OCEANIC PROCESSES IN MARINE POLLUTION Volume 5

URBAN WASTES IN COASTAL MARINE ENVIRONMENTS

Edited By

DOUGLAS A. WOLFE
Ocean Assessments Division
U.S. National Oceanic and Atmospheric Administration
Rockville, Maryland

THOMAS P. O'CONNOR
Ocean Assessments Division
U.S. National Oceanic and Atmospheric Administration
Rockville, Maryland

ROBERT E. KRIEGER PUBLISHING COMPANY
MALABAR, FLORIDA 1988

Chapter 6

Fin Erosion and Epidermal Tumors in Demersal Fish from Southern California

Jeffrey N. Cross

Southern California Coastal Water Research Project
Long Beach, California

ABSTRACT

The relationship between municipal wastewater discharge and the two most prevalent external diseases of demersal fish collected near the outfalls in the coastal waters off Los Angeles, California (U.S.A.), was examined using monitoring data collected from 1971 through 1983. Fin erosion occurred in 8.5% of all individuals and in 23% of all species collected. Epidermal tumors occurred in 0.3% of all individuals and in 12% of all species collected. Dover sole (*Microstomus pacificus*) accounted for 89% of the fish with fin erosion, 93% of the fish with tumors, and 23% of all fish collected. Thirty-two percent of the Dover sole had fin erosion and 1.2% had epidermal tumors. Both diseases developed some time after the fish recruited to the area around the outfalls. Fin erosion occurred in all size classes examined; epidermal tumors occurred primarily in smaller individuals. Fin erosion did not appear to affect the nutritional condition or seasonal migratory behavior of juvenile Dover sole but did lower survival. Epidermal tumors, however, appeared to alter the seasonal migratory behavior of Dover sole. During the study period, the number of species with both diseases declined, and the prevalence of fin erosion declined in two of the three most affected species. The declines were directly correlated with decreased mass emission of contaminants in the effluent, decreased contamination of surface sediment, and decreased body burdens of contaminants in fish. The prevalence of epidermal tumors in Dover sole did not decline during the study period; however, the prevalence was significantly higher at stations closer to the outfalls than at those farther away.

6.1. INTRODUCTION

The most prevalent and visible external abnormalities observed in fish collected near the municipal wastewater outfalls in the coastal waters off Los Angeles (California, U.S.A.) are fin erosion and epidermal tumors (Mearns and Sherwood, 1974, 1977; Sherwood and Mearns, 1977). Both conditions occur in marine fish, especially pleuronectid flatfishes, in coastal waters off urban and industrialized areas in other parts of the world (Stich et al., 1976; Möller, 1979; Dethlefsen, 1980; Murchelano and Ziskowski, 1982). The role that pollution plays in these conditions remains controversial and elusive (Möller, 1979; Sindermann, 1983; Patton and Couch, 1984). In this chapter, the relationship between municipal wastewater discharge and fin erosion and epidermal tumors in fish is examined through the use of data collected over more than a decade of monitoring in the coastal waters off Los Angeles.

6.2. METHODS

The data analyzed in this study were collected by County Sanitation Districts of Los Angeles County (CSDLAC) during regular monitoring cruises. The station numbers used herein are the CSDLAC designations.

The data consisted of catch records of fishes and the frequency of fin erosion and epidermal tumors by species along seven transects sampled by otter trawl on the Palos Verdes shelf (Fig. 6.1). At each transect, 10-min daytime trawls were made along depth isobaths at 23, 61, and 137 m twice a year (spring and fall) from 1971 through 1978 and quarterly after 1979. Additional trawls at irregular intervals were also included in the analyses. Fishes were sorted from the catch by species and measured to the nearest cm board standard length (BSL). As each fish was measured, it was examined externally for fin erosion and epidermal tumors by trained biologists.

Time trends in the diseases were determined with linear regressions of the prevalence [proportion (p) of diseased fish per trawl transformed to arcsin $\sqrt{p}$] against time in months (numbered consecutively from 1971). The null hypothesis of slope = 0 was tested with a t-test.

Seasonal trends in the quarterly trawl data (1979–1983) were estimated from a multiplicative decomposition model (Bowerman and O'Connell, 1979), using numbers of fish per trawl and prevalence data after the appropriate transformations:

$$Y_t = T_t \times S_t + e_t \quad (1)$$

where Y_t is the number of fish per trawl (or proportion with the disease) at time t, T_t is the trend component at time t, S_t is the seasonal component at time t, and e_t are the remaining components (cyclical and aperiodic) at time t. Regressions were fitted to the catch and to the prevalence data to estimate T (regression coefficient) for each quarter. The trend was eliminated by dividing the quarterly Y values by T. The value for S was then estimated for each quarter (assuming e was small), normalized to four (the number of quarters in one year), and multiplied by 100. The seasonal index is a correction factor (in percent) that adjusts for seasonality in the time series. Values > 100 indicate that Y_t is greater than that predicted by

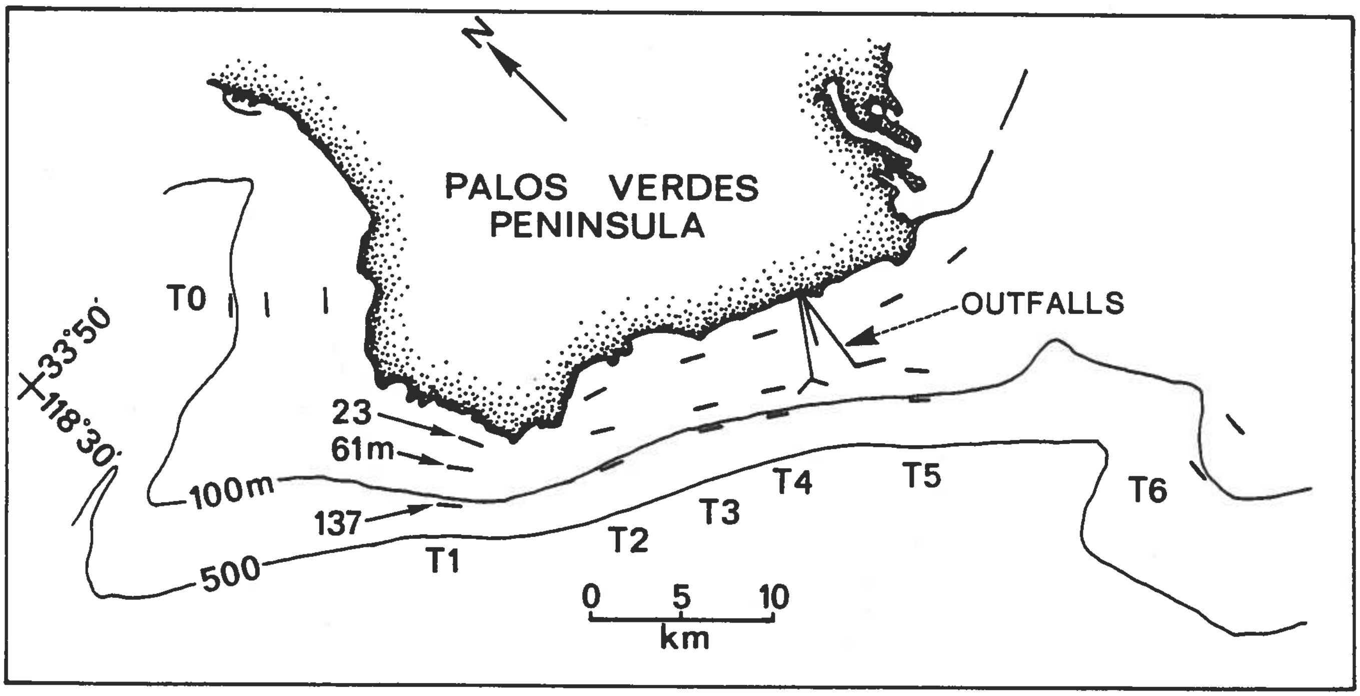

Figure 6.1. Map of the study transects (T0, T1, . . . , T6) on the Palos Verdes shelf. Three depths were sampled at each transect.

the trend; likewise, values < 100 indicate that Y_t is less than that predicted by the trend.

6.3. RESULTS AND DISCUSSION

From 1971 through 1983, 672 otter trawls produced 15,670 individuals with fin erosion, representing 8.5% of all fishes collected, distributed among 29 species (23% of all collected). The trawls also produced 539 individuals with epidermal tumors, representing 0.3% of all fishes collected, distributed among 15 species (12% of all collected). It is not known whether the etiology of the epidermal tumors was the same in all affected species. Dover sole (*Microstomus pacificus*) accounted for 89% of the fish with fin erosion, 93% of the fish with epidermal tumors, and 23% of the fish collected.

6.3.1. Characteristics of the Diseases in Dover Sole

Of the Dover sole collected from 1971 through 1983, 32% had fin erosion, and 1.2% had epidermal tumors. Most Dover sole recruited to the study area when they were 40–50 mm BSL. Fin erosion was rarely observed in fish <80 mm BSL, and epidermal tumors were rarely observed in fish <60 mm BSL (Fig. 6.2).

The prevalence of fin erosion increased with fish size up to 120–129 mm BSL and then declined slowly to <1% in fish >270 mm BSL (Fig. 6.3). The prevalence of epidermal

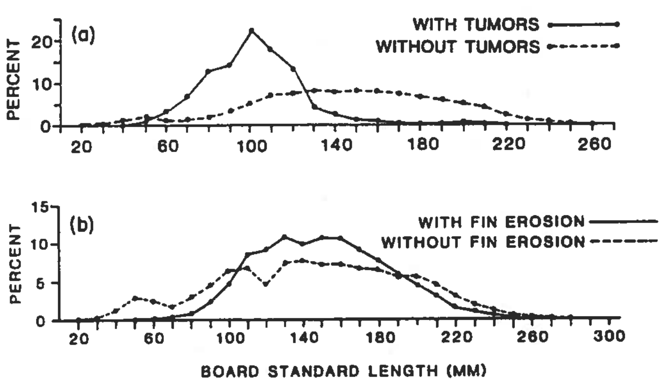

Figure 6.2. Size distribution of Dover sole (*Microstomus pacificus*) collected on the Palos Verdes shelf from 1971 through 1983 (a) with and without epidermal tumors and (b) with and without fin erosion.

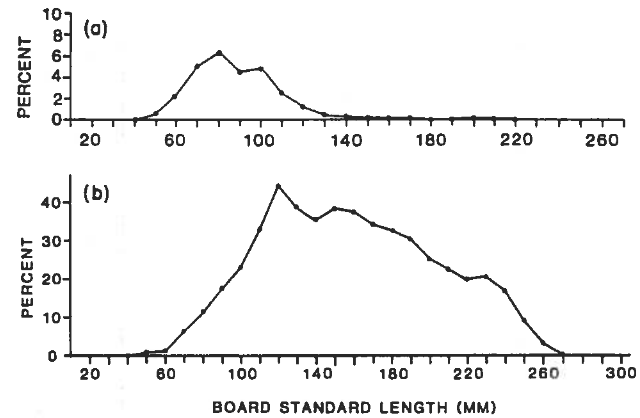

Figure 6.3. Prevalence of (a) epidermal tumors and (b) fin erosion by size class in Dover sole (*Microstomus pacificus*) collected on the Palos Verdes shelf from 1971 through 1983.

tumors peaked in fish 80–90 mm BSL and then declined rapidly to <0.1% in fish >150 mm BSL (Fig. 6.3).

Among Dover sole <120 mm BSL (the average size of individuals ~1 y after recruiting to the Palos Verdes shelf), 16.9% had fin erosion, 3.4% had epidermal tumors, and 1.1% had both diseases. The two diseases were not independent; significantly more individuals were afflicted with both diseases than predicted ($\chi^2 = 45.4$, $p < .001$).

The weight–length relationships for Dover sole were not significantly different either for males or for females with and without fin erosion (Cross, 1985). Comparable data are not available for Dover sole with epidermal tumors; however, Campana (1983) showed that starry flounder (*Platichthys stellatus*) with similar epidermal tumors had lower growth rates than did individuals without tumors.

Time series analyses of the quarterly trawl data for Dover sole showed consistent seasonal peaks in total catch, number of individuals with fin erosion (but not proportion), and proportion of individuals with epidermal tumors (but not number) (Fig. 6.4). Total catch and number of fish with fin erosion were highest in the spring and summer, and lowest in the fall and winter. These trends are probably the result of seasonal onshore–offshore migrations. Dover sole migrate in the winter into deeper water to reproduce and return in the summer to shallower water to feed (Hagerman, 1952). Apparently the juveniles also participate in the offshore migration in the winter.

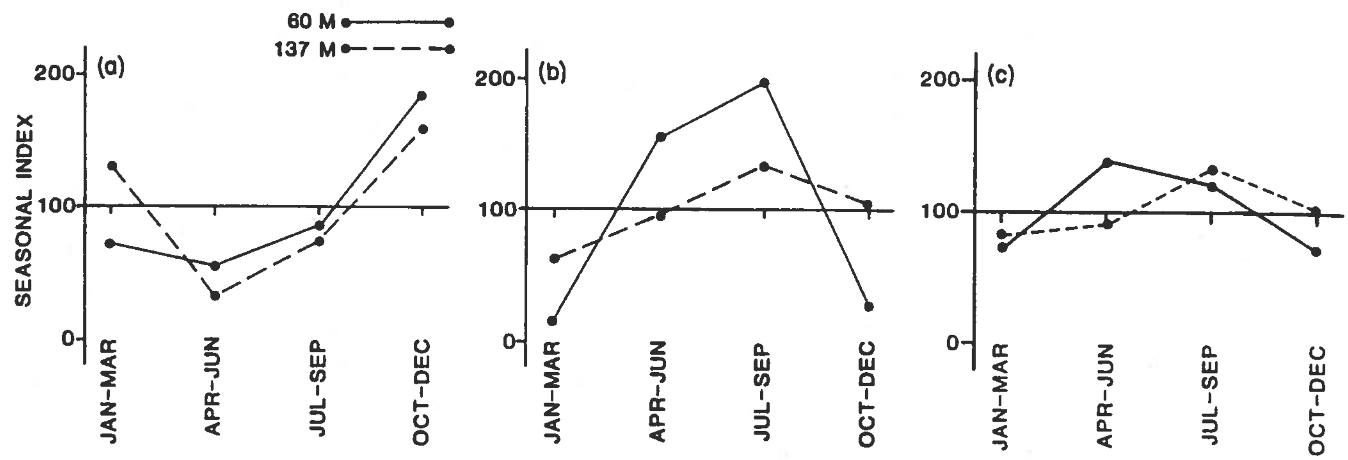

Figure 6.4. Seasonal trends in (a) the proportion of Dover sole (*Microstomus pacificus*) with epidermal tumors per trawl, (b) the number of Dover sole caught per trawl, and (c) the number of Dover sole with fin erosion per trawl from 1979 through 1983.

The high proportion of tumorous Dover sole that were collected during the fall and winter suggests that these individuals do not participate in the offshore movement to the same extent as do fish without tumors. Stich et al. (1976) suggested that the emigration of juvenile English sole (*Parophrys vetulus*) from shallow nursery areas to deeper water may be slower in individuals with epidermal tumors.

Cross (1985) estimated the survival rates of Dover sole that were collected on the Palos Verdes shelf between 1972 and 1975 from age–length data. The survival rates of fish with and without fin erosion were not significantly different from ages 1–3 y; thereafter, however, the survival rates of fish with the disease were significantly lower. Comparable data are not available for Dover sole with epidermal tumors; however, Campana (1983) showed that starry flounder with epidermal tumors were more susceptible to stress and had much higher mortality rates than did individuals without tumors.

The two diseases possess important similarities and differences. Both diseases develop some time after the fish recruit to the area around the outfalls. Epidermal tumors affect far fewer individuals than does fin erosion but reach peak prevalence earlier and decline more rapidly. Over 90% of Dover sole with tumors were estimated to be <2 y of age. The tumor prevalence of <0.1% in fish between 150 and 220 mm BSL suggests, however, that some individuals either survive several years with tumors or develop them later in life. Fin erosion is a more chronic disease that takes longer than tumors to reach peak prevalence and declines more slowly with increasing fish size. It occurred in all size classes of Dover sole examined.

6.3.2. Relationship to Municipal Wastewater Discharge

The number of species affected by fin erosion declined from a high of 18 in 1971 to a low of 3 in 1981 and rose slightly through 1983 (Fig. 6.5). The number of species affected by epidermal tumors declined from 6 in 1971 to 1 in 1976 and remained at 1 or 2 through 1983 (Fig. 6.5). The negative Spearman rank correlations (r_s) between the number of species with fin erosion and year ($r_s = -0.626$), and between the number of species with epidermal tumors and year ($r_s = -0.706$) were significant ($p < .05$), while the correlation between the total number of species collected and year ($r_s = -0.080$) was not significant ($p > .50$).

The number of species affected by either disease declined most rapidly from 1971 to 1976 (Fig. 6.5). As discussed by Stull et al. (Chapter 2) and Young et al. (Chapter 3), the modifications to the wastewater treatment made by CSDLAC in the early 1970s greatly reduced the mass emission of many contaminants during this period (Table 6.1). This was reflected in decreased concentrations of DDT in surface sediments and in the muscle tissue of Dover sole around the outfalls (Fig. 6.6). The decline of DDT was exponential for effluent and sediment and linear for muscle.

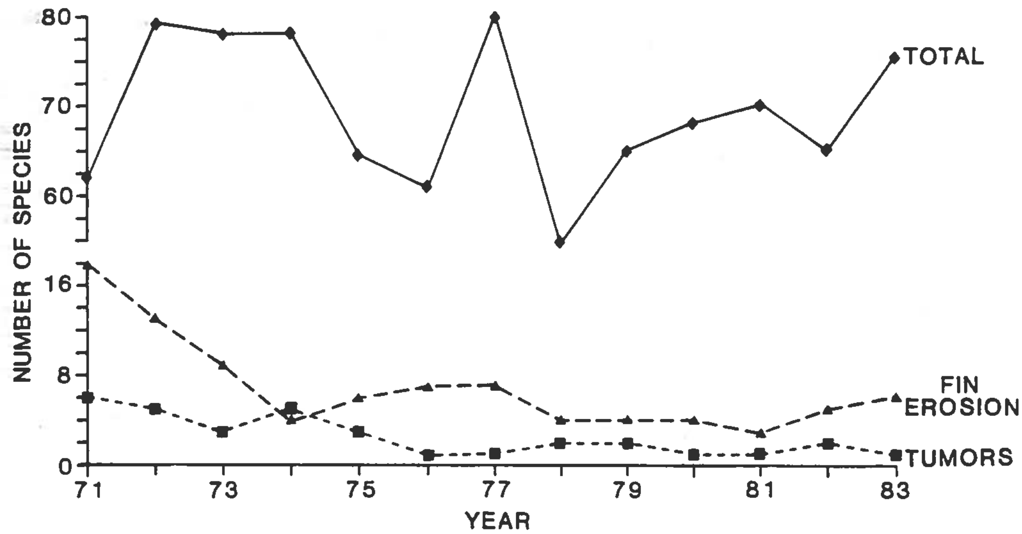

Figure 6.5. Total annual number of species, number of species with fin erosion, and number of species with epidermal tumors collected on the Palos Verdes shelf from 1971 through 1983.

Table 6.1. Mass Emission of 15 Contaminants from Los Angeles County Outfalls (t y⁻¹)[a]

Contaminant	Concentration in 1971 (t y⁻¹)	Maximum Emission Concentration (t y⁻¹)	Maximum Emission Year	Concentration in 1983 (t y⁻¹)	r_s	p
Oil and grease	38,000	38,000	1971	13,640	−0.934	**
Cyanide	62	205	1974	19	−0.681	*
Phenols	1,640	1,945	1975	1,260	−0.500	
Ag	10.8	10.8	1971	5.1	−0.533	
As	—[b]	11.3	1974	3.1	−0.385	
Cd	15.4	19.6	1974	7.4	−0.731	**
Cr	462	462	1971	70	−0.951	**
Cu	267	286	1974	62	−0.951	**
Hg	0.7	0.7	1971	0.4	−0.486	
Ni	144	157	1976	75	−0.848	**
Pb	144	144	1971	41	−0.956	**
Se	8.2	14.5	1981	6.5	0.286	
Zn	1,400	1,400	1971	254	−0.967	**
DDT	21.5	21.5	1971	0.2	−0.984	**
PCB	5.2	5.2	1971	0.2	−0.967	**

[a]Data presented for years 1971, 1983, and the year of maximum mass emission (Schafer, 1984). Spearman rank correlation (r_s) between year and mass emission is for the years 1971–1983; p = probability that $r_s = 0$ (two-tailed); * = significant at 0.05, ** = significant at 0.01.
[b]Not measured in 1971.

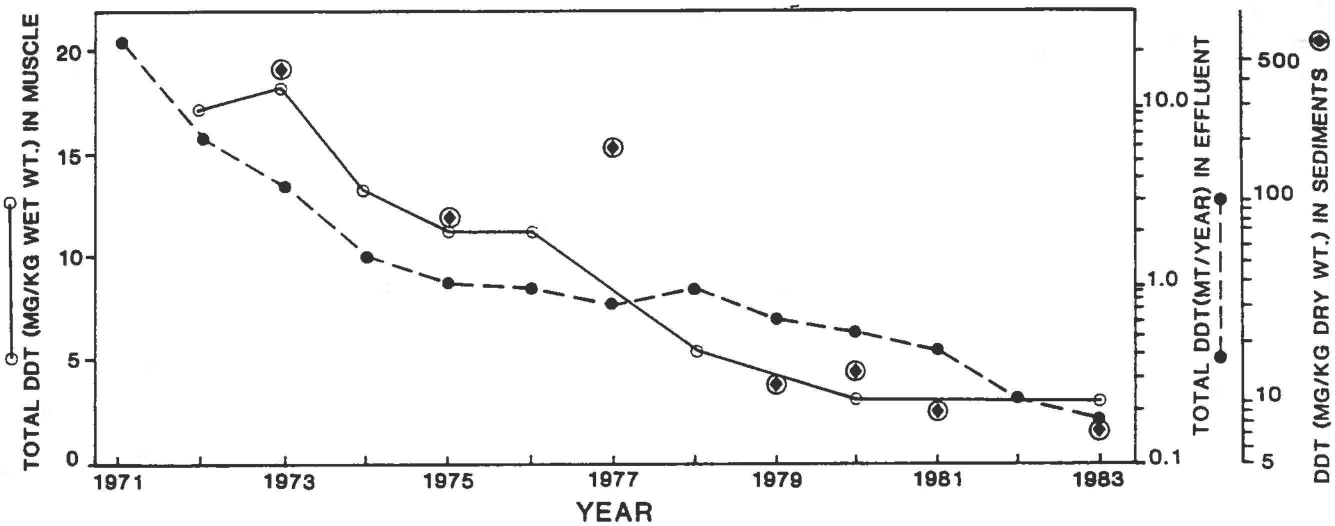

Figure 6.6. Median total DDT concentration (mg kg^{-1} wet wt) in muscle of Dover sole (*Microstomus pacificus*) collected between transects T1 and T5 on the Palos Verdes shelf during regular monitoring cruises (sample sizes were $n = 21$, 1972; $n = 9$, 1973; $n = 20$, 1974; $n = 10$, 1975; $n = 6$, 1976; $n = 10$, 1978; $n = 10$, 1980; $n = 7$, 1983) (County Sanitation Districts of Los Angeles County, 1983), mass emission [metric tons (t) y^{-1}] of total DDT in effluent (Schafer, 1984), and total DDT concentration (mg kg^{-1} dry wt) in surface sediments (0–2 cm) at 61 m on transect T4 by year (Cross, 1985).

The prevalence of fin erosion in Dover sole declined during the study period (Fig. 6.7). The slopes of the trend lines were significantly ($p < .05$) negative at stations T1, T4, and T5; the slope of the trend line for station T0 was not significantly different from zero. The prevalence of epidermal tumors in Dover sole that were <120 mm BSL did not show a significant decline during the study period. Tumor prevalence in these smaller fishes was, however, significantly ($\chi^2 = 25.4$, $p < .001$) greater at stations closer to the outfalls (station T1, 4.4% prevalence in all individuals that were collected from 1971 through 1983 and were <120 mm BSL; T4, 4.4%; T5, 3.5%) than at the farthest station (T0, 1.2%).

While the prevalence of fin erosion declined in Dover sole and in rex sole (*Glyptocephalus zachirus*), which were the third most frequently affected species on the Palos Verdes shelf (Cross, 1985), the prevalence increased in calico rockfish (*Sebastes dallii*), the second most frequently affected species (Fig. 6.7). This increase was significant ($p < .05$) at stations T4 and T5.

Calico rockfish were rarely collected before 1975 (only 0.8% of the individuals collected during the study were caught before 1975). None of the 1485 calico rockfish collected in 1975 and 1976 had fin erosion, while 26% of the 1947 individuals collected in 1977 and 1978 had the disease. Most of the calico rockfish collected were adults. Since the

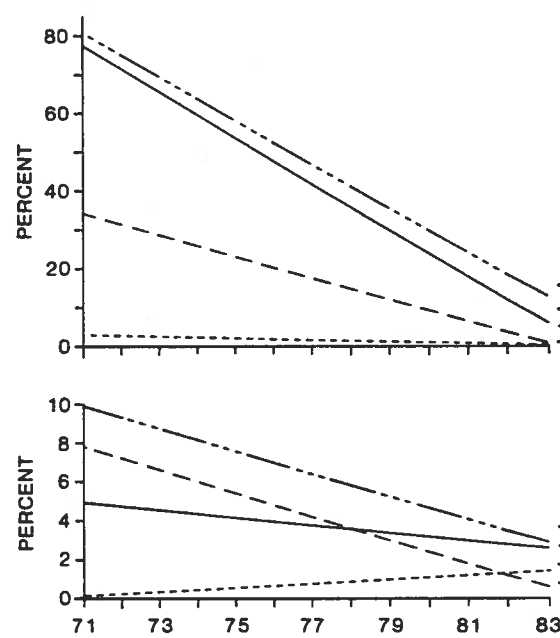

Figure 6.7. Trends as determined by linear regression in the prevalence of fin erosion (a) in Dover sole (*Microstomus pacificus*) and (b) in calico rockfish (*Sebastes dallii*) collected at four transects on the Palos Verdes shelf (1971–1983 for sole; 1975–1983 for rockfish). Closed circles are actual data for T4.

presence and severity of fin erosion appear to be directly related to the magnitude of body burdens of chlorinated hydrocarbon (McDermott-Ehrlich et al., 1977; Sherwood and Mearns, 1977; Sherwood, 1982), several years may be necessary for newly exposed adult fish to accumulate the contaminants that directly or indirectly contribute to the disease. In a laboratory experiment, juvenile Dover sole that were collected from relatively uncontaminated sites off southern California were exposed to contaminated sediments from the Palos Verdes shelf and developed fin erosion in 13 months. Control fish held on clean sediments did not develop the lesions (Sherwood and Mearns, 1977).

The spatial patterns of disease prevalence in fish collected on the Palos Verdes shelf are closely related to the spatial patterns of sediment contamination (Fig. 6.8). The prevalence of both diseases was highest at T4 and T5, the stations flanking the outfalls; lowest at T0, the station farthest from the outfalls; and intermediate at station T1 (Fig. 6.9).

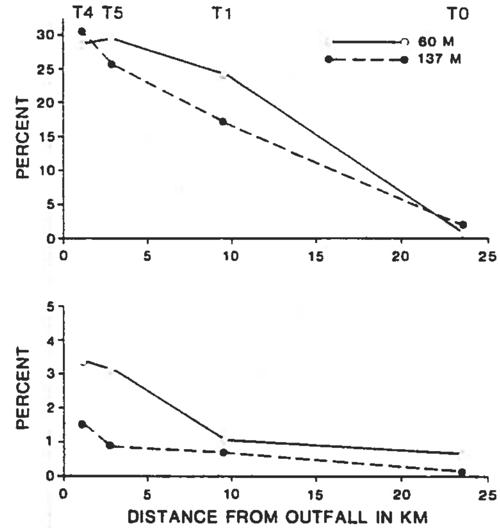

Figure 6.9. Overall (1971–1983) prevalence (a) of fin erosion and (b) of epidermal tumors in Dover sole (*Microstomus pacificus*) collected on the Palos Verdes shelf as a function of distance from the outfalls. Station transects labeled across the top.

6.4 CONCLUSIONS

The spatial patterns of fin erosion and tumors in demersal fish on the Palos Verdes shelf show enhancement of both diseases near the municipal wastewater outfalls. The spatial patterns of contaminants in surface sediments suggest that the magnitude of disease prevalence is directly related to the magnitude of sediment contamination. The temporal patterns in disease prevalence, body burdens of contaminants in fish, mass emission of contaminants, and contamination of surface sediment further suggest that both diseases are directly related to the environmental contaminants that emanated from the outfalls.

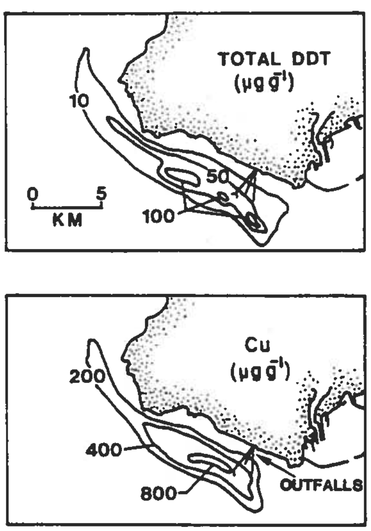

Figure 6.8. Distribution of total DDT (mg kg^{-1} dry wt) and Cu (mg kg^{-1} dry wt) in surface sediments (0–2 cm) on the Palos Verdes shelf in 1975 (after Hershelman et al., 1977).

While there are strong correlations between the presence and magnitude of both diseases and degraded environments, the etiologies of the lesions are either unknown (fin erosion) or controversial (epidermal tumors). Sindermann (1979) described fin erosion as "the best known but least understood disease of fish from polluted waters" and attributed it to a combination of environmental stress, facultative pathogens, host resistance, and latent infections. Recent evidence suggests that epidermal tumors are caused by a unicellular protozoan parasite resembling a parasitic amoeba (Dawe et al., 1979; Dawe, 1981; Watermann and Dethlefsen, 1982). Peters et al. (1981, 1983), however, suggest that the tumor cells are virus-transformed fish cells.

ACKNOWLEDGMENTS

The Los Angeles County Sanitation District kindly provided access to the monitoring data. A. J. Mearns encouraged me to undertake the project; his conversations were informative and stimulating. The comments of D. A. Wolfe and an anonymous reviewer improved the quality of the manuscript.

REFERENCES

Bowerman, B. L., and R. T. O'Connell. 1979. Time Series and Forecasting. Duxbury Press, North Scituate, Massachusetts, 481 pp.

Campana, S. E. 1983. Mortality of starry flounders (*Platichthys stellatus*) with skin tumors. *Canadian Journal of Fisheries and Aquatic Sciences*, **40**, 200–207.

County Sanitation Districts of Los Angeles County (CSDLAC). 1983. Joint Water Pollution Control Plant Revised Application for Modification of Secondary Treatment Requirements for Discharges into Marine Waters. Unpublished 301 (h) waiver application, County Sanitation Districts of Los Angeles County, submitted to U.S. Environmental Protection Agency, Washington, D.C., 14 sections (paginated separately) + 7 appendices.

Cross, J. N. 1985. Fin erosion among fishes collected near a southern California municipal wastewater outfall (1971–1982). *Fishery Bulletin*, **83**, 195–206.

Dawe, C. J., J. Bagshaw, and C. M. Poore. 1979. Amoebic pseudotumors in pseudobranchs of Pacific cod, *Gadus macrocephalus. Proceedings of the American Association of Cancer Research*, **20**, 245.

Dawe, C. J. 1981. Polyoma tumors in mice and X-cell tumors in fish, viewed through telescope and microscope. *In*: Phyletic Approaches to Cancer, C. J. Dawe, J. C. Harshbarger, S. Kondo, T. Sugimura, and S. Takayama (Eds.). Japan Scientific Society Press, Tokyo, pp. 19–49.

Dethlefsen, V. 1980. Observations on fish diseases in the German Bight and their possible relation to pollution. *Rapports et Procès-Verbaux des Réunions Conseil International pour l'Exploration de la Mer*, **179**, 110–117.

Hagerman, F. B. 1952. The biology of the Dover sole, *Microstomus pacificus* (Lockington). *California Department of Fish and Game, Fish Bulletin* **85**, 48 pp.

Hershelman, G. P., T.-K. Jan, and H. A. Schafer. 1977. Pollutants in sediments off Palos Verdes. *In*: Coastal Water Research Project Annual Report, W. Bascom (Ed.). Southern California Coastal Water Research Project, El Segundo, California, pp. 63–68.

McDermott-Ehrlich, D. J., M. J. Sherwood, T. C. Heesen, D. R. Young, and A. J. Mearns. 1977. Chlorinated hydrocarbons in Dover sole, *Microstomus pacificus*: local migrations and fin erosion. *Fishery Bulletin*, **75**, 513–517.

Mearns, A. J., and M. J. Sherwood. 1974. Environmental aspects of fin erosion and tumors in southern California Dover sole. *Transactions of the American Fisheries Society*, **103**, 799–810.

Mearns, A. J., and M. J. Sherwood. 1977. Distribution of neoplasms and other diseases in marine fishes relative to the discharge of wastewater. *Annals of the New York Academy of Sciences*, **298**, 210–224.

Möller, H. 1979. Geographical distribution of fish diseases in the NE Atlantic. *Meeresforschung*, **27**, 217–235.

Murchelano, R. A., and J. Ziskowski. 1982. Fin rot disease in the New York Bight (1973–1977). *In*: Ecological Stress and the New York Bight: Science and Management, G. F. Mayer (Ed.). Estuarine Research Foundation, Columbia, South Carolina, pp. 347–358.

Patton, J. S., and J. A. Couch. 1984. Can tissue anomalies that occur in marine fish implicate specific pollutant chemicals? *In*: Concepts in Marine Pollution Measurements, H. H. White (Ed.). Maryland Sea Grant, University of Maryland, University Park, pp. 511–538.

Peters, N., H. Stich, and H. Kranz. 1981. The relationship between lymphocystis disease and X-cell papillomatosis in flatfish. *In*: Phyletic Approaches to Cancer, C. J. Dawe, J. C. Harshbarger, S. Kondo, T. Sugimura, and S. Takayama (Eds.). Japan Scientific Society Press, Tokyo, pp. 111–121.

Peters, N., W. Schmidt, H. Kranz, and H. F. Stich. 1983. Nuclear inclusions in the X-cells of skin papillomas of Pacific flatfish. *Journal of Fish Diseases*, **6**, 533–536.

Schafer, H. 1984. Characteristics of municipal wastewater. *In*: Coastal Water Research Project Biennial Report, 1983–1984. Southern California Coastal Water Research Project, Long Beach, California, pp. 11–19.

Sherwood, M. J. 1982. Fin erosion, liver condition, and trace contaminant exposure in fishes from three coastal regions. *In*: Ecological Stress and the New York Bight: Science and Management, G. F. Mayer (Ed.). Estuarine Research Foundation, Columbia, South Carolina, pp. 359–377.

Sherwood, M., and A. J. Mearns. 1977. Environmental significance of fin erosion in southern California demersal fishes. *Annals of the New York Academy of Sciences*, **298**, 177–189.

Sindermann, C. J. 1979. Pollution-associated diseases and abnormalities of fish and shellfish: A review. *Fishery Bulletin*, **76**, 717–749.

Sindermann, C. J. 1983. An examination of some relationships between pollution and disease. *Rapports et Procès-Verbaux des Réunions Conseil International pour l'Exploration de la Mer*, **182**, 37–43.

Stich, H. F., A. B. Acton, and C. R. Forrester. 1976. Fish tumors and sublethal effects of pollutants. *Journal of the Fisheries Research Board of Canada*, **33**, 1993–2001.

Watermann, B., and V. Dethlefsen. 1982. Histology of pseudobranchial tumors in Atlantic cod (*Gadus morhua*) from the North Sea and the Baltic Sea. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, **35**, 231–242.