SOUTHERN CALIFORNIA'S INSHORE DEMERSAL FISHES: DIVERSITY, DISTRIBUTION, AND DISEASE AS RESPONSES TO ENVIRONMENTAL QUALITY

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INTRODUCTION

The Southern California Coastal Water Research Project (SCCWRP)[1] has been established to study the coastal water environment, especially with respect to the effects of municipal wastewater discharges. In the summer of 1971, the project began an intensive analysis of fish data that was being collected by coastal monitoring agencies using small otter trawls. The objectives of the SCCWRP study were (1) to determine whether or not previously reported diseased and abnormal fish populations were related to the discharge of wastewaters in southern California and (2) to determine whether or not information useful to marine pollution control problems was being taken by these trawl surveys.

Today, I am going to summarize some of our observations on the abundance, diversity, and health of southern California's inshore demersal fish populations and, for purposes of discussion, present some new hypotheses on the possible impact of man's activities on these fish populations.

[1] The project is jointly sponsored by the five agencies (Ventura County, the Cities of San Diego and Los Angeles, and the County Sanitation Districts of Orange and Los Angeles Counties) responsible for most of the municipal wastewater discharges into the ocean off southern California. A commission of local civic leaders administers the project; scientific guidance is provided by a consulting board of environmental experts. The project has received two grants from the Environmental Protection Agency and has recently released a report summarizing its first 3 years of research (Southern California Coastal Water Research Project 1973).

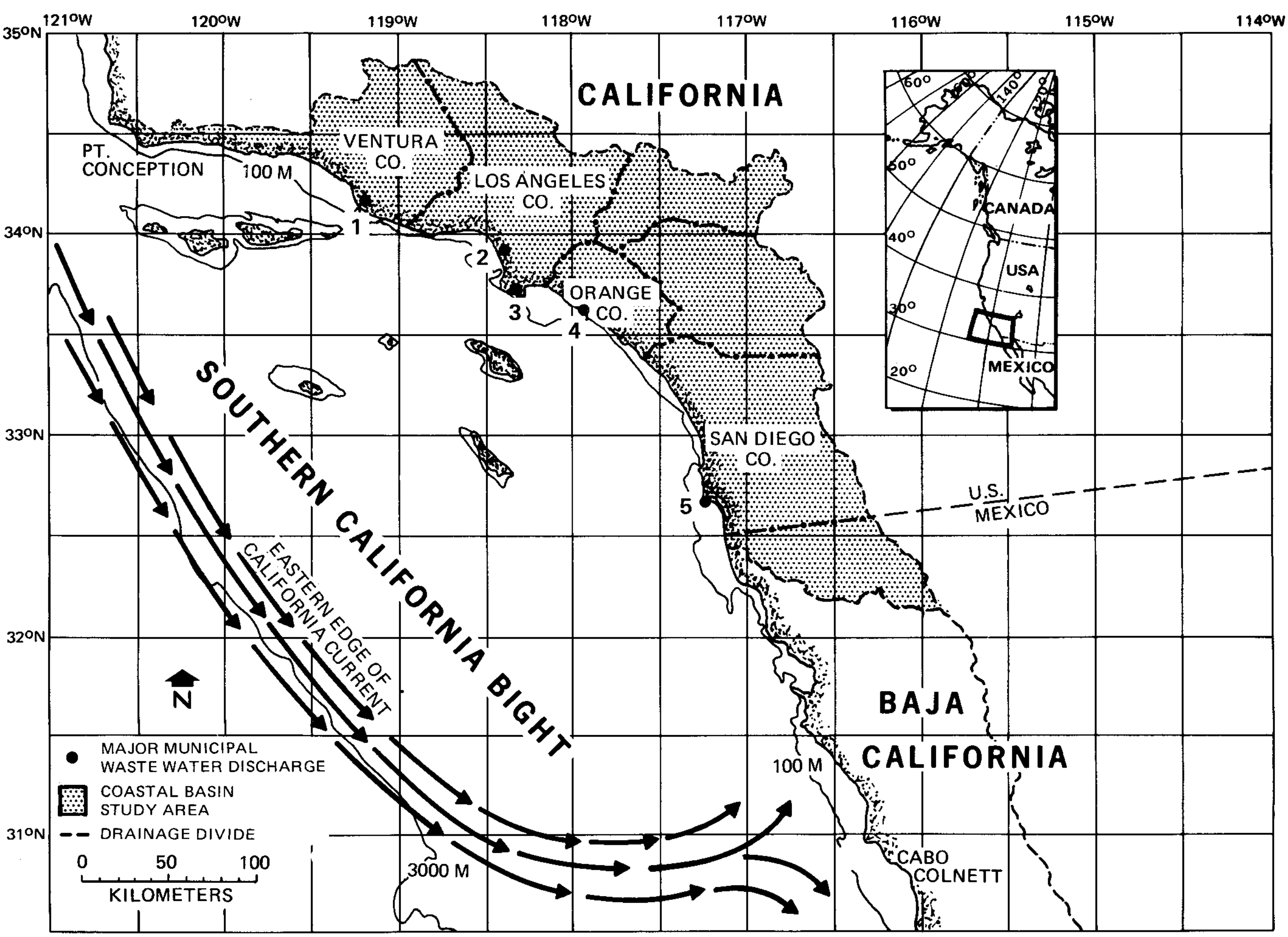

FIGURE 1. The Southern California Bight and the adjacent coastal basin. Major municipal wastewater discharges are (1) City of Oxnard, (2) City of Los Angeles, (3) County Sanitation Districts of Los Angeles County, (4) County Sanitation Districts of Orange County, and (5) City of San Diego.

STUDY AREAS AND METHODS

The Southern California Bight (Figure 1) is the major area of concern in all of SCCWRP's physical, chemical, and biological investigations. The Bight is defined on the east by the coastal shoreline extending from Point Conception, California, to Cabo Colnett, Baja California, and on the west by the California Current. At present, we have fish data for only a small fraction of the Bight—primarily, the waters near the most densely populated areas of the southern California coast.

Most of the data obtained and analyzed by SCCWRP were collected in trawl surveys off Los Angeles County during 1957–63 (Carlisle 1969) and off Ventura, Los Angeles, and Orange Counties between 1969 and the present. The data were taken by several different agencies, including the California Department of Fish and Game, local sanitation districts, and universities and colleges. Most of the investigators used 25 ft (headrope length) shrimp trawls with 1½ in. mesh and ½ in. cod ends or cod-end liners. The County Sanitation Districts of Los Angeles County, which trawled off the Palos Verdes Peninsula, used a 40 ft trawl with slightly larger mesh size. Trawls were made at depths of 10 to 400 meters; most tows were 10 minutes in duration, but the area sampled varied according to vessel speed.

SCCWRP is now analyzing data from about 1,800 otter trawl hauls for species composition, relative abundance, dominance, information-theory diversity, disease frequency, and recurrent groups. In 1971 and 1972, we made special collections to identify and resolve problems concerning species identifications, gear characteristics, disease descriptions, and methods of measuring fishes. The following summary is based primarily on data from approximately 300 samples taken at 119 stations (Figure 2) since 1969.

FINDINGS

Populations and Communities

The data from the trawl samples showed that at least 121 species, representing 41 families of cartilaginous and bony fishes, were present on or near the bottom of the coastal shelf survey areas. The 20

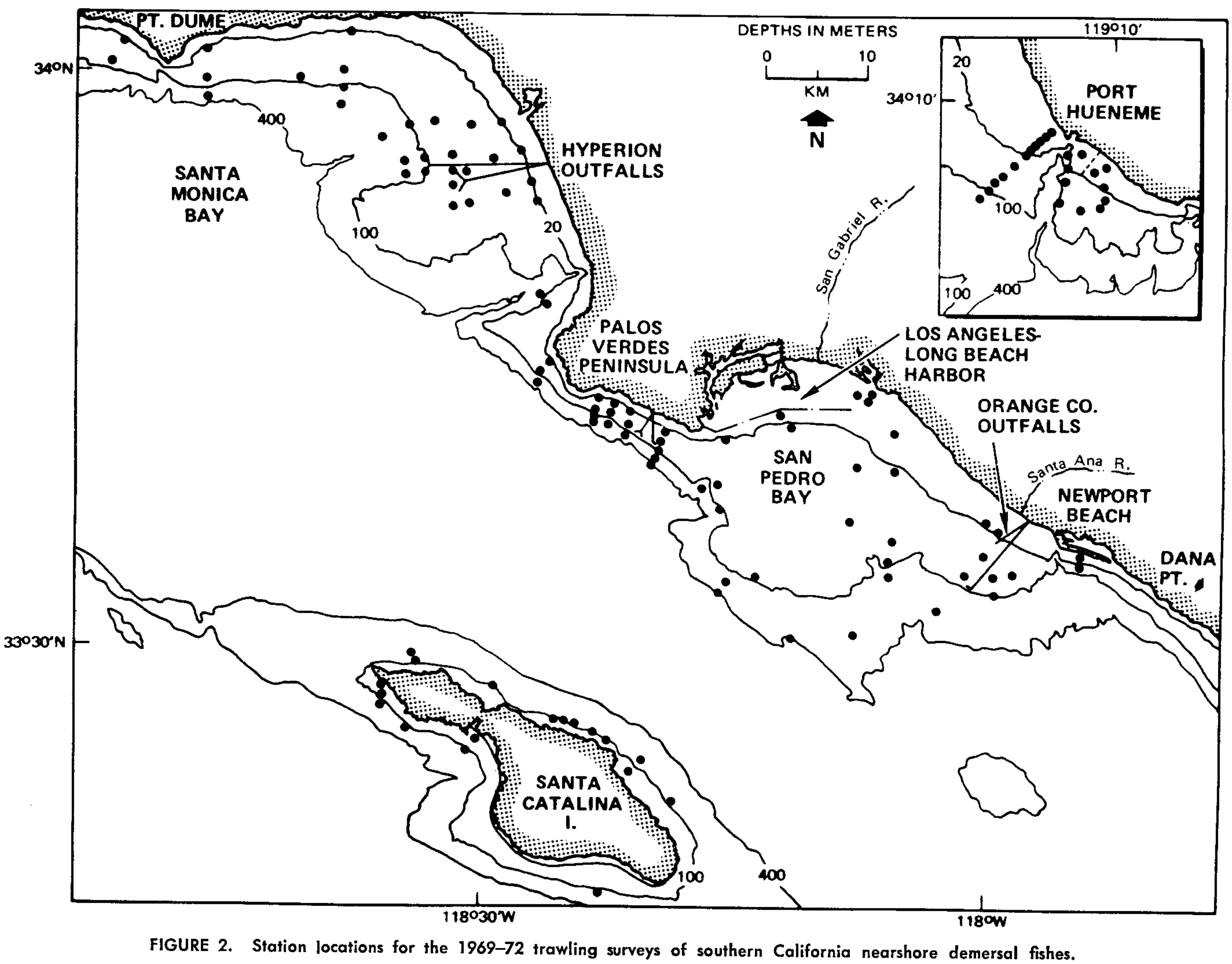

FIGURE 2. Station locations for the 1969–72 trawling surveys of southern California nearshore demersal fishes.

most abundant species are listed in Table 1. Although the catches were dominated by flatfishes, rockfishes, and perches, there were occasional large catches of white croaker, *Genyonemus lineatus*, and northern anchovy, *Engraulis mordax*. The dover sole, *Microstomus pacificus*, was the most common and among the most abundant species captured; this species is also interesting because (1) it was apparently rare in some 200 trawls taken by the University of Southern California between 1912 and 1922 in the same coastal areas (Ulrey and Greeley 1928) and (2) it is represented by populations bearing several kinds of diseases.

TABLE 1

Total number of specimens of each of the 20 species most abundant in samples from the 1969–72 trawling surveys of southern California coastal waters

Species	Common Name	No. of specimens
Citharichthys stigmaeus	Speckled sanddab	17,626
Citharichthys sordidus	Pacific sanddab	10,312
Microstomus pacificus	Dover sole	9,375
Sebastes saxicola	Stripetail rockfish	5,535
Genyonemus lineatus	White croaker	4,155
Porichthys notatus	Plainfin midshipman	3,943
Lyopsetta exilis	Slender sole	3,893
Symphurus atricauda	California tonguefish	3,590
Sebastes semicinctus	Halfbanded rockfish	3,310
Icelinus quadriseriatus	Yellowchin sculpin	2,836
Cymatogaster aggregata	Shiner perch	2,008
Zalembius rosaceus	Pink surfperch	1,975
Engraulis mordax	Northern anchovy	1,952
Glyptocephalus zachirus	Rex sole	1,865
Seriphus politus	Queenfish	1,864
Zaniolepis latipinnis	Longspine combfish	1,402
Sebastes diploproa	Splitnose rockfish	1,186
Pleuronichthys decurrens	Curlfin sole	1,063
Lycodopsis pacifica	Blackbelly eelpout	849
Zaniolepis frenata	Shortspine combfish	815
Total		79,554
Total (all species)		87,418

Fish populations occurred in all bottom areas sampled, including those highly contaminated by discharged wastes. There were considerable differences in fish abundance (catch per haul) and diversity (species per haul) in the various areas: Median catches ranged from 60 to 100 fish per haul in the Santa Catalina Island and Port Hueneme surveys to 200 to 500 fish per haul in the San Pedro Bay and Orange County coast surveys. As different sampling methods were used in each survey, it was not possible to relate variations in catch and species per unit effort to the environmental conditions in the areas. However, when a single vessel and gear combination was used for all sampling in an area, fish abundance and diversity (Table 2 and Figure 3) was related to depth, season, and in some cases, proximity to wastewater discharge.

Diversity, as measured by the Shannon-Weaver information theory formula,[2] was high off Laguna Beach (2.1), Santa Ana River (1.7 and Santa Catalina Island (1.5), moderate off Palos Verdes (1.3) and in Santa Monica Bay (1.3), and low off Port Hueneme (1.14), at many shallow stations, and at several

[2] Diversity $= H' = -\Sigma_i^s\ (n_i/N)\ \log_e\ (n_i/N)$, where N is the total number of fish per sample, S is the total number of species per sample, and n_i is the number of fish of the ith species per sample.

TABLE 2

Description of 1969–72 trawling surveys of southern California coastal waters

Area	Depth range (ft)	No. of samples	No. of species	Median catch/ haul	Mean species/ haul	Mean diversity/ haul
Port Hueneme	30–600	18	48	314	11.5	1.14
Santa Monica Bay	60–600	49	72	135	9.9	1.34
Palos Verdes	75–600	76	72	117	9.8	1.30
San Pedro Bay	30–1,200	51	88	225	12.3	1.47
Santa Ana River	35–465	48	86	475	17.3	1.68
Laguna Beach	80–300	9	47	250	18.0	2.10
Santa Catalina Island	75–450	13	41	217	12.0	1.48

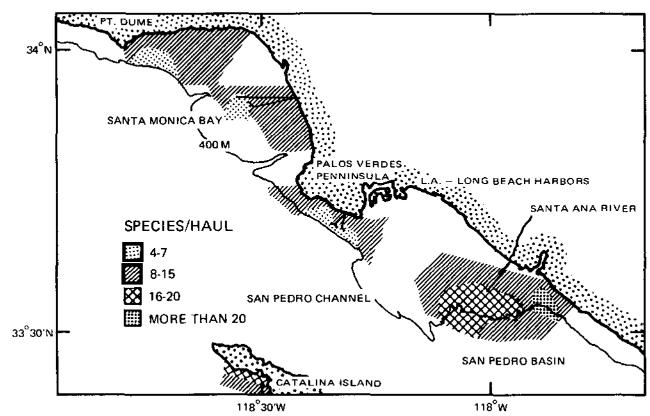

FIGURE 3. Number of species collected in southern California traw surveys, February to April 1971.

stations near the Palos Verdes discharges (0.9 to 1.1) but not at other discharge sites. Diversity appeared to increase with decreasing latitude (Table 2), but additional sampling during all seasons is required to verify this trend. In general, diversity in the areas sampled was moderate compared to that reported for demersal fish populations in Texas, Georgia, and Puget Sound, Washington.

Recurrent group analysis (Fager 1957) revealed at least five groups of associated species among the most common species (Figures 4 and 5). Three depth-related flatfish groups were identified (Group 1, middepth dover sole group; Group 2, shallow-water speckled sanddab group; Group 4, slender sole/rex sole group). The yellowchin sculpin and longspine combfish (Group 5) formed a middepth association. The white croaker dominated a nearshore group of free-swimming fishes that had affinity with the northern anchovy.

Distinct recurrent groups were not noted in samples from some areas off Palos Verdes and Santa Catalina Island and in Santa Monica Bay. Several members of the groups described above were not found in these areas: Most notable was the absence of the yellowchin sculpin off Palos Verdes (this species was present in the area 50 years ago and is otherwise widely distributed). These observations suggested that fish community relations in these areas were, in fact, different than those in adjoining areas, possibly re-

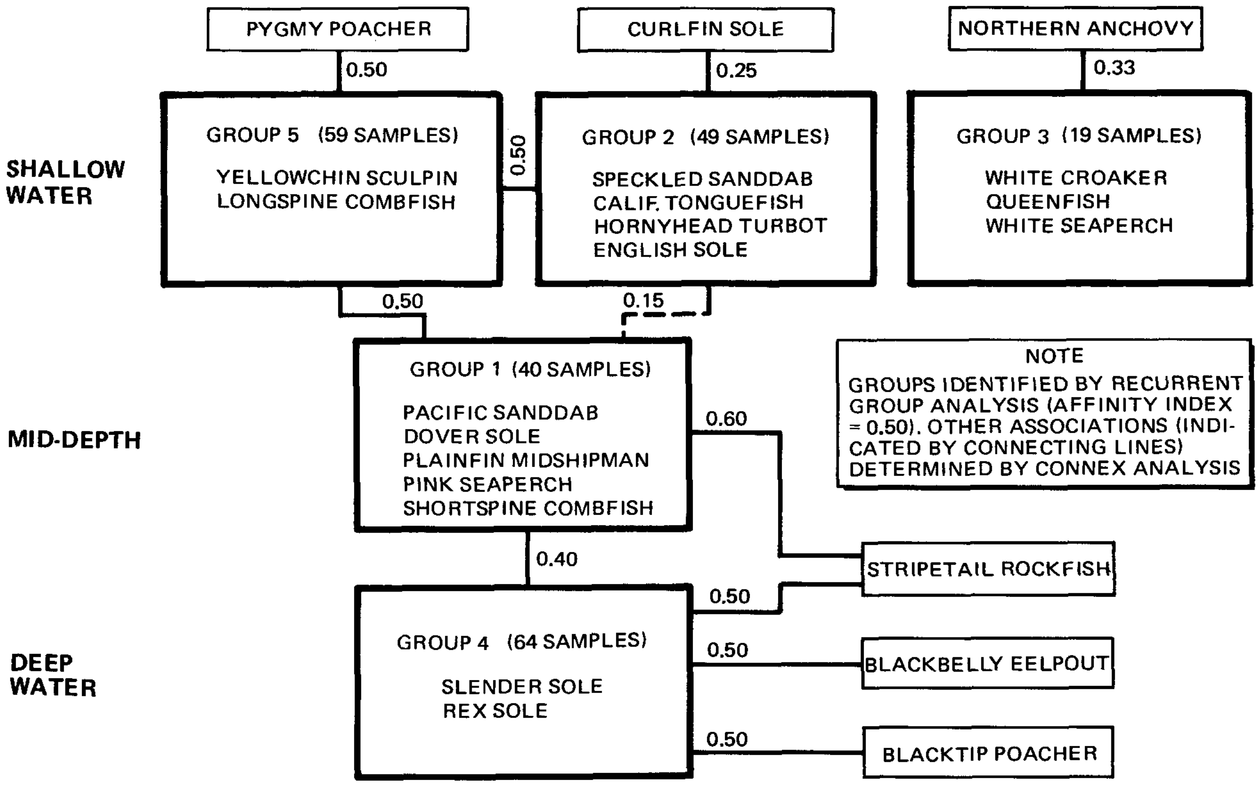

FIGURE 4. Species associations of southern California nearshore demersal fishes, 1969–72.

flecting the influence of the Palos Verdes wastewater discharge. However, the differences cannot be clearly attributed to wastewater discharges without additional observations of other communities. Likewise, the value of Santa Catalina Island as a "control" site for coastal demersal fish studies was not particularly evident from these observations.

Several special analyses indicated that some demersal fish species—in particular, the dover sole and white croaker — were attracted to wastewater discharges, even while normal periodic migrations were in progress. However, regional trends in the population density of these species could not be established because of the differences in vessels and gear used in collecting the data for each region.

Upwelling may be a factor determining the abundance and distribution of bottom fish in the coastal zone. Although benthic water quality data are rarely taken in conjunction with trawl surveys, water characteristics were measured during several of the trawl surveys in Santa Monica Bay during 1970. The data revealed a major benthic influx of cold, highly saline water of low oxygen content extending far into the shelf region of Santa Monica Bay in the late spring of 1960 (indicated by dissolved oxygen contours in Figure 6). The density of bottom fish in the bay appeared to be inversely related to the presence of this water at the bottom: The bottom fish populations appeared to move inshore in response to the onset of upwelling. This response has been noted in many coastal areas but apparently has not been used in recent monitoring surveys as an aid in understanding the distribution of fishes. Bottom water properties should always be measured as part of bottom fish surveys of coastal shelf areas.

Diel (day/night) changes in nearshore fish communities also may occur along the southern California coast. Some of our observations suggest that sampling is much more efficient at night, and further, that a number of species such as the shortbelly rockfish, *Sebastes jordani*, Pacific hake, *Merluccius productus*, and sable fish, *Anoplopoma fimbria*, may be present in shallow areas and at wastewater outfall sites only at night. Probable diel changes in fish populations must be considered in any future work on the biomass and food web dynamics of nearshore bottom fish populations.

Diseased and Abnormal Populations

Approximately 1% of all the fish collected in the recent surveys were diseased or abnormal in some way. At least five distinct disease syndromes were noted. Four of these (skin tumors in dover sole, lip papillomas in white croaker, tail erosion in white croaker, and bone deformities in sand bass) occurred in samples from all areas surveyed. These diseases were related to changes in population density (as shown for tail erosion in white croaker in Figure 7).

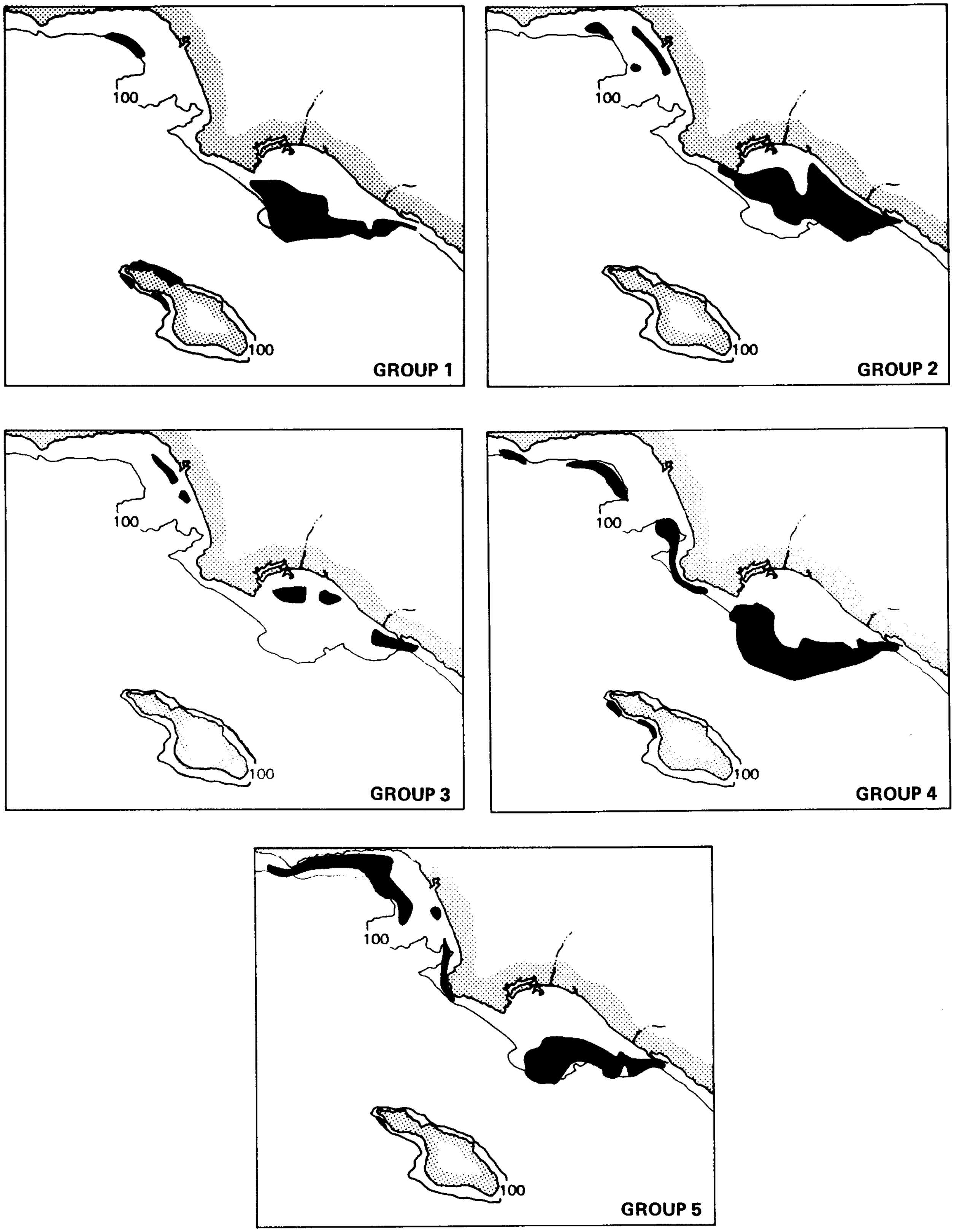

FIGURE 5. Distribution of recurrent groups of southern California nearshore demersal fishes, 1969–72. Depth line is 100 meters.

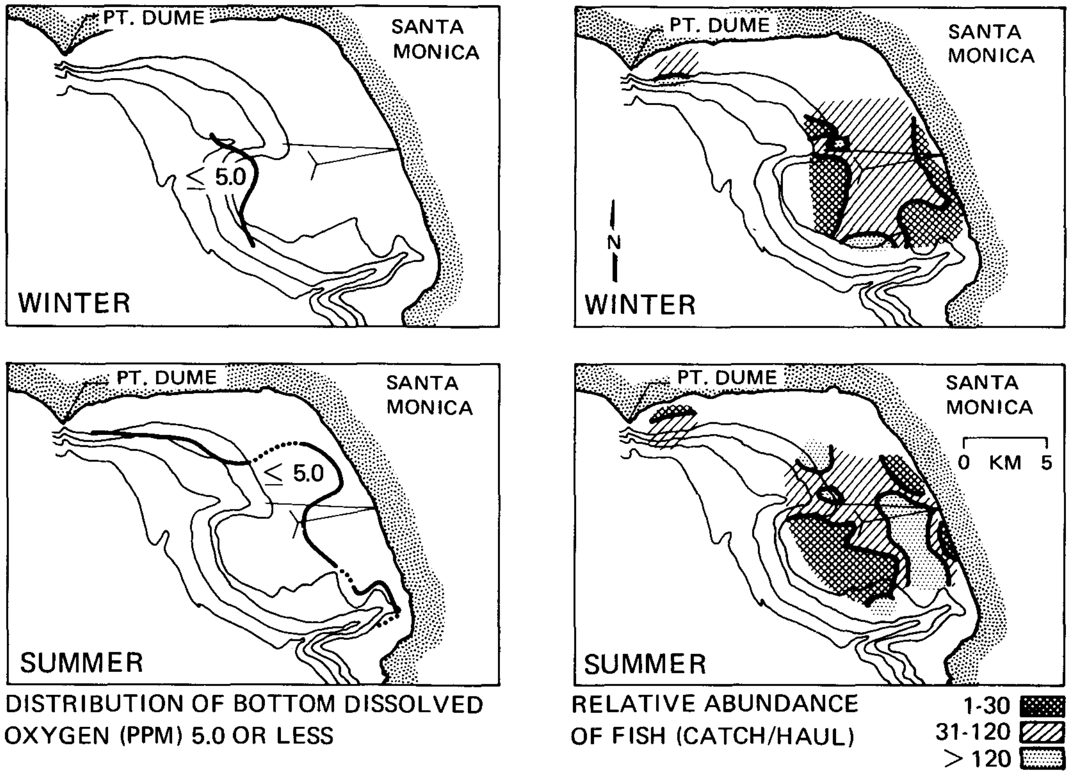

FIGURE 6. Bottom dissolved oxygen and fish abundance in Santa Monica Bay, winter (January–February) and summer (June–July) 1960.

age, or some other characteristic of the sampled populations. Figure 8 shows that the tumor size in dover sole was related to the size (standard length) of fish, indicating that the disease was, in part, a function of the juvenile biological characteristics of the species.

SCCWRP's observations on these four disease syndromes suggest that wastewater discharges, even when not the cause of a disease, may influence the disease indirectly by enhancing the survival of anomalous fish or the density of the fish population. Information on wastewater characteristics that enhance some but not all fish populations is needed: I believe such factors include freshwater, temperature, nutritional content of sewage particles, and sewage characteristics stimulatory to the benthic organisms that are food for the affected fish species.

A fifth disease, fin erosion in benthic fish, was limited to the sewage discharge sites off Palos Verdes and in Santa Monica Bay and, recently, to the new Orange County deepwater discharge. This disease appeared to be directly related by proximity to these discharges but was unrelated to the other diseases and anomalies such as skin tumors. The length frequency relations of this disease in dover sole are shown in Figure 9. The dover sole was always the most affected species, with infection frequencies of 20 to 100% of samples taken off Palos Verdes and 5 to 20% of samples taken at the head of Santa Monica Canyon. A detailed study of the environmental and physiological aspects of this disease revealed that the disease syndrome (1) included gill hyperplasia, which was not detected aboard ship, (2) was histologically detectable in fish that did not display gross symptoms, (3) was apparently not systemic in origin (internal organs were not affected), (4) was statistically related to predicted benthic locomotor activity, and (5) was unrelated to liver concentrations of 10 metals or flesh concentrations of DDT. These observations generally support the hypothesis that the disease is external in origin and not related to body-burden buildup of these toxicants; it may result from contact of the fins with contaminated bottom sediments in the vicinity of the discharges. There is a definite need to determine if the cause of the disease is an infectious (microbial) or irritation (physical or chemical) process.

SUMMARY AND DISCUSSION

Data on the distribution, abundance, and diversity of fishes collected in recent years along the coastal shelf of southern California shows the demersal fish fauna of this region to be moderately diverse and abundant compared to that in other coastal areas. Diversity is low near some wastewater discharge sites; however, there is no area that can be called a "biological desert" relative to all areas studied.

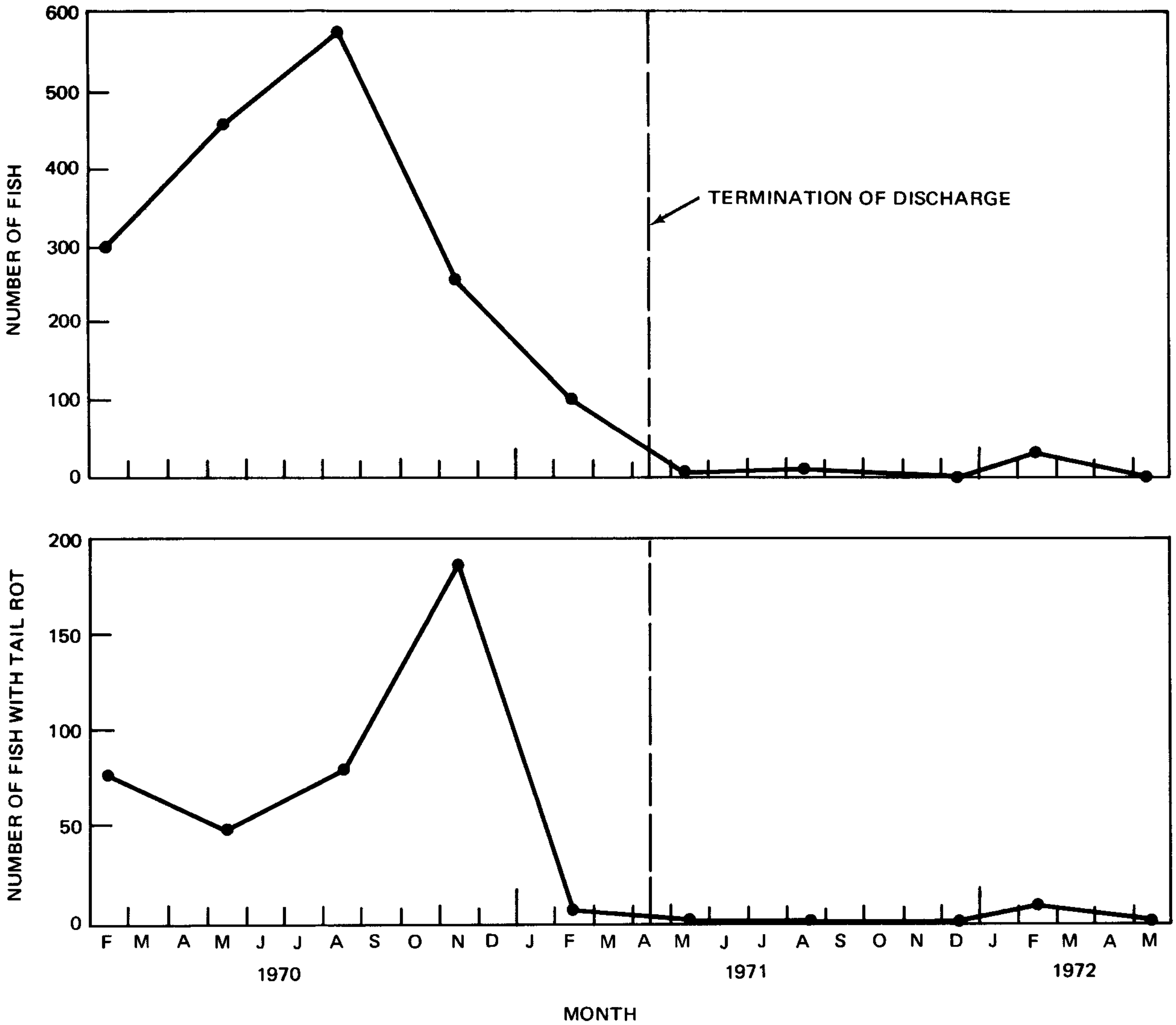

FIGURE 7. Incidence of tail erosion in white croaker from the Orange County shallow water outfall area, 1970–71.

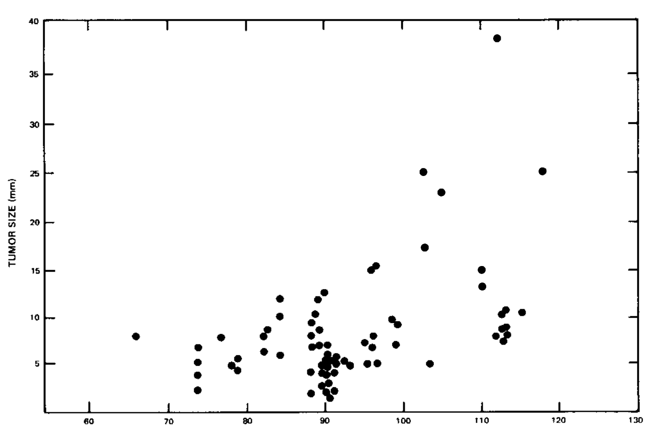

FIGURE 8. Relation between the length of tumor-bearing dover sole and the tumor size (diameter).

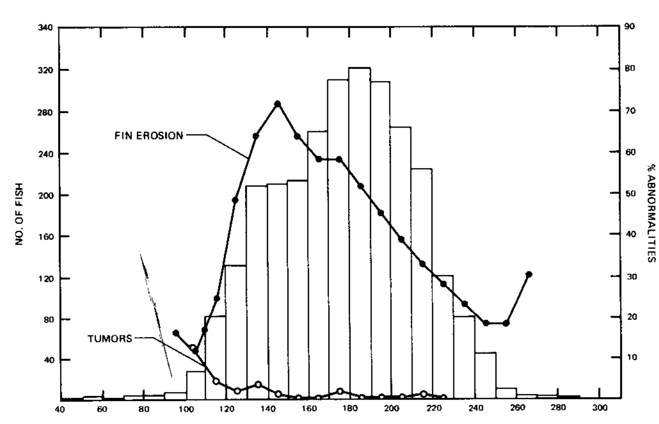

FIGURE 9. Length frequency distribution of normal and diseased dover sole populations off Palos Verdes.

Although a variety of bottom fishes were found in the southern California coastal zone, concern about the quality of this fauna remains. It appears that great shifts in the relative and absolute abundance of some species have occurred (Stephens, 1972). The occurrence of diseased anomalous populations is a further sign of instability and imbalance of some bottom fish communities. Predators apparently are not in sufficient abundance to remove sick or injured fish commensurate with their rate of injury, no matter what the cause. Our observations suggest that the affected populations are over-abundant, that predators are avoiding or being removed from the anomalous communities or that both factors are operating.

Human activities in the coastal zone may be indirectly enhancing the survival rates of some populations and increasing mortality rates in others. Some conditions that may have affected the structure of bottom fish communities are:

A. The change in the character of the coastline from depositional to erosional as a result of flood control projects (maximum activity, 1930–50).
B. The relatively constant freshwater inputs through wastewater outfalls (now estimated to be 1,231,000 acre-ft/year).
C. The relatively constant particulate input through outfalls and dumping and dredging in the coastal zone.
D. The reduction in backbay spawning and rearing grounds resulting from construction in the coastal zone.
E. The removal of predator and competitor species through sport fishing (current rate of increase: 100,000 fish/year).
F. The current lack of a significant bottom fishery, which would reduce the number of forage fish.
G. Local toxicity and biostimulation from outfalls.

From the standpoint of coastal fish populations, the important effect of these activities over the past 50 to 100 years may have been the enhancement of nearshore species that favor organically rich, silty benthic habitats and those with an innate attraction to constantly flowing freshwaters or areas of depressed salinity. The species composition of the present coastal shelf fauna of the Los Angeles area appears oriented toward a mud or silt (rather than sand) assemblage. This change in basic community orientation is exemplified by the increased commonness of the dover sole over the past 60 years.

It is clear that man and nature act at many levels of fish population dynamics and community structure and that management of coastal zone resources must be based on an understanding of all long-term influences. Conversely, there is as yet no evidence that control of one factor, such as wastewater discharges, will return the coastal fish fauna to some particular former state.

Quantitative studies in areas not now affected substantially by man (such as the Gulf of California and Pacific coasts of Baja California) should provide better understanding of man's impact on the coastal zone. And, in areas already affected, changes that have occurred—such as the apparent increase in abundance of dover sole—should be viewed in terms of their resource potential and managed accordingly.

ACKNOWLEDGEMENTS

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