Marjorie J. Sherwood

THE FIN EROSION SYNDROME

The objective of this article is to summarize the results of our investigations into the occurrence of fin erosion, a progressive destruction of fin tissues, in the demersal fishes of southern California nearshore waters. Cur studies have focused on determining seasonal and geographical variations in the prevalence of the diseased fishes, on de-scribing the nature of the fin lesions and any associated conditions, and on eliminating some factors from the list of those considered to be possible causes of the disease. The most frequently affected species was the subject of most of the studies.

Fin erosion has been reported in demersal fishes from a number of regions in which toxic wastes have been discharged. These regions include southern California; the Duwamish River Waterway in Seattle, Washington; Raritan and Sandy Hook Bays and the Apex dumping area in the New York Bight; Boston Harbor; the northeast Irish Sea; and Suruga Bay, Japan (Table 1). In the first three areas, where it has been studied in detail, the disease does not appear to result primarily from an infectious process and is not related to a skin tumor condition that is found in various juvenile Pleuronectid flatfishes along the Pacific Coast of North America (Wellings et al. 1965; Cooper and Keller 1969; Mearns and Sherwood 1974, 1976, 1977). Fin erosion does appear to be associated with the exposure of susceptible species to sediments contaminated with chemical wastes. The widespread occurrences of fin erosion in contaminated areas and in a variety of demersal species suggests that it could be useful as an indicator of environmental health.

Our investigation consisted of field and laboratory studies conducted over the past 9 years. Over 290,000 fishes representing 151 species were examined in the period from 1969 to 1976. Approximately 5 percent of the fishes were affected with external abnormalities or signs of disease, such as fin erosion, tumors, color anomalies, and attached macroparasites. Fin erosion diseases were reported in the greatest number of species and occurred at the highest frequencies. Fin erosion in Dover sole *Microstomus pacificus* Lockington) and in several other species with similar disease distribution patterns was the only condition with external symptoms that appeared to be directly associated with the discharge of municipal wastewaters in southern California (Mearns and Sherwood 1977).

DISTRIBUTION OF FISHES WITH FIN EROSION IN SOUTHERN CALIFORNIA

Numerous bottom fish surveys have been conducted by various public and private agencies and universities and by the Coastal Water Research Project in investigating the occurrence of diseased fishes. The four areas sampled most intensively were Santa Monica Bay, the Palos Verdes shelf, San Pedro Bay, and the region off Dana Point.

Host surveys were conducted with small otter trawls with headropes that ranged in length from 4.9 to 12.2 meters (a net with a 7.6-meter headrope was used most frequently) and with cod-end stretch mesh netting of 1.3 to 3.5 cm (primarily 1.3 cm). Average on-bottom trawl time ranged from 10 to 20 minutes (primarily 10 minutes), and trawling speeds were from 2.8 to 5.6 km/hour. Tows were taken along constant-depth contours at depths that ranged from 15 to approximately 610 meters. The primary depth range sampled was from 25 to 150 meters. Because many surveys were organized by monitoring agencies or universities, survey frequency and depth of coverage varied from area to area. Catches of fishes and invertebrates were sorted, and individuals were identified to species and weighed. Fishes were measured to the nearest millimeter (or to the nearest centimeter if catches were large) and examined for external signs of disease.

To extend the geographic range of observations, we examined museum collections of Dover sole from Point Arguello, California, north of the Southern California Bight, and from areas as far south of the Bight as Cedros Island, Baja California. In addition, we conducted a limited collaborative study of diseased and apparently healthy flat-fishes in the New York Bight and in Puget Sound.

The numbers of diseased and apparently healthy fishes from all collections within specific coastal regions were tabulated. Special attention was given to assessing the size distribution of the affected fish relative to that of the total sample. Trawl data analyses were coordinated by Dr. A. Mearns of the Project. Trace contaminant studies were coordinated by Dr. D. Young of the Project, and analyses were performed in the Project's laboratories as well as in the laboratories of Dr. J. de Goeij (presently at the Inter University Reactor Institute, Delft, the Netherlands) and G. Alexander (University of California, Los Angeles).

There was evidence of fin erosion in 33 of 151 fish species collected in southern California coastal waters from 1972 to 1976 (Table 2). Approximately 60 percent of the affected species and over 97 percent of the affected individuals belonged to the three families of flatfishes and the rockfishes. The Dover sole was the most frequently affected species; 30 percent of the 27,991 specimens examined had eroded fins. Other species frequently affected were the rex sole (*Glyptocephalus zachirus*; 13 percent affected) , the slender sole (*Lyopsetta exilis*; 4.8 percent affected), the greenstriped rockfish (*Sebastes elongatus*; 14 percent affected), and the vermilion rockfish (*Sebastes miniatus;* 5.4 percent affected).

Most species affected with fin erosion had highest frequencies of the disease in the vicinity of the wastewater discharge on the Palos Verdes shelf (Table 3 and Figure 1). Thirty-nine percent of the Dover sole collected there between 1972 and 1976 had eroded fins. Frequencies were at least 10 times lower to the north and south: In Santa Monica Bay, 3.5 percent were affected; in south San Pedro Lay, 2.0 percent were affected; and off Dana Point, 0.67 per- cent were affected (Sherwood and Mearns 1977). In more recent surveys (1977), 28 percent of the calico rockfish (*Sebastes daili*) taken on the Palos Verdes shelf also had fin erosion. Most data for the Palos Verdes region were collected at depths between 23 and 137 meters. However, a few trawls were taken in deeper water; even at a depth of 360 meters, approximately 20 percent of the Dover sole collected had eroded fins.

Fin erosion disease was not present in all Dover sole populations near municipal wastewater outfalls: No affected individuals were taken near the discharges of the City of San Diego and the County of Ventura. The disease was also not seen in the catches taken in the area of multiple, natural oil seeps around Coal Oil Point.

DESCRIPTION OF DISEASED DOVER SOLE

Selected fishes were examined histologically by Dr. R. Bendele (Texas Veterinary Medical Diagnostic Laboratory, College Station), Dr. J. Harshbarger (Smithsonian Institution, Washington, D.C.), Dr. G.W. Klontz (University of Idaho, IIoscow), Dr. H. Stich (University of British Columbia, Vancouver), Dr. S.R. Wellings (University of California, Davis), and K.V. Pierce and Dr. B. McCain (National Marine Fisheries Service, Seattle, Washington). Aquarium studies were conducted in the Project laboratories, using a recirculating, refrigerated seawater system.

Erosion was generally restricted to the fins. However, some specimens also had slight gill hyperplasia (Klontz and Bendele 1973). The fin lesions appeared to be those of a chronic fibrosing disease accompanied by reabsorption of the fin rays (Pierce et al., in preparation). The lesions were characterized by epidermal hyperplasia, papillary folding of the epidermis and underlying dermis, the absence or small number of mucocytes and eosinophilic granular cells in advanced stages, the proliferation of dermal fibroblasts and fibrosis, the abnormal distribution of melanophores, focal hyperemia and hemorrhages, a minimal number of inflammatory cells, and the presence of large basophilic cells associated with fin ray reabsorption (Figure 2).

Mucus production appeared depressed in fish with severe fin erosion, and those brought to the laboratory seemed to be less able to adapt to changes in substrate color than did specimens from control areas.

Dover sole with fin erosion from the Palos Verdes shelf also had enlarged livers containing increased amounts of fat and exhibiting structural disorganization (Table 4; Pierce et al. 1977; Sherwood et al. 1977). Histologically, there was an increase in the size and irregularity of fatty vacuoles in the liver cells. The structure of the tissue (muralia and sinusoids) showed evidence of disarray, and, in some cases, the disappearance of sinusoid spaces occurred. Melanin-macrophage centers (collections of cells containing yellow-brown to black pigment) were larger and more numerous; there appeared to be an increase in the amount of interstitial fibrotic tissue present; and there were areas of de-generating liver cells (Pierce et al. 1977).

The enlarged liver condition was not restricted to specimens with eroded fins but occurred in other individuals that appeared to have unaffected fins. Liver enlargement was measured using the liver-somatic index (the ratio of liver weight to body weight multiplied by 100). Values were highest in specimens from the Palos Verdes shelf; however, specimens from Santa Monica and San Pedro Bays also had enlarged livers.

MIGRATION OF DISEASED FISH FROM ONE AREA TO ANOTHER

Since we observed that Dover sole were participating in onshore/offshore seasonal migrations and that movement of individuals along the coast was a possibility, we attempted to distinguish between sites at which the disease was actually being initiated and those to which diseased fish had only migrated. Several types of data were helpful in investigating this question: (1) the prevalence of fin erosion; (2) the levels of chlorinated hydrocarbons in fish tissues--in particular, the ratio of total DDT to total PCB (the ratio is of interest because the Palos Verdes shelf is a point source of DDT contamination); and (3) the degree to which liver enlargement was present in fishes with and without eroded fins.

The prevalence data, with respect to both the number of diseased specimens and the number of affected species, suggested that the Palos Verdes shelf was the primary site at which fin erosion was being initiated in bottom fishes. One hypothesis considered was that those Dover sole with eroded fins collected in the vicinity of the wastewater discharge in south San Pedro Bay had migrated there from the shelf area. The data offered some support for this hypothesis:

- On the Palos Verdes shelf, all sizes of Dover sole had eroded fins, including those that had settled into the area within the year. In south San Pedro Bay, near the Orange County wastewater discharge site, eroded fins were observed primarily on the larger specimens, those that participate in onshore/offshore migrations (Mearns and Sherwood 1974).
- The chlorinated hydrocarbon levels and the DDT/PCB ratio in the tissues of Dover sole with fin erosion from Orange County suggested that these specimens had been exposed to the sediments of the Palos Verdes shelf (Table 5; McDermott-Ehrlich et al. 1977).

- The liver-somatic index in Dover sole with eroded fins collected off Orange County and on the Palos Verdes shelf were similar (Table 5).

Although the Palos Verdes shelf appeared to be the primary site at which fin erosion was initiated in Dover sole and several other bottom species, the disease may also have been developing in Santa IIonica Bay at the end of the 7-mile out-fall pipe. The evidence for this hypothesis is as follows:

- Discharge of sludge through the 7-mile pipe was initiated in 1957. Between 1957 and 1963, a quarterly trawl survey was conducted in Santa Monica Bay. In November 1958, two Dover sole with eroded fins were collected at the trawl station nearest the end of the 7-mile pipe[1]. The specimens were 101 and 127 mm, standard length (SL), and had probably settled within the year. One specimen with a "rotten tail" was collected in 1962 at a station of similar depth approximately 5 km to the northwest. Later, in Hay 1963, abnormal Dover sole were collected again at the outfall station. They were described as "total number 15, badly eaten away, further measurements impossible, mud from sludge outfall." There were no other reports of Dover sole with eroded fins in the 6-year study.
- In October 1978, three trawl samples were taken in Santa Monica Bay—one between the arms of the Y-shaped diffuser at the end of the 5-mile outfall pipe (61-meter depth), one at 152 meters directly off the end of the 7-mile pipe, and one at 146 meters 4.25 km northwest of the 7-mile pipe. Prevalence of fin erosion in Dover sole in the first sample was 4.2 percent (1 of 24); in the second sample, 14 percent (86 of 597); and in the third sample, 0 percent (0 of 33).
- In a 1977 survey, the chlorinated hydrocarbon concentrations and DDT/PCB ratios in tissues of Santa Monica Bay Dover sole with and without fin erosion were characteristic of those of Santa Monica Bay specimens, as measured in recently settled individuals, and different from those of specimens taken from the Palos Verdes shelf in 1976 (Table 5).

FIN EROSION IN RECENTLY SETTLED DOVER SOLE

Dover sole settle out of the plankton primarily in the spring (Mearns and Sherwood 1974). To record the development of fin erosion in newly settled specimens, we took a series of trawl samples at one 137-meter station just north-west of the outfall pipes on the Palos Verdes shelf in April, May, June, August, and October 1978. The fish were returned to the laboratory and carefully examined for signs of fin erosion. Based on size-frequency

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1. J. Carlisle, California Department of Fish and Game, Long Beach, original data, 1957-63 trawl survey.

histograms, we estimated that, in April, the newly settled fish ranged from 30 to 70 mm, SL, with a median in the size class having a midpoint of 55 mm. The prevalence of fin erosion in this sample group of 538 individuals was 0.93 percent. In October, the estimated size range of these fish was 80 to 110 mm, SL, with a median in the size class having a midpoint of 105 mm. Prevalence of the disease in this sample group of 52 individuals was 44 percent.

The newly settled Dover sole collected in April were not present in a trawl sample taken approximately 6 weeks earlier. These data suggest that slight fin erosion had developed in less than 2 months in a small number of the newly settled individuals (less than 1 percent) and that the disease affected almost 50 percent of the individuals 6 months later.

TEMPORAL TRENDS IN FIN EROSION PREVALENCE

Trends in fin erosion in Dover sole were determined from data collected at three 137-meter stations on the Palos Verdes shelf between 1972 and 1978. The results, shown in Figure 3, were based upon the following assumptions: (1) that fin erosion was the result of the exposure of bottom fishes to contaminated sediments, (2) that prevalence of the disease will decrease in relation to decreases in surface sediment concentrations, and (3) that these decreases will be exponential. The data suggest that fin erosion prevalence in Dover sole at the three stations had been decreasing. Estimated half-time for the presence of diseased Dover sole at those sites was approximately 6 years. This estimated half-time was similar to those estimated for various chlorinated hydrocarbon and metal concentrations in the sediments on the Palos Verdes shelf (Coastal Water Research Project 1978). Additional surveys will be required to determine the validity of the trend.

HYPOTHESES ON POSSIBLE CAUSES OF FIN EROSION

Fin and tail erosion diseases occur in both wild and captive populations of fresh and saltwater fishes. The lesions have been attributed to a variety of factors, including microbial infections, abrasions, dietary insufficiencies, and behavioral interactions.

A number of possible etiologies for the fin erosion disease in southern California demersal fishes were investigated in the Project's studies. Among the first considered were the infectious agents such as bacteria, fungi, protozoa, and viruses. By histological examination, the fin lesions were characterized as having minimal inflammatory response; bacteria, fungi, and protozoa were not seen in histological sections or in a small number of photographs taken by scanning electron microscopy (Cundell 1976; Klontz and Bendele 1973; Pierce et al., in preparation). Bacterial culture studies of specimens with and without eroded fins from contaminated and control areas were conducted by E. Manfredi (University of Washington, Seattle) and Dr. J. Kirn (California State University, Long Beach); they found no systemic infectious agent (Manfredi 1976). And although pathogens were isolated from all specimens, there were no specific pathogens in abundance at the site of the lesions. The total number of bacteria and the diversity of the bacteria were greater on specimens from the Palos Verdes shelf. However, these differences could have been related to the enriched organic environment on the shelf or to the fact that Dover sole with severe fin erosion appeared to produce less protective mucus than apparently healthy fish. Despite the noninfectious appearance of the disease and its chronic or long-term nature, viruses cannot be eliminated as a possible contributing cause.

A number of noninfectious processes were also considered as possible causes of fin erosion disease; these included irritation by macroparasites, fin-nipping, and exposure to sediments. No macroparasites were reported in association with fin lesions in Dover sole collected in the trawl surveys. In the laboratory, fin-nipping did occur, but observations indicated that the individuals were most often nipped in the head region or in the area of the caudal fin and not on the fins most frequently eroded in field specimens. The data did suggest that exposure to contaminated sediments was a factor in the development of the disease:

- The fins contacting the bottom most frequently—the dorsal and anal fins (especially the midportion, upon which the Dover sole supports itself for feeding)—were the most frequently and severely affected (Mearns and Sherwood 1974). The pectoral fin on the blind side, which extends into the sediment, was eroded more often than the one that projects into the water column.
- Apparently healthy Dover sole from the Dana Point and Santa Catalina Island control areas were exposed in the laboratory to sediments from the most contaminated region of the Palos Verdes shelf. At the end of 1-1/2 years, three of the four test animals had a fin disease that resembled early stages of fin erosion seen in field specimens; none of five control individuals were affected (Sherwood and Mearns 1977).
- Recently settled Dover sole reflect bottom sediment conditions more reliably than adults, which have had more time to migrate. Among recently settled individuals, prevalence of the disease was highest where bottom sediment contamination was highest (Figure 4).

Some sediment constituents that could possibly cause the fin erosion disease are abrasives, hydrogen sulfide in interstitial waters, metals, petroleum hydrocarbons, and chlorinated hydrocarbons. No abrasives were seen in the limited number of fin tissue samples examined under the scanning electron microscope,[2] and two specimens exposed to a sand-paper substrate in the

2. Dr. A Cundell and Dr. R. Mitchell, Harvard University, personal communication.

laboratory for close to 1 year did not develop eroded fins. Although not conclusive, these observations suggest that abrasives alone were not responsible for the fin erosion disease.

Monitoring data collected by the Los Angeles County Sanitation Districts on the Palos Verdes shelf indicated that the size of the hydrogen sulfide field in bottom sediment interstitial waters decreased from approximately 10 sq km in June 1973 to approximately 1 sq km in June 1975. A corresponding decrease in fin erosion prevalence in recently settled Dover sole was not observed (Sherwood and Mearns 1977). These data suggest that hydrogen sulfide in interstitial waters was not the primary cause of the disease in the field.

To narrow the field of chemical constituents in the sediments considered as possible causes of the fin erosion disease, we compared trace contaminant levels in sediments and fish tissues from three areas where the fin erosion disease occurs—southern California, Washington, and the New York Bight. There was no consistent pattern in metal concentrations in tissues of the fishes from the three areas, although highly contaminated sediments were present in the geographical region to which diseased specimens from each area had been exposed. Total DDT levels in the tissues of diseased fish from contaminated areas off Palos Verdes were two to three orders of magnitude higher than levels in the tissues of diseased specimens from contaminated sites in the other two regions. However, total PCB levels in fish from the three areas were similar: There were no statistically significant differences in brain tissue concentrations; median liver concentrations differed by factors of less than five; and median muscle concentrations differed by factors of less than ten (Table 6).

Chlorinated hydrocarbon concentrations in the livers of Dover sole with fin erosion from Santa Monica Bay and the Palos Verdes shelf were also compared. The median level of total PCB in the Santa Monica Bay samples (from fish collected in the vicinity of the 7-mile outfall) differed from the median value in Palos Verdes samples by a factor of less than four; but levels of total DDT in the Santa Monica Bay samples were approximately 100 times lower than the levels in the Palos Verdes samples. Sediments in the vicinity of the 7-mile discharge pipe in Santa Monica Bay and those on the Palos Verdes shelf had similar levels of total PCB and metals, but total DDT values were higher off Palos Verdes.

These comparisons suggest that exposure to PCB's may be a factor in the development of fin erosion in bottom fish, and that future experiments should be designed to directly test this hypothesis. The data collected to date do not prove a cause or eliminate contaminants other than PCB's as contributing factors. The mechanisms involved in the development of fin erosion are not known.

Although liver size and fat content are affected by factors such as diet, reproductive condition, and disease, they also appear to change in relation to exposure to chlorinated hydrocarbons (Sherwood et al. 1978). Liver size and fat content in Dover sole from one station on the Palos Verdes shelf and one off the Dana Point control area were compared with chlorinated hydrocarbons in the muscle tissue of the specimens (Figure 5). The results suggested that in-creases in tissue burdens of chlorinated hydrocarbons were associated with increases in the magnitude of liver enlargement and fat infiltration.

IMPLICATIONS

Flatfishes constitute an important part of California's commercial fish landings (Frey 1971). The trawl fishery, however, is limited by state restriction to the area north of Oxnard, California. This restriction is based on a historical concern for the competition between commercial and recreational fisheries in southern California. Other types of commercial and recreational flatfish fisheries are presently important in southern California coastal waters. Emphasis in the trammel net fishery is on California halibut, petrale sole, and rock sole; sport fishermen take halibut, sanddabs, and petrale sole (Frey 1971). These species are not among those frequently affected with fin erosion; how-ever, these species may develop liver anomalies when exposed to contaminated sediments.

CONCLUSIONS AND RECOMMENDATIONS

Both fin erosion and liver anomalies appear to be indicators of depressed environmental health. Fin erosion appears to result from the exposure of susceptible species to sediments contaminated with chemical wastes. The precise causes of the disease remain unknown; however, elevated levels of FCB's may be a factor in the development of the disease. Liver anomalies also appear to be associated with exposure to contaminants; however, liver anomalies are present in Dover sole with and without fin erosion and may also occur in other bottom fishes in which the prevalence of fin erosion is low or not detectable. The primary results of this study have been (1) a narrowing of the field of hypo-theses on the causes of fin erosion and a suggestion of toxic materials to test in the laboratory and (2) the identification of the liver-somatic index as a useful map-ping technique in measuring responses of certain bottom fishes to waste discharges.

Additional research should be directed toward (1) further narrowing the range of possible causes of fin erosion through laboratory tests and investigation of contaminants in other areas in which fin erosion has been or may be found; (2) improving capabilities to predict the occurrence of fin erosion; (3) investigating liver anomalies in other bottom species and determining the relation of such anomalies, if any, to gonad development; and (4) determining the nature of the fundamental disturbance leading to the symptoms of fin erosion.

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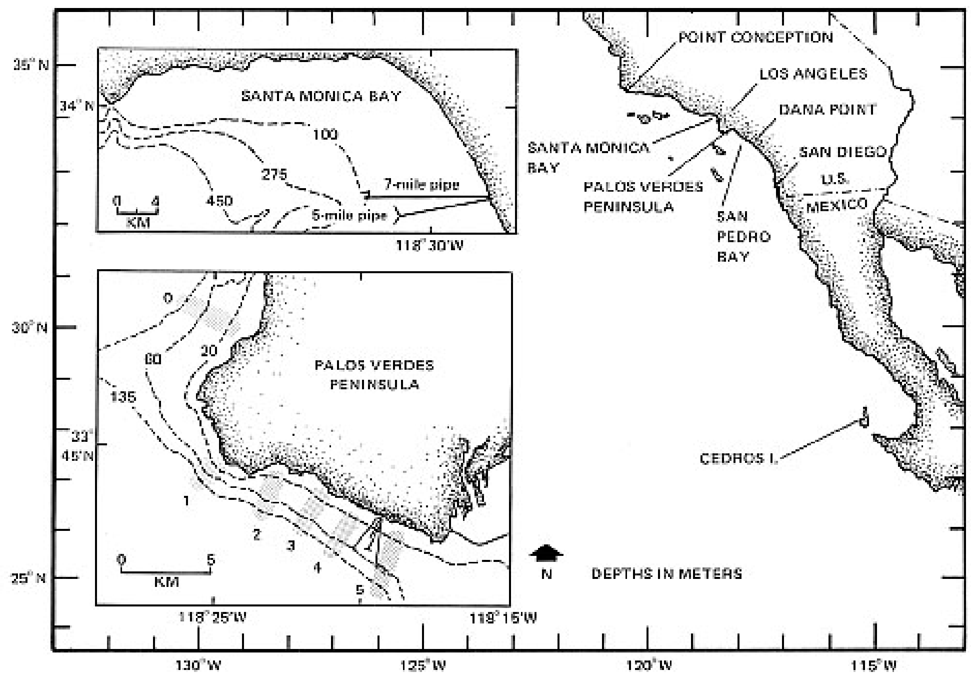

Figure 1. Areas surveyed in investigation into fin erosion disease in southern California demersal fishes.

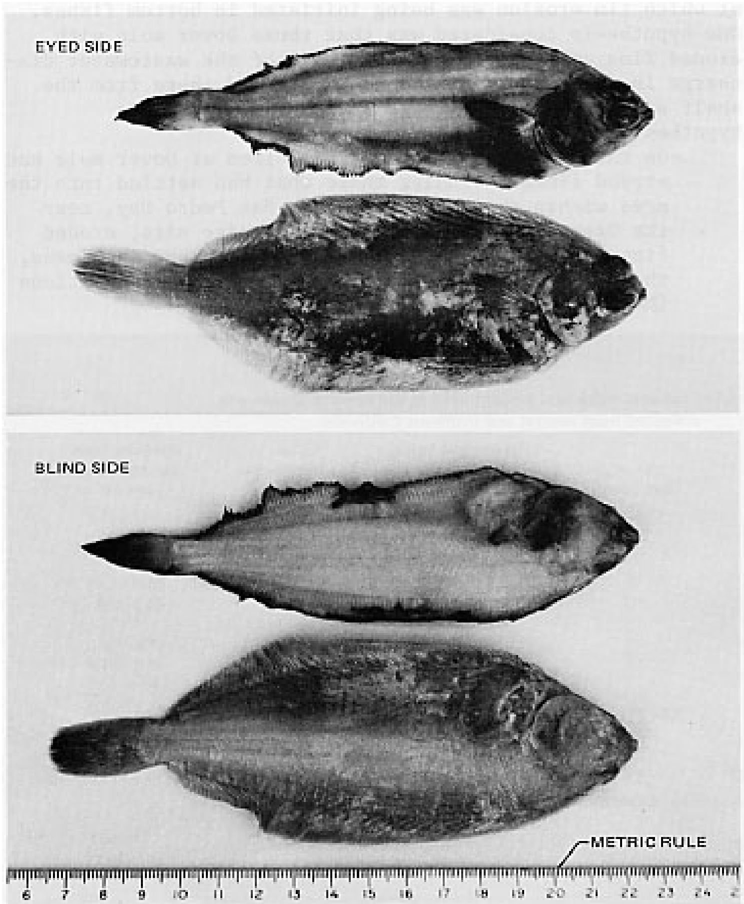

Figure 2. Fin erosion in Dover sole. Top specimen, with severe fin erosion, was collected in May 1972 on the Palos Verdes shelf. Bottom specimen, with apparently unaffected fins, was collected in September 1975 off San Diego.

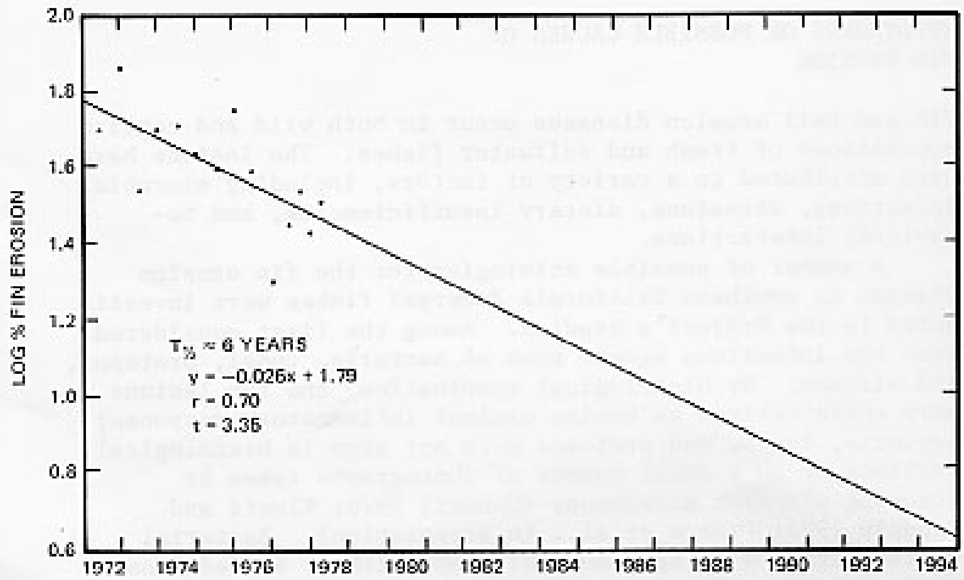

Figure 3. Decreases in the prevalence of fin erosion in all Dover sole collected at 137-meter depths from Transects 1, 4, and 5 on the Palos Verdes shelf.

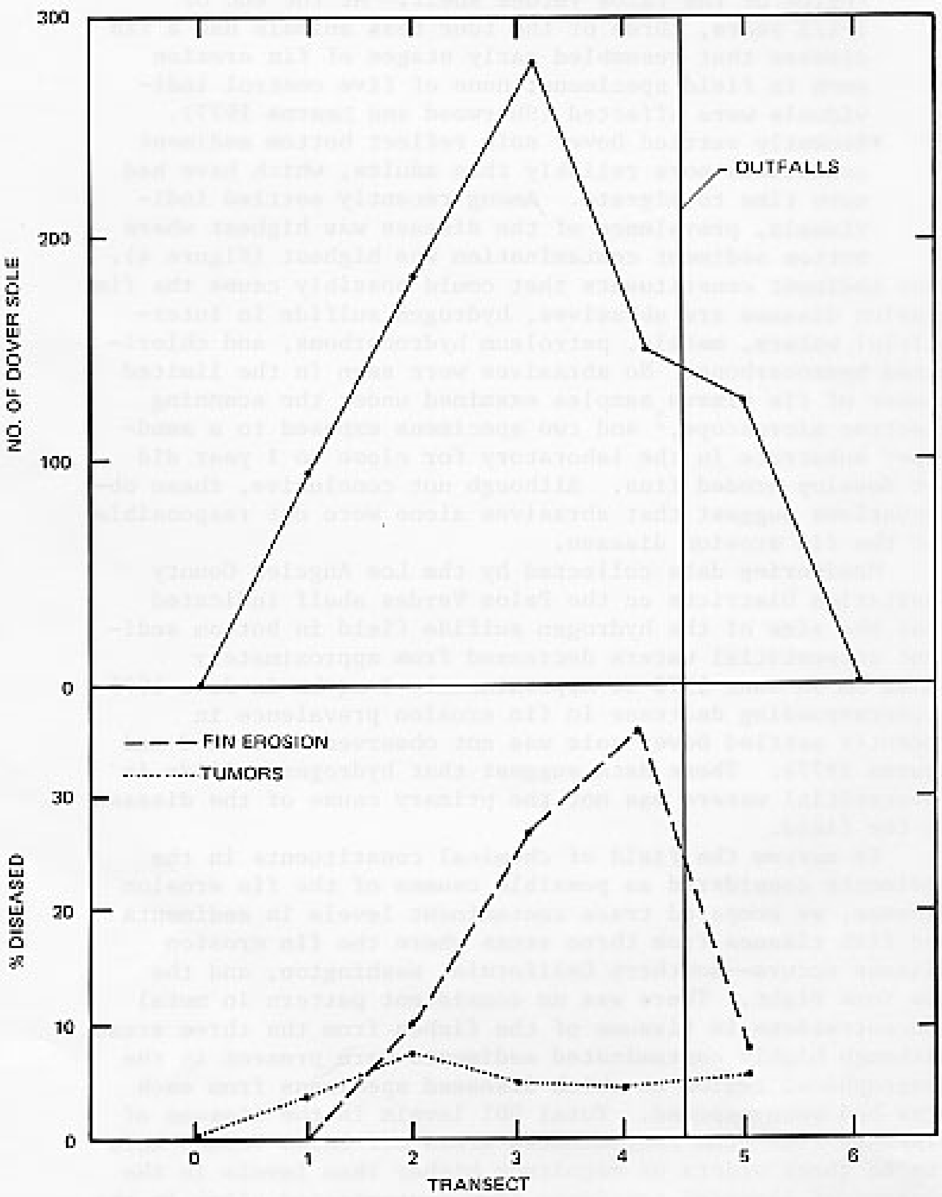

Figure 4. Prevalence of fin erosion and skin tumors in Dover sole less than 120 mm, SL, collected on the Palos Verdes shelf at 137-meter depths, December 1976.

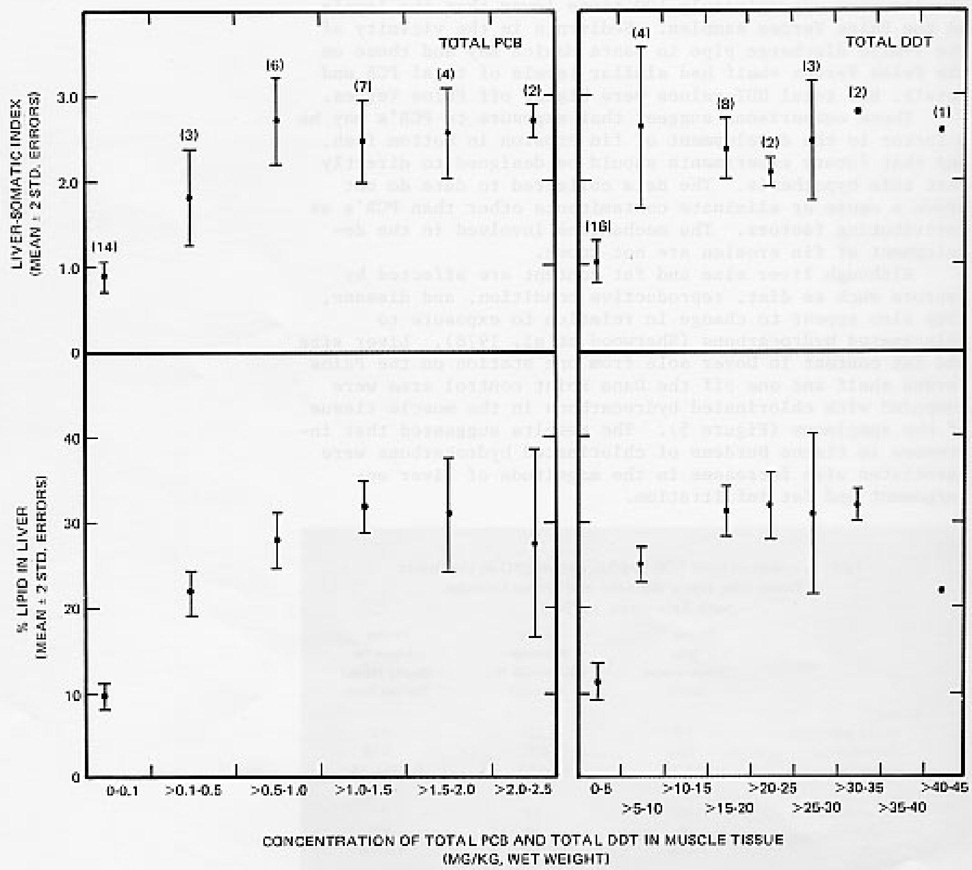

Figure 5. Relationship of chlorinated hydrocarbon concentrations in the muscle tissue to the lipid content and relative size of the liver in Dover sole from the Palos Verdes shelf (with and without fin erosion) and from Dana Point, November 1976. Number of samples is given in parentheses.

Table 1. Fin erosion in demersal fishes from various coastal areas.

Location	Some Affected Species	Reference
Southern California nearshore waters	*Microstomus pacificus* (Dover sole) *Glyptocephalus zachirus* (rex sole) *Lyopsetta exilis* (slender sole) *Sebastes elongatus* (greenstriped rockfish) *Sebastes miniatus* (vermilion rockfish)	Mearns and Sherwood 1974 Sherwood and Mearns 1977
Duwamish River Waterway, Puget Sound	*Platichthys stellatus* (starry flounder) *Parophrys vetulus* (English sole)	Wellings et al. 1976
Sandy Hook/Raritan Bays; Apex dumping area, New York Bight	*Pseudopleuronectes americanus* (winter flounder)	Murchelano and Ziskowski 1976
Boston Harbor, Mass.	*Pseudopleuronectes americanus* (winter flounder)	Charles A. Willingham, Battelle Columbus Laboratories, Duxbury, Mass., personal communication
Northeast Irish Sea	*Pleuronectes platessa* (plaice) *Limanda limanda* (dab)	Perkins et al. 1972
Suruga Bay, Japan	*Uranoscopus japonicus* (Japanese stargazer)	Nakai et al. 1973

Table 2. Prevalence of fin erosion in southern California demersal fishes captured by otter trawl from Santa Monica Bay to Dana Point, May 1972 to May 1976. From Sherwood and Mearns 1977.

Species	Common Name	Number Total	Number Fin Erosion	%. Fin Erosion
Pleuronectidae				
Microstomus pacificus	Dover sole	27,991	8,318	30
Glyptocephalus zachirus	Rex sole	2,666	349	13
Lyopsetta exilis	Slender sole	3,277	158	4.8
Pleuronichthys decurrens	Curlfin sole	3,656	84	2.3
Parophrys vetulus	English sole	2,924	12	0.41
Pleuronichthys verticalis	Hornyhead turbot	1,311	6	0.46
Eopsetta jordani	Petrale sole	18	1	5.6
Bothidae				
Citharichthys sordidus	Pacific sanddab	17,879	4	0.02
Citharichthys fragilis	Gulf sanddab	28	1	3.6
Hippoglossina stomata	Bigmouth sole	696	1	0.14
Xystreurys liolepis	Fantail sole	66	1	1.5
Cynoglossidae				
Symphurus atricauda	California tonguefish	4,762	27	0.57
Scorpaenidae				
Sebastes miniatus	Vermilion rockfish	555	30	5.4
Sebastes elongatus	Greenstriped rockfish	138	20	14
Sebastes jordani	Shortbelly rockfish	2,803	12	0.43
Sebastes rosenblatti	Greenblotched rockfish	193	11	5.7
Sebastes dalli	Calico rockfish	6,459	8	0.12
Sebastes rubrivinctus	Flag rockfish	75	2	2.7
Sebastolobus alascanus	Shortspine thornyhead	99	2	2.0
Sebastes semicinctus	Halfbanded rockfish	4,027	1	0.02
Sciaenidae				
Genyonemus lineatus	White croaker	7,224	183	2.5
Embiotocidae				
Cymatogaster aggregata	Shiner perch	7,498	10	0.13
Phanerodon furcatus	White seaperch	966	1	0.10
Zalembius rosaceus	Pink seaperch	5,913	1	0.02
Ophidiidae				
Chilara taylori	Spotted cusk-eel	254	6	2.4
Anoplopomatidae				
Anoplopoma fimbria	Sablefish	560	5	0.89
Hexagrammidae				
Zaniolepis latipinnis	Longspine combfish	2,239	4	0.18
Zaniolepis frenata	Shortspine combfish	591	2	0.34
Batrachoididae				
Porichthys notatus	Plainfin midshipman	5,782	2	0.03
Serranidae				
Paralabrax nebulifer	Barred sand bass	22	2	9.1
Agonidae				
Xeneretmus latifrons	Blacktip poacher	1,186	1	0.08
Engraulidae				
Engraulis mordax	Northern anchovy	3,304	1	0.03
Zoarcidae				
Lycodopsis pacifica	Blackbelly eelpout	2,184	1	0.04

	Santa Monica Bay (109 Samples)	Palos Verdes Shelf (268 Samples)	South San Pedro Bay (138 Samples)	Dana Point (77 Samples)
Dover sole				
Total	894	20,854	5,354	889
Fin erosion	31 (3.5)*	8,176 (39)	105 (2)	6 (0.67
Rex sole				
Total	194	1,661	758	63
Fin erosion	4 (2.1)	345 (21)	0 (0)	0 (0)
Slender sole				
Total	341	655	1,657	309
Fin erosion	19 (5.5)	138 (21)	1 (0.06)	0 (0)
Greenstriped rockfish				
Total	11	111	9	7
Fin erosion	0 (0)	20 (18)	0 (0)	0 (0)
Vermilion rockfish				
Total	80	282	175	18
Fin erosion	0 (0)	30 (11)	0 (0)	0 (0)

*Values in parentheses are percentages of the total.

Table 3. Geographic distribution of fin erosion for five of the most frequently affected species, May 1972 to May 1976. From Sherwood and Mearns 1977.

Table 4. Liver-somatic index and percent lipid in the livers of Dover sole collected from central and southern California.

Collection Site and Date	No. of Specimens	Liver-Somatic Index, Median and Range	% Lipid in Liver, Median and Range	Specimen Total Weights, Range (grams)
Monterey Bay, 1975[a]	15	0.7, 0.4-1.0	–	74.7-321.3
Santa Monica Bay, 1972-74[b]	14	1.6, 0.5-2.2	–	48.7-291.3
Palos Verdes				
Transect 0, 1977[c]	10	1.4, 1.0-2.2	–	44.8-113.0
Transect 4, 1977[c]	10	2.3, 1.8-3.3	–	45.9-97.6
Transect 3, 1976[b]				
No apparent fin erosion	12	2.2, 0.9-3.0	29, 8.8-35	64.8-100.0
Fin erosion	12	2.6, 1.6-3.8	28, 19-40	75.5-101.4
San Pedro Bay, 1972-74[b]				
No apparent fin erosion	66	1.6, 0.7-2.9	–	15.3-273.0
Fin erosion	9	2.4, 2.2-3.9	–	31.9-129.7
Dana Point, 1976[b]	12	0.8, 0.6-1.2	9.0, 6.2-16	63.3-106.8
Santa Catalina Island, 1972-74[b]	29	1.0, 0.2-1.6	–	18.7-111.4

a. Collected by G. Cailliet, Moss Landing Marine Laboratory.
b. Collected by the Project.
c. Collected by Los Angeles County Sanitation Districts.

Table 5. Liver-somatic index; concentrations of total DDT and total PCB (mg/kg, wet weight); and ratios, total DDT to total PCB in southern California Dover sole.

			Liver			Muscle		
Collection Site and Date	No. of Samples[a]	Liver-Somatic Index, Median	Total DDT, Median	Total PCB, Median	Ratio, Total DDT to Total PCB, Median	Total DDT, Median	Total PCB, Median	Ratio, Total DDT to Total PCB, Median
Santa Monica Bay near 7-mi. pipe								
Sep 77								
No apparent fin erosion								
Individuals 180-213 mm, SL	6	2.4	3.8	7.2	0.55	0.062	0.094	0.62
Individuals <120 mm, SL	6	1.9 (24)	1.7	4.0	0.40	0.044	0.10	0.40
Fin erosion, 148-175 mm, SL	6	2.0	2.8	5.4	0.51	0.10	0.22	0.48
Mar 62, no apparent fin erosion[b]	2	2.0	15	11	1.4	–	–	–
Palos Verdes, Transects 3-4								
Nov 76, 150 meters								
No apparent fin erosion	12	2.2	240	14	18	16	1.2	17
Fin erosion	12	2.6	310	20	17	16	0.98	15
Sep 76; 53 weeks in lab.; 120 meters[c]	3	1.7	86	4.9	18	1.8	0.12	17
San Pedro Bay near outfall, May/Sep 74 and Feb 75[d]								
No apparent fin erosion	12	1.5 (10)	–	–	–	0.50	1.4	0.34
Fin erosion	9	2.8 (5)	–	–	–	6.5	1.6	2.6
Dana Point, Nov 76; no apparent fin erosion	12	0.8	0.38	0.048	9.2	0.026	0.008	3.1

a. Three of the liver-somatic index values are based on analyses of different numbers of samples, given in parentheses after the values.

b. These specimens were maintained in an alcohol solution at the Los Angeles County Museum of Natural History; thus, chlorinated hydrocarbon values are estimates.

c. Caudal fins were eroded, but dorsal and anal fins were unaffected.

d. Chlorinated hydrocarbon values not corrected for blanks.

Table 6. Levels of total PCB (mg/kg, wet weight) in the tissues of Dover sole, starry flounder, and winter flounder with fin erosion, 1976-77.

	Dover Sole (Palos Verdes Shelf)	Starry Flounder (Duwamish R. Estuary)	Winter Flounder (Sandy Hook/ Raritan Bays
Muscle			
No. of specimens	12	12	12
Median value	0.98	0.41	0.10
Range	0.16-2.4	0.16-2.1	0.073-0.14
Liver			
No. of specimens	12	12	11
Median value	20	16	4.2
Range	7.4-56	9.0-160	1.4-7.4
Brain			
No. of specimens	4	4	4
Median value	1.0	1.1	1.8
Range	0.83-1.3	0.67-3.1	0.46-2.0