Jeffrey N. Cross

TRENDS IN FIN EROSION AMONG FISHES ON THE PALOS VERDES SHELF

Fin erosion in the Southern California Bight is most prevalent in fishes collected in the vicinity of the major municipal wastewater outfalls. Of the major outfalls, the disease is most frequently encountered around the JWPCP outfalls on the Palos Verdes shelf (Mearns and Sherwood 1974, 1977a, Sherwood and Mearns 1977). Approximately 20% of the 151 species of fish collected off southern California between 1969 and 1976 were affected by the disease, but flatfishes (*Pleuronectidae, Bothidae,* and *Cynoglossidae*) and rockfishes (*Scorpaenidae*) accounted for 60% of the affected species and 97% of the affected individuals (Mearns and Sherwood 1977a, Sherwood 1978). The Los Angeles County Sanitation District Annual Report (1981) and previous Project studies (Mearns and Sherwood 1977b, Sherwood 1978) showed that the incidence of fin erosion in Dover and rex soles declined from 1972 to 1977. The purpose of this study was to determine the present status of fin erosion among fishes collected by otter trawl on the Palos Verdes shelf. Data collected by Los Angeles County Sanitation District from 1971 to 1981 during monitoring cruises were analyzed for long term and seasonal trends in the incidence of fin erosion in the total catch and among the most affected species.

Ten percent of all individuals and 26% of all species collected by otter trawl on the Palos Verdes Shelf from 1971 to 1981 had identifiable fin erosion. Flatfishes and rockfishes accounted for 66% of the affected species and 99% of the affected individuals; Dover sole accounted for nearly 90% of the individuals with the disease. The incidence of the disease declined from 1971 to 1981 among the demersal fishes, but increased among fishes with swim-bladders suggesting that there are two types of fin erosion. The decline in the incidence of fin erosion is correlated with a decrease in the organic content and contaminant concentrations in surface sediments on the shelf. A seasonal trend in the occurrence of fin erosion was detected in the quarterly trawl data (1978-1981). The incidence of fin erosion peaked between July and September and is probably related to movements of Dover sole. The incidence and the disease among Dover sole increases from the time of settlement, when they are about 40-50 mm long, until they reach about 140 mm, when the disease begins to decline, probably because of increased mortalities.

Although the incidence of fin erosion has declined on the Palos Verdes shelf over the last 11 years, the disease is still a problem - 11% of the fishes collected near the outfalls in 1981 had fin erosion, and the population of at least one species (Dover sole) may be adversely affected.

METHODS

The data analyzed in this study were collected by Los Angeles County Sanitation District during regular monitoring cruises; the station and transect identifications used herein and their designations. The data included catch records of fishes and the incidence of fin erosion by species along seven transects on the Palos Verdes shelf (Figure 1). Trawls were made during daylight hours at three depths (23, 61, and 137 m) with an otter trawl towed along the depth isobath at 1.1 m/sec for 10 minutes with a scope ratio of about 3:1. A 7.3 m (headrope length) otter trawl was used from 1971 until 1974, when it was replaced by a 7.6 m net; a 1.25 cm mesh cod-end liner was used in both nets. Two samples were collected annually at each depth from 1971 through 1978 - one between April and June and the other between October and December. Additional trawls were made at irregular intervals and were included in the analysis. Quarterly trawling began in 1979 and has continued to the present. Sampling was discontinued at stations T2, T3, and T6 in 1977; consequently the trend analysis was performed on data from T0, T1, T4, and T5 (Figure 1).

The mean percent of fish with fin erosion was calculated for each year for the 61 and 137 m depths at each of the four stations; the incidence of fin erosion was negligible at 23 m at all stations, so this depth was dropped from the trend analyses. Trends in the incidence of fin erosion and catch per unit of effort (CPUE = total number of fish caught in one 10 minute trawl)

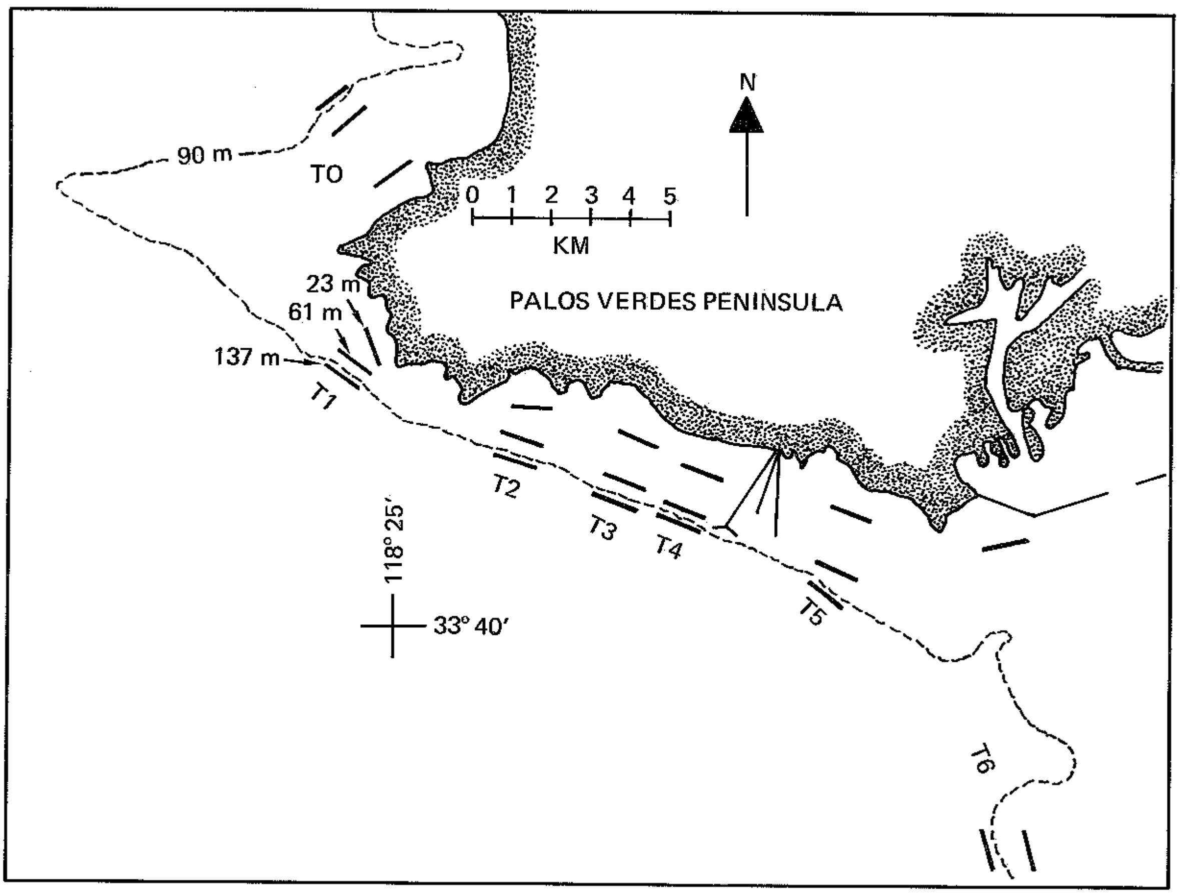

Figure 1. Location of sampling transects on the Palos Verdes Shelf. Three depths (23, 61 and 137 m) were sampled at each transect. JWPCP outfalls are located between transects T4 and T5.

were determined from linear regressions of annual means against years after the appropriate transformations (numbers were transformed to $\log_{10}$ and proportions (p) were transformed to arcsin $\sqrt{p}$). The correlation coefficients (r) for the regressions are presented to indicate the strength of the relationships: Correlations above .602 (either + or –) are strong and indicate a significant relationship ($p < .05$); correlations between .521 and .602 are moderate and border on statistical significance ($.05 < p < .10$); correlation below .521 are weak and indicate little or no change over time.

The quarterly trawl data (1979-1981) for stations T4 and T5 (at 61 and 137 m) were examined for seasonal trends in the incidence of fin erosion. The following model was used to estimate the trends:

$$P_t = f(T_t, S_t, R_t)$$

Where P_t = percent fin erosion at time t, T_t = the trend component at time t, S_t = the seasonal component at time t, R_t = the remaining components (cyclical components and irregular variation), and f is a function relating the observed value of the time series to the trend, seasonal, and remaining components. The assumption is that T, S, and R are related to each other, but result from different causes (Harnett and Murphy 1980). Regressions were fitted to the transformed incidence data to estimate T (the regression coefficient) for each quarter. The trend is eliminated by dividing the quarterly P values by T. S, the seasonal index, is then estimated for each quarter of the year assuming that R is small (Harnett and Murphy 1980).

RESULTS

From 1971 to 1982, 15,403 individuals (representing 29 species of teleost fishes) affected by fin erosion were collected in 578 otter trawls on the Palos Verdes Shelf (Table 1). Flatfishes and rockfishes comprised 66% of the affected species and 99% of the affected individuals. Dover sole comprised nearly 90% of the affected individuals.

Table 1. Taxonomic list of fishes collected in 578 trawls on the Palos Verdes Shelf between 1971-1981 affected with fin erosion.

Common Name	Scientific Name	Number Collected	Frequency of Occurrence (%) in Trawl Collections	Percent With Fin Erosion	Percent of all Fish with Fin Erosion
Spotted cuskeel	*Chilara taylori*	182	16.8	0.5	<0.1
Blackbelly eelpont	*Lycodopsis pacifica*	1,917	19.2	<0.1	<0.1
Shortspine thornyhead	*Sebastolobus alascanus*	295	4.5	0.3	<0.1
Calico rockfish	*Sebastes dallii*	8,854	22.7	10.0	5.8
Shortbelly rockfish	*Sebastes jordani*	3,244	26.6	0.2	<0.1
Stripetail rockfish	*Sebastes saxicola*	18,217	54.0	<0.1	<0.1
Vermillion rockfish	*Sebastes miniatus*	381	18.2	0.5	<0.1
Pink rockfish	*Sebastes eos*	37	1.2	5.4	<0.1
Greenstripe rockfish	*Sebastes elongatus*	234	13.0	2.6	<0.1
Splitnose rockfish	*Sebastes diploproa*	5,998	23.2	<0.1	<0.1
Sablefish	*Anoplopoma fimbria*	711	16.8	0.3	<0.1
Sportspine combfish	*Zaniolepis frenata*	722	19.2	0.1	<0.1
Longspine combfish	*Zaniolepis latipinnis*	778	19.7	0.5	<0.1
Barred sand bass	*Paralabrax nebulifer*	29	3.3	3.4	<0.1
White croaker	*Genyonemus lineatus*	8,921	20.9	1.6	0.9
White surfperch	*Phanerodon furcatus*	846	12.8	0.2	<0.1
Shiner surfperch	*Cymatogaster aggregata*	9,470	28.5	<0.1	<0.1
Pacific butterfish	*Peprilus simillimus*	30	2.1	20.0	<0.1
California tonguefish	*Symphurus atricauda*	1,003	24.7	1.8	0.1
Pacific sanddab	*Citharichthys sordidus*	10,493	59.7	0.6	0.4
Speckled sanddab	*Citharichthys stigmaeus*	14,400	39.8	<0.1	<0.1
Bigmouth sole	*Hippoglossina stomata*	133	13.8	2.3	<0.1
C-O sole	*Pleuronichthys coenosus*	166	10.2	1.2	<0.1
Curlfin turbot	*Pleuronichthys decurrens*	3,751	41.2	2.4	0.6
Hornyhead turbot	*Pleuronichthys verticalis*	390	23.4	0.8	<0.1
English sole	*Parophrys vetulus*	1,229	45.8	0.9	<0.1
Rex sole	*Glyptocephalus zachirus*	4,236	28.0	7.0	1.9
Slender sole	*Lyopsetta exilis*	3,590	25.1	4.3	1.0
Dover sole	*Microstomus pacificus*	39,685	62.3	34.5	88.9

The incidence of fin erosion among all the fishes at 61 m declined strongly at T1 and weakly at T0, T4, and T5 between 1971 and 1981 (Figure 2). The incidence of fin erosion at 137 m declined strongly at T1, moderately at T0, and showed no trend at T4 and T5. Over the same period, there was no statistically detectable change in CPUE.

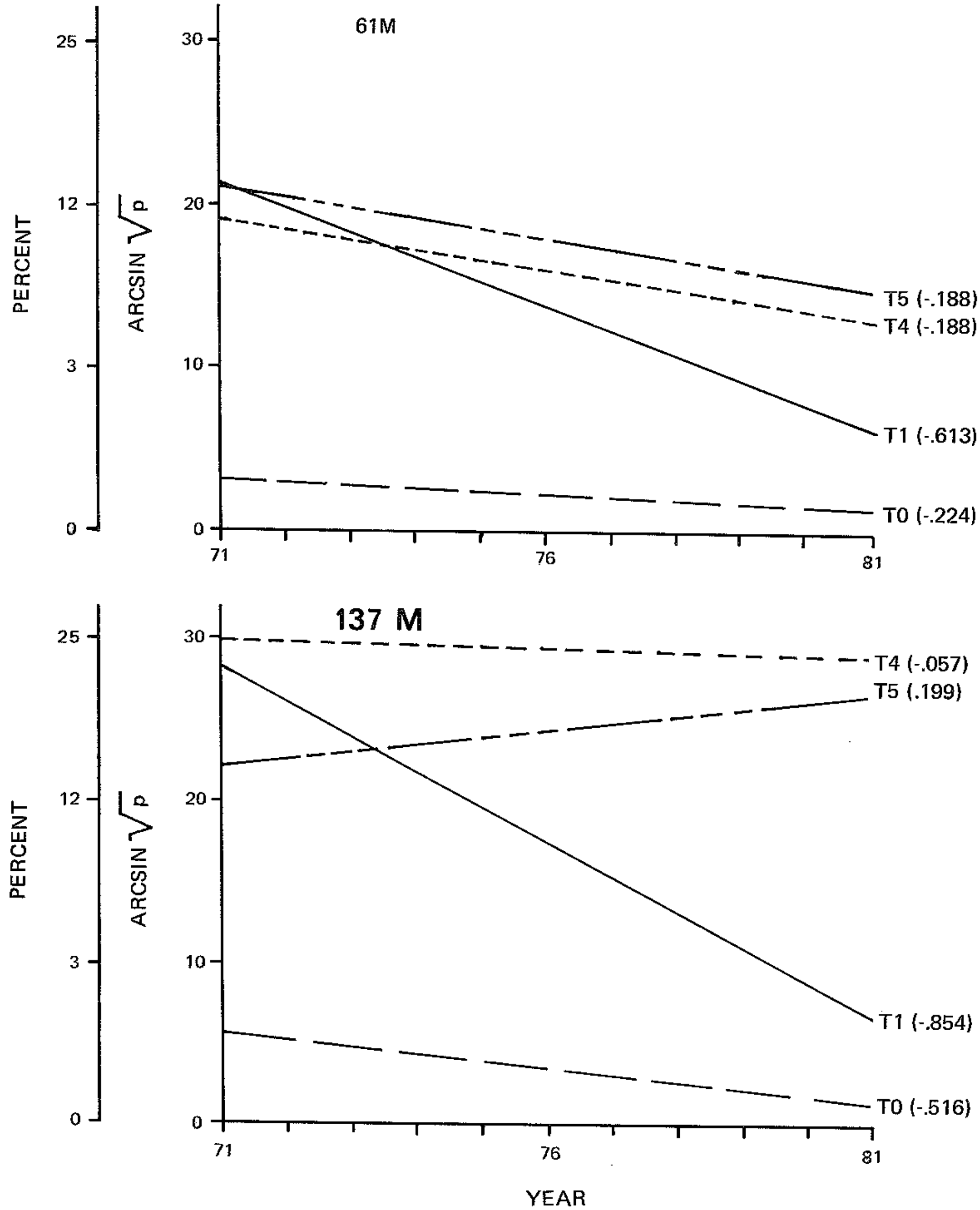

Figure 2. Trends in the incidence of fin erosion for the total catch from 1971 to 1981 at 61 m (above) and 137 m (below); correlation coefficients are given in parentheses. This shows that fin erosion has declined substantially at T1, moderately at T0, and is unchanged at T4 and T5.

Trends in the incidence of fin erosion among the most affected species (Dover sole, calico rockfish, and rex sole; Table 1) were examined. The incidence of the disease in Dover sole declined moderately at T4-61 m and strongly at the remaining stations from 1971 to 1981 (Figure 3). (T0 was not included in the analysis because few Dover sole were collected there.)

Calico rockfish were rarely collected prior to 1975; beginning in 1975 they increased in abundance at all stations, but were collected primarily at 61 m. The incidence of fin erosion between 1974 and 1981 increased strongly at T1, T4, and T5, and slightly at T0 (Figure 4).

Rex sole were collected primarily at 137 m. The incidence of fin erosion from 1971 to 1981 declined strongly at T0, T1, and T4, and weakly at T5 (Figure 5).

Analysis of the quarterly trawl data (1978-1981) revealed a seasonal trend in the occurrence of the disease. The seasonal fin erosion index was similar at T4-137 m, T5-61 m, and T5-137 m peaking in the third quarter (July - September) (Figure 6). At T4-61 m the seasonal index peaked during the second quarter (April - June), but was also high during the third quarter.

The incidence of fin erosion was examined over the size range of Dover sole captured by the trawls. For this analysis, all Dover sole captured during the study period were combined by station, and size frequency distributions of fish with and without fin erosion were calculated. The disease was first observed in fish between 60-79 mm and increased with fish size (Figure 7). Fishes between 120-200 mm had the highest incidence of the disease, while the disease began to decline in fish larger than 140 mm.

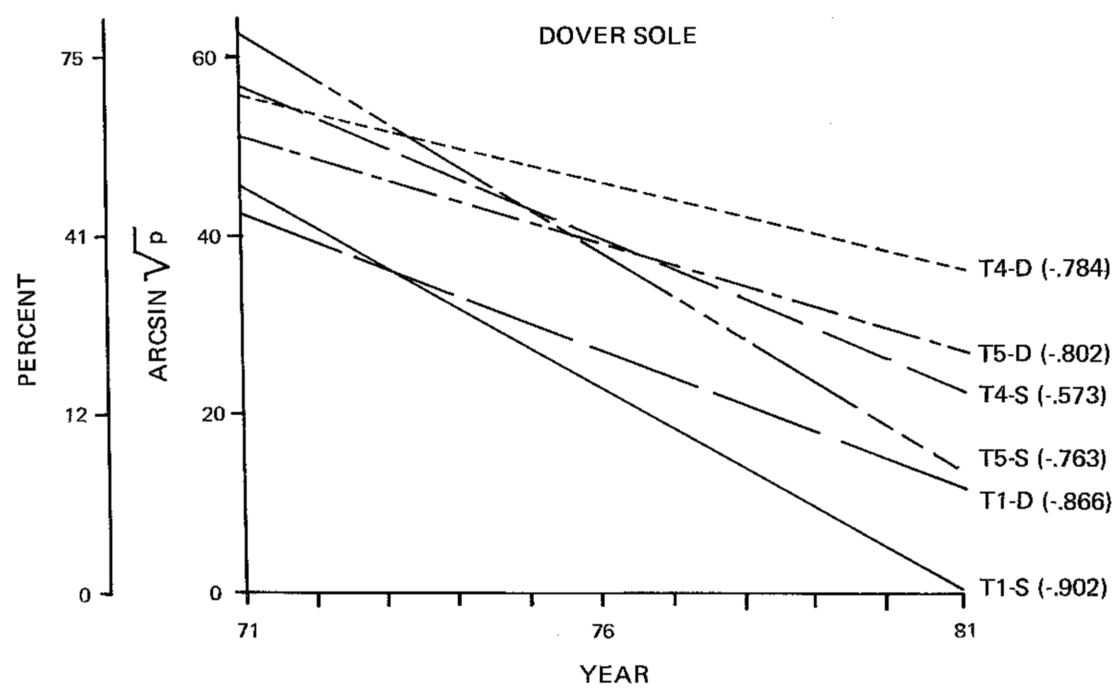

Figure 3. Trends in the incidence of fin erosion among Dover sole at 61 m (S) and 137 m (D); correlation coefficients given in parentheses. This shows that the incidence of fin erosion has declined significantly at all stations.

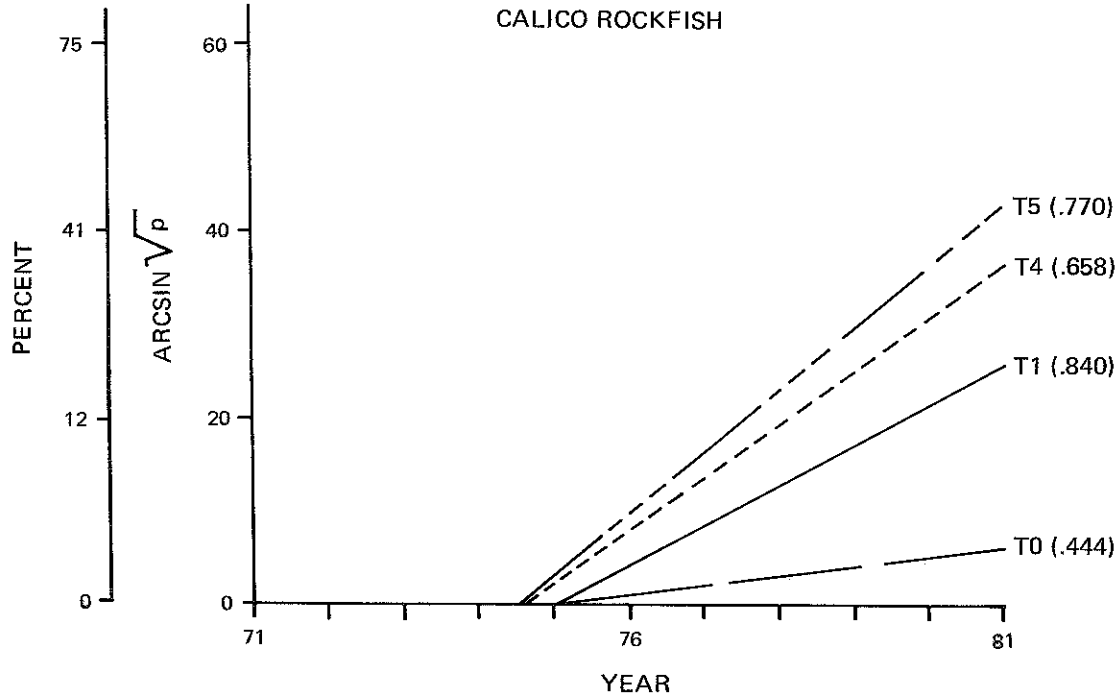

Figure 4. Trends in the incidence of fin erosion among calico rockfish at 61 m; correlation coefficients given in parentheses. This shows that the incidence of fin erosion has increased significantly at all stations except T0.

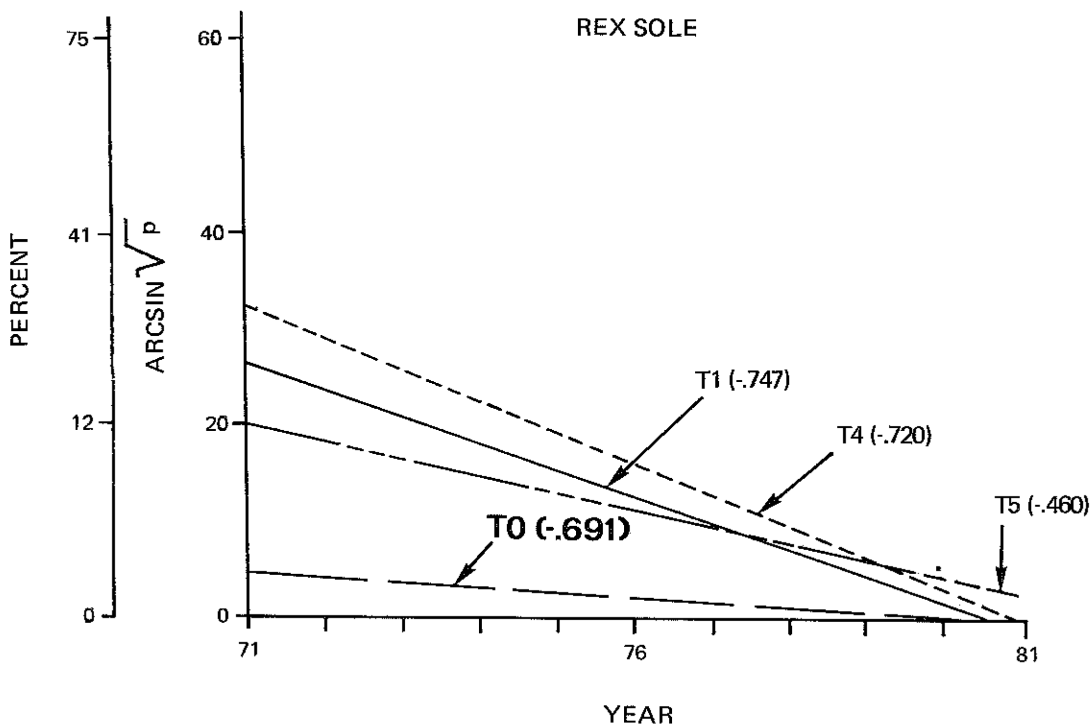

Figure 5. Trends in the incidence of fin erosion among rex sole at 137 m; correlation coefficients given in parentheses. This shows that the incidence of fin erosion has declined significantly at all stations except T5.

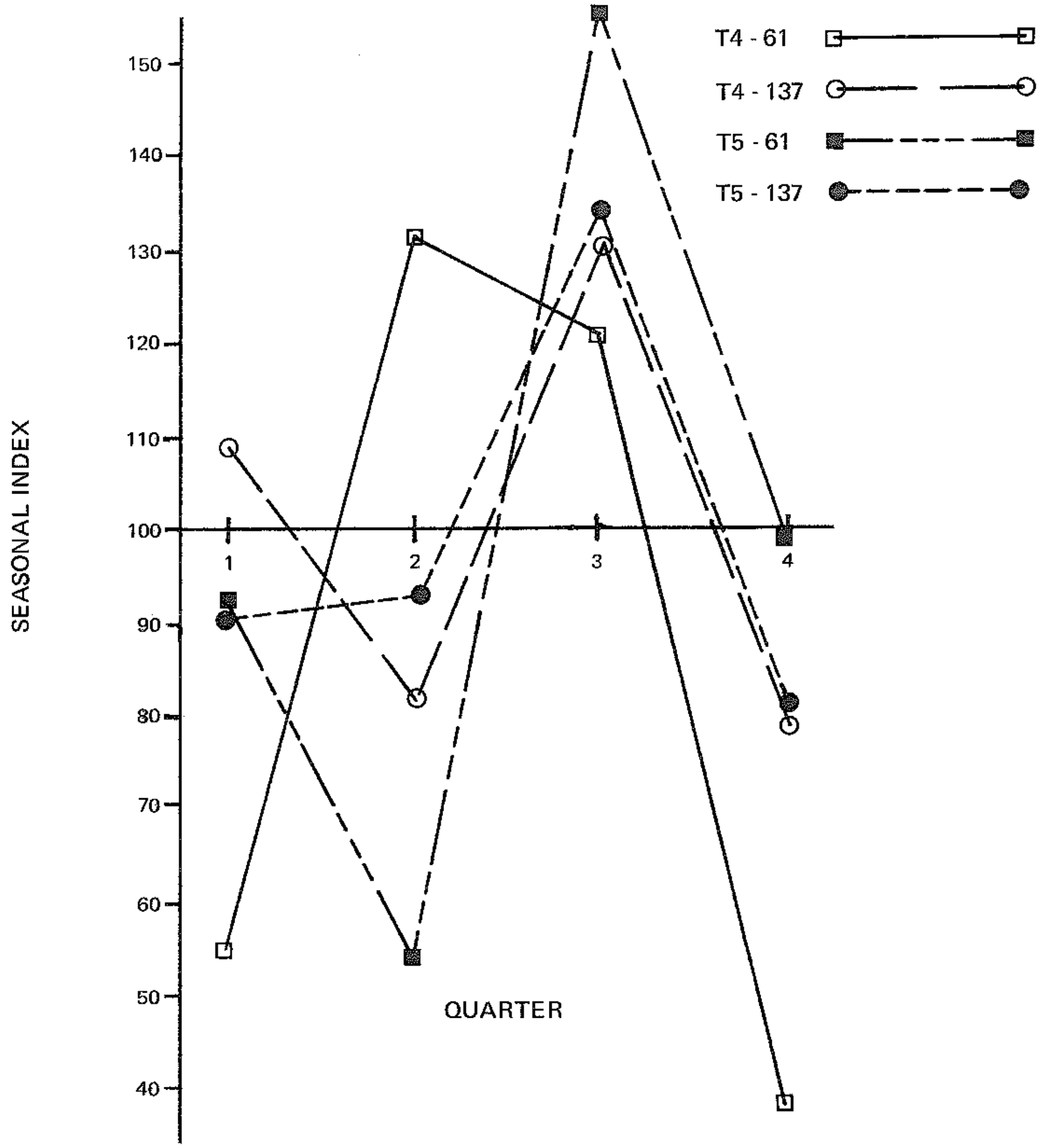

Figure 6. Seasonal trends in the incidence of fin erosion by quarters (1 = Jan-Mar, 2 = Apr-Jun, 3 = July-Sept, 4 = Oct-Dec) for 1979 to 1981 at T4 and T5. This shows that the incidence of fin erosion peaked at three of the four stations in the third quarter.

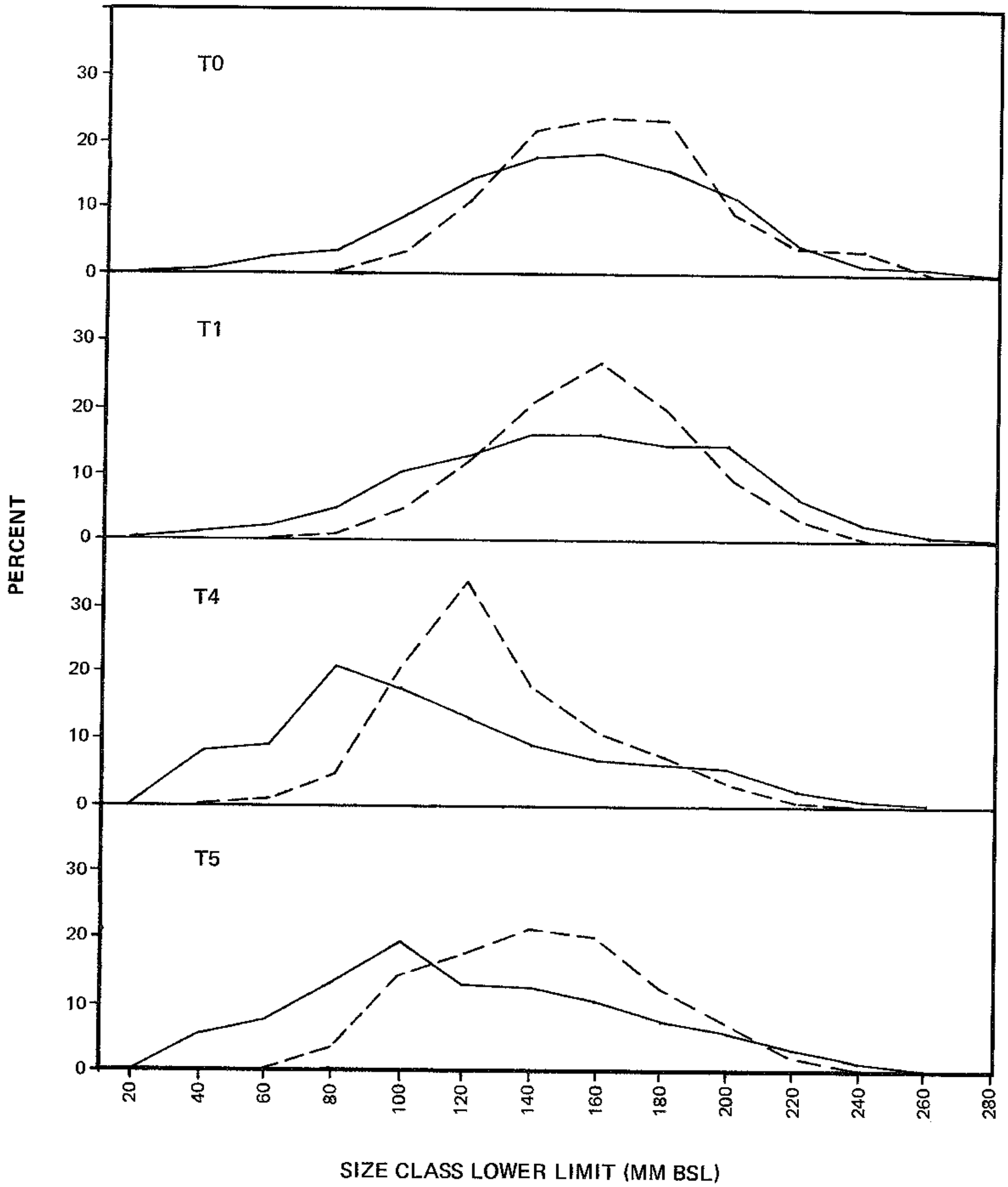

Figure 7. Size-frequency distributions of Dover sole with fin erosion (broken line) and without fin erosion (solid line) for the four transects. The figures represent the combined size-frequency distributions of sole collected at 61 and 137 m from 1971 to 1981. This shows that the disease is first observed when the fish are 60-79 mm board standard length (BSL), the incidence is highest in fish 120-200 mm BSL, and declines in fish larger than 140 mm BSL.

DISCUSSION

From 1971 to 1981, 578 trawls on the Palos Verdes Shelf produced 15,403 individuals (9.7% of all individuals collected) representing 29 species (26.4% of all species collected) with identifiable fin erosion (Table 1). Over that period, the incidence of fin erosion in trawl-caught fishes decreased strongly at T1-61 m and T1-137 m, moderately at T0-137 m, and was little changed at the remaining stations (Figure 2). The number of species affected by the disease also declined significantly ($r = -.815$, $.002 < p < .005$) from 18 in 1971 to three in 1981. The incidence of fin erosion in Dover sole, the most affected species, declined substantially at 61 and 137 m at T1, T4, and T5 (Figure 3). The incidence of the disease in rex sole declined strongly at 137 m at T0, T1, and T4, and weakly at T5 (Figure 5). The incidence of the disease in calico rockfish, however, increased strongly at 61 m at T1, T4, and T5, and slightly at T0 (Figure 4). The CPUE of the most affected species generally increased over the study period indicating that the decline in the incidence of fin erosion was real and not a sampling phenomenon.

Sinderman (1979) noted two forms of fin erosion: ". . . one in bottomfish, where damage seems site-specific and related to direct contact with contaminated sediments, and another in pelagic nearshore species, characterized by more generalized erosion, but with predominant involvement of the caudal fin" (p. 719). The decreased incidence of fin erosion in Dover and rex soles and the increased incidence in calico rockfish suggest that the two forms of the disease behave independently. Although calico rockfish possess a swimbladder, they are frequently observed resting on the bottom. Differential susceptibility or exposure (Sinderman 1979), rather than independence of the two forms of the disease, may account for the decreased incidence in the soles and increased incidence in the calico rockfish.

While the etiology of fin erosion is uncertain, its association with contaminated sediments is strong (Murchelano and Ziskowski 1976, Sinderman 1979). The presence of the disease in the environment has been correlated with high sediment concentrations of bacteria (Mahoney *et al.* 1973), heavy metals (Carmody *et al.* 1973, Mearns and Sherwood 1974, Sherwood and Mearns 1977b), and chlorinated hydrocarbons (Wellings *et al.* 1976, McDermott-Ehrlich *et al.* 1977, Sherwood 1978). In the laboratory, fin erosion has been induced in fish exposed to bacteria (Oppenheimer 1958), crude oil (Minchew and Yarbrough 1977), PCB (Couch 1974), and zinc and cadmium (Bengtsson 1974, 1975).

The decline in the incidence of fin erosion among the demersal fishes on the Palos Verdes Shelf suggests that sediment contamination and concomitantly, the mass emission of contaminants from the outfalls, have declined from 1971 to 1981. This is supported by: 1) Declines in surface sediment concentrations of DDT (Table 2), copper, cadmium, and chromium (Table 3), and 2) strong negative correlations between surface sediment organic content and years from 1972 to 1981 (Table 4). T0 is the control for the remaining stations; at 61 m the sediment organic content has not changed significantly since 1972 (Table 4) and falls within the 95% confidence interval (2.12 - 2.84%) for control stations in northern Santa Monica Bay. That T0 is a reasonable control is further supported by the low incidence of fin erosion there (Figure 2).

The incidence of fin erosion in Dover sole was examined over the range of sizes collected. Dover sole recruit to the study area from February to May (Sherwood 1980) when they are 40-50 mm SL (Allen and Mearns 1976). Fin erosion was first observed in fish 60-79 mm BSL (Figure 7). Based on growth curves presented in Sherwood (1980), the disease is contracted by young Dover sole within approximately 100 days after settlement. The incidence of fin erosion increases with increasing fish size and about one year after settlement (when the fish are 100-140 mm), the proportion of fish in a size class with the disease is greater than the proportion of fish without it (Figure 7). The decline in the incidence of the disease among the larger fish

Table 2. Total DDT concentration (ppm dry weight) of surface sediments at the sampling transects from 1971 to 1981. Note the deeper samples were taken at 152 m while the trawls were made at 137 m. Depth (cm) of surface sediments analyzed at bottom of table. Determinations made by SCCWRP.

STATION	YEAR							
	71	72	73	75	77	79	80	81
T0-61 m				3.5				
T0-152 m				3.7				
T1-61 m	31		160	62		11		4.0
T1-152 m	2.3		55	17				
T4-61 m	90		440	70	175	12	14	8.7
T4-152 m	130		220	133			72	
T5-61 m	73	130	95	29	20			12
T5-152 m	49	80	95	124				
Depth	0–1	0–2	0–5	0–5	0–2	0–2	0–2	0–2

Table 3. Copper, cadmium and chromium concentrations (ppm) in surface sediments (1971: 0-1 cm, 1975: 0-5 cm, 1978: 0-2 cm, 1980: 0-2 cm) at the sampling transects. Note that the deeper samples were taken at 152 m while the trawls were made at 137 m. Depth (cm) of surface sediments analyzed at bottom of table. Determinations made by SCCWRP.

	COPPER				CADMIUM				CHROMIUM			
YEAR	71	75	78	80	71	75	78	80	71	75	78	80
STATION												
T0-61 m		48	42			1.7	1.3			137	119	
T0-152 m		66	66			3.3	2.6			170	174	
T1-61 m	110	362			12	21			280	828		
T1-152 m	160	148			10	11			290	317		
T4-61 m	670	937	427	352	57	61	28	31	1000	1480	1042	972
T4-152 m	140	555	408		17	66	24		210	968	862	
T5-61 m	230	134	234		24	8.3	9.2		390	254	521	
T5-152m	220	433	301		32	41	16.0		400	769	605	
Depth	0–1	0–5	0–2	0–2								

suggests that: 1) Fin erosion results in increased mortalities (natural or due to predation); 2) emigration from the study area is greater in fish with the disease than without it; or 3) the disease goes into remission or disappears altogether. These hypotheses cannot be separated with the present data, but it seems likely that fin erosion results in increased mortalities.

Seasonal trends in the incidence of fin erosion calculated from quarterly trawl data (1979-1981) show that fin erosion was highest in the third quarter (July-September) (Figure 6). The reason for the peak in the third quarter is not known, but since Dover sole comprised nearly

Table 4. Correlations between organic content (percent) of surface sediments at 61 m and years from 1972 to 1981. r = correlation coefficient, p = significance of relationship, $\overline{X}$ = mean, SD = one standard deviation, n = sample size. Data from JWPCP six-month summary reports.

Transects	r	p	$\overline{X}$ percent organic content	SD	n
T_0	.052	.50	2.13	0.18	13
T_1	-.761	.001	6.83	1.45	17
T_4	-.831	.001	11.21	1.39	17
T_5	-.532	.05	7.83	1.62	17

90% of the fishes with fin erosion, a much more detailed seasonal analysis of size frequency distributions and incidence of fin erosion by depth may suggest an explanation.

CONCLUSION

The incidence of fin erosion among fishes collected by otter trawl on the Palos Verdes shelf declined from 1971 to 1981. The decline of the disease correlates with reduced surface sediment concentrations of chlorinated hydrocarbons, heavy metals, and organic matter. The disease however remains a problem - 11% of the fishes collected at 61 m and 137 m at T4 and T5 in 1981 had fin erosion - and appears to affect at least one population (Dover sole) adversely by causing increased mortalities.

Sinderman (1979) described fin erosion as "probably the best known but least understood disease of fish from polluted waters. . ." (p. 719) and concluded ". . . that generalized disease signs, such as fin rot. . . may be characteristic of fishes resident in degraded habitats, where environmental stresses of toxic chemicals, low dissolved oxygen, and high microbial populations exist" (p. 722). The etiology of the disease is unknown, probably because of its complexity. "The multifactorial genesis of disease in marine species is becoming apparent, involving environmental stress, facultative pathogens, resistance of hosts, and latent infections" (Sinderman 1979: 741). Because of difference among species in the incidence of fin erosion, interspecific studies on how contaminants enter the animals and how contaminants affect metabolic processes may help elucidate the etiology of the disease.

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