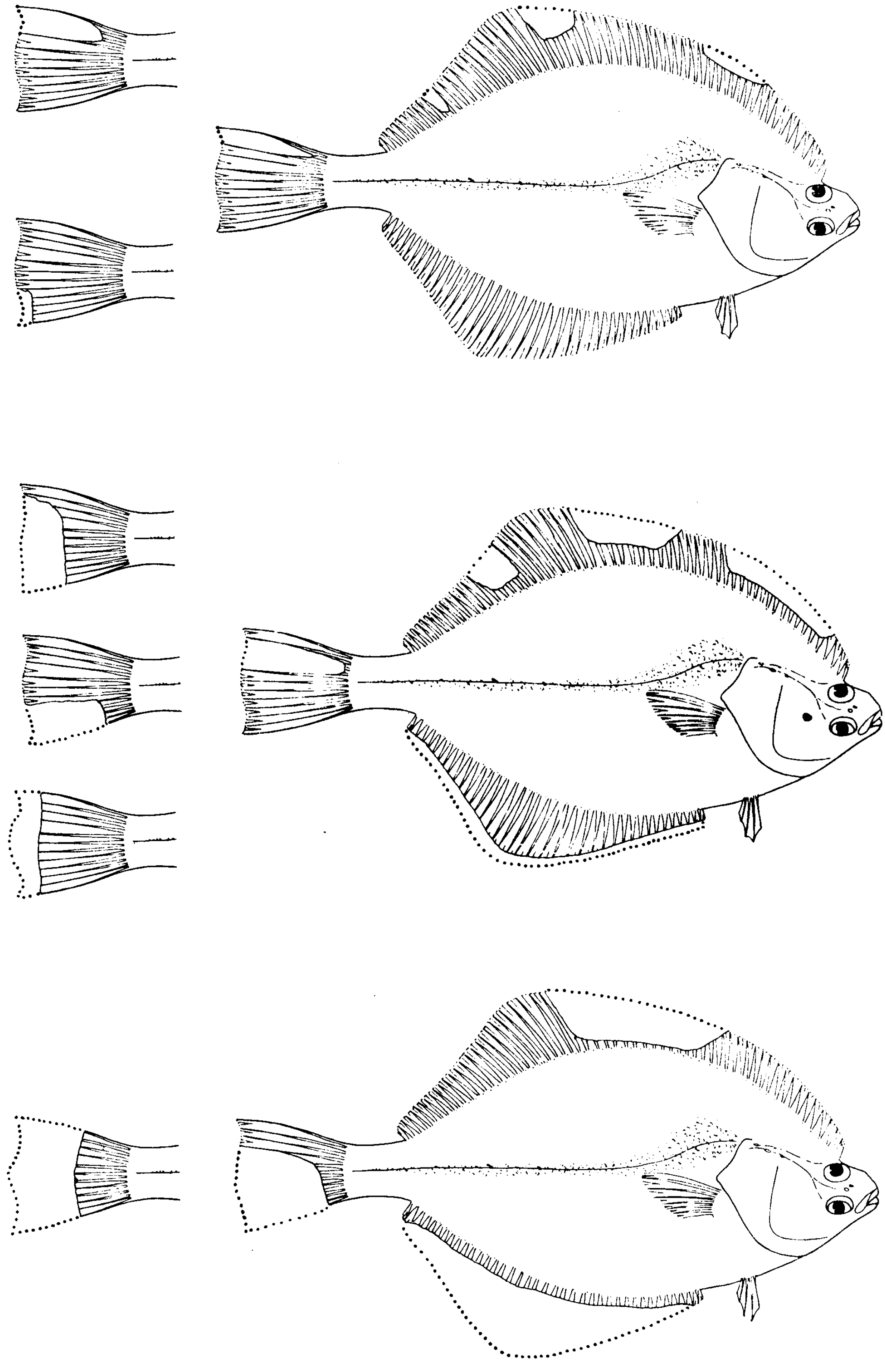

Figure A1 Examples of classification of various degrees of fin rot on flounder (first number = degree of erosion along fin; second number = percentage erosion into fin).

An objective assessment of the extent of fin rot

The degree of fin rot in an affected fish was categorised as slight, moderate or severe on the basis of the extent of erosion both *along* and *into* the fin in question (Figure A1). Where more than one fin was affected, all the affected sites were considered when deciding the appropriate category.

Table A 1 sets out an arbitrary classification of the extent of fin rot *along* the fin; the extent of fin rot *into* the fin is expressed as a percentage. An attempt was made to set a single classification which was applicable to different species and even families, i.e. fish with differing fin size and design and fin/body size ratios. Although the table can be used for all species, interspecific comparisons are not really

Table A1 Objective assessment of fin rot

A. Extent *along* fin margin

i. *Dorsal and ventral fins*

Degree 1	=	1 ray affected
" 2	=	2-5 rays affected
" 3	=	5-10 rays affected*
" 4	=	> 10 rays or 20-99% of rays affected
" 5	=	all fin rays affected

*In round fish 'less than 10 rays' may be equivalent to more than 20% of the fin length; in which case degree 4 should be used.

ii. *Caudal fin*

Degree 1	=	1 ray affected
" 2	=	2 rays affected
" 3	=	25-49% of rays affected
" 4	=	50-99% of rays affected
" 5	=	all fin rays affected

B. Extent *into* fin

Quantify as percentage of the lengths of the fin rays, measuring away from the margin and taking a mean percentage where erosion is irregular.

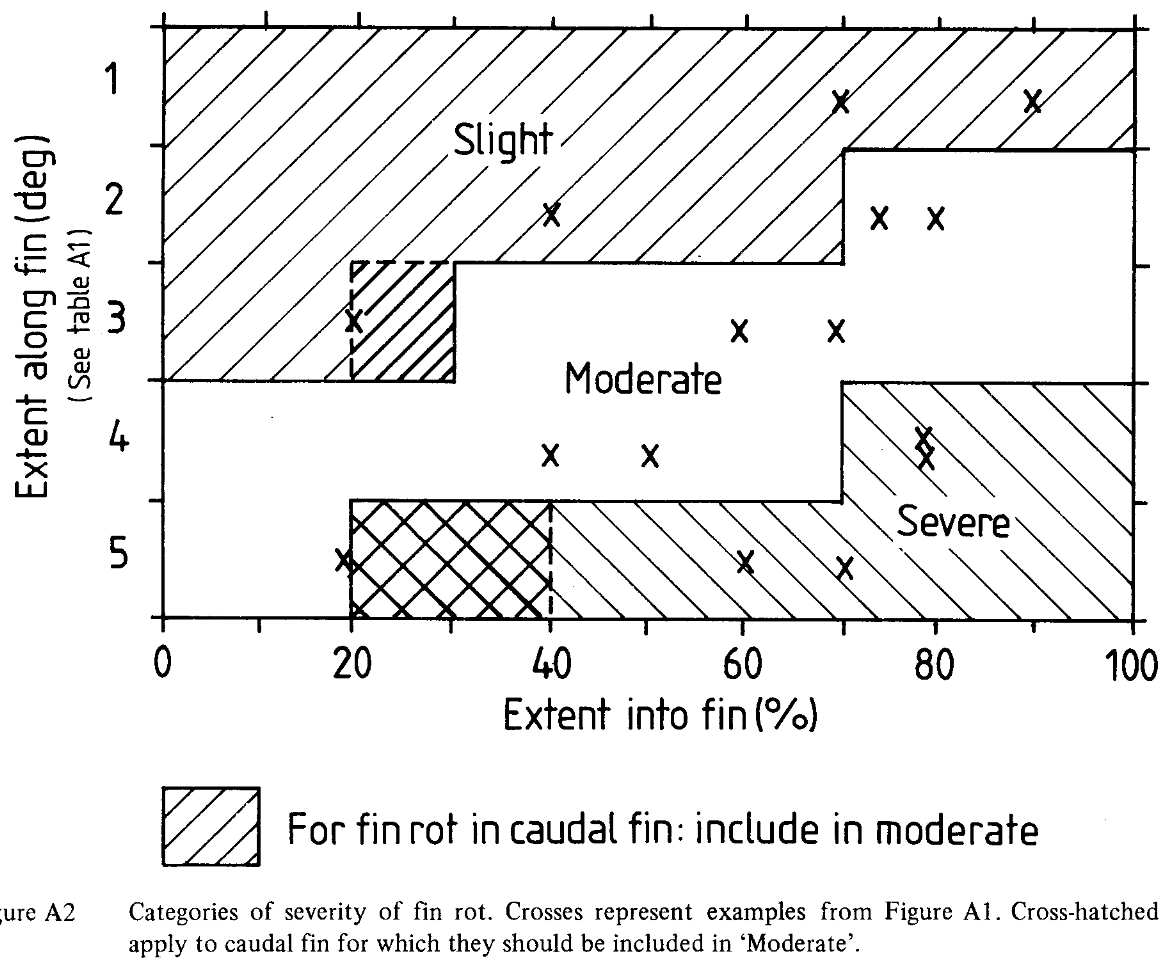

Figure A2 Categories of severity of fin rot. Crosses represent examples from Figure A1. Cross-hatched areas apply to caudal fin for which they should be included in 'Moderate'.

meaningful and should be avoided. Even within a single species it is difficult to assess the relative significance of fin rot on different fins, hence the separate classification for damage to the caudal fin, which in flat fish is much smaller than the lateral fins. For cod, each of the dorsal and ventral fins was regarded separately.

Having determined the extent of damage along the fin and percentage damage into it, the severity of fin rot was categorised using Figure A2. Hypothetical examples of eroded fish illustrating the three categories of fin rot are shown in Figure A1 which is based on line drawings from Wheeler (1969).

Reference

WHEELER, A., 1969. The fishes of the British Isles and North-West Europe. Macmillan, London, 613 pp.

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