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AGE, LENGTH, AND  
WEIGHT RELATIONSHIPS  
IN SOUTHERN CALIFORNIA  
POPULATIONS OF DOVER SOLE

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## INTRODUCTION

Data on the life history of coastal fishes is essential to an understanding of man's effects on coastal marine resources. The purpose of this paper is to summarize new information that the Coastal Water Research Project has accumulated on local variations in the growth rate of a key species, the Dover sole (Microstomus pacificus).

The Dover sole is presently one of the most abundant demersal fishes of the southern California coastal shelf. Data from numerous otter trawl surveys in recent years (Southern California Coastal Water Research Project, 1973) show the species to be particularly concentrated in the vicinity of major municipal wastewater outfalls at depths between 35 and 180 m. The Dover sole is frequently found associated with the Pacific sanddab (Citharichthys sordidus), plainfin midshipman (Porichthys notatus), pink seaperch (Zalembeius rosaceus) and shortspine combfish (Zan-  
iolepis frenata) but also occurs in deeper water with the slender sole (Lyopsetta exilis) and rex sole (Glyptocephalus zachirus).

The Dover sole is one of the few demersal fishes that actually feeds on the infauna (Allen, in preparation) and thus may survive quite well at waste discharge sites where polychaetes and small pelecypods are extremely abundant (Southern California Coastal Water Research Project 1973).

The Dover sole is also the predominant member of a group of species that show clear responses to wastewater discharge. The effect most frequently noted is a fin erosion or "fin rot" disease, which affects up to 70 percent of the 1- to 5-year-old fish living and feeding off sediments near the Whites Point discharge site off Palos Verdes. The disease occurs in lower frequencies near discharge sites off Orange County (in the southern portion of San Pedro Bay) and in Santa Monica Bay but is rarely encountered in fish from Oxnard, Dana Point, and Santa Catalina Island (Mearns and Sherwood 1974a). The cause of the disease is still unknown; however, available evidence indicates that it is not bacterial in nature and is completely unrelated to an epizootic skin tumor disease affecting Age I fish from all areas (Mearns and Sherwood 1974a and b). Concentrations of trace contaminants (DDT, PCB, and Dieldrin, Southern California Coastal Water Research Project 1973) and trace elements (deGoeij et al. 1974) in outfall areas and fish tissues have been measured, but they provide an even more complicated picture: Although tissue levels of DDT reflect environmental gradients, tissue concentrations of metals and trace elements do not, but rather show inverse relationships with environmental levels.

In 1972, the Project began compiling data on age/length/body weight ratios of Dover sole in an effort to determine the impact of the

environmental responses on the population and to provide a better base for relating pollutant burdens to age and size. The data described here are from several localities, including the Laguna Beach and Dana Point area, southern San Pedro Bay (Orange County), the Palos Verdes shelf, Santa Monica Bay, and Catalina Island.

## METHODS

The fish used for age analysis were subsamples from catches taken during a number of routine trawl surveys between May 1972 and December 1974 (summarized, in part, in Mearns and Sherwood 1974a). In most cases, the samples came from depths of 18 to 180 m; the nets were otter trawls with 25- or 40-ft headropes and 1/2- to 1-in. stretch mesh codends. The general catch data have been documented in several reports (for Palos Verdes and the west end of Catalina Island, Mearns et al. 1973b and c; for Santa Monica Bay, Mearns et al. 1974; for Dana Point/Laguna Beach, Mearns et al. 1973a; for San Pedro Bay, Chapter 7, Southern California Coastal Water Research Project 1973 and Marine Biological Consultants 1972).

The fish were initially collected for trace constituent analysis, which required that they be somewhat uniform in size -- either small (80 to 120 mm SL), medium (150 to 200 mm SL), or large (larger than 200 mm SL). Sampling was more random in 1973 and 1974.

Individual fish were frozen immediately after being captured. In the laboratory the specimens were thawed, measured to the nearest millimeter (both standard and total lengths), and weighed. Otoliths (primary ossicles) were removed and stored dry for later determination of age. We then opened the body cavity of each specimen and determined the sex by direct observation of gonads or by microscopic examination of immature gonad smears. The entire liver (all lobes) was excised and weighed to the nearest tenth of a gram.

We determined the age of each specimen by counting the number of translucent rings in the left otolith. (We were not able to estimate ages at intervals shorter than a year because of the irregularity of the sample sizes and sampling frequencies.) Often the first internal ring (annulus) could only be seen by altering the intensity and angle of the light or by wetting the ossicle for a few minutes before the examination. Two sets of otoliths, representing 16 fishes of a variety of age classes, were examined in our laboratory and then submitted to Mr. Tom Jow, California Department of Fish and Game, Menlo Park, for verification and intercalibration.

Data on the sampling location, liver and body weights, age, length, sex, and condition of the fins of each of the aged specimens were tabulated so that regional differences in relationships between

these parameters could be compared. In addition, data on the 1972 and 1973 Dover sole catches from which fish were taken for aging were compiled. Finally, we obtained information on age/length relationships in southern, central, and northern California populations from Mr. Jow. Demory (1972) and Hagerman (1952) provided similar data on Oregon (Columbia River) populations and earlier northern California collections. (As Hagerman did not record the first annulus in aging his specimens,<sup>1</sup> we advanced all ages in his data by 1 year.)

## RESULTS

A total of 681 fish were measured and aged (Table 1). Specimens ranged from 1 to 8 years in age and from 30 to 355 mm TL in size. Specimens in a subsample of 247 of these fish ranged in weight from 1.5 to 291 g.

As mentioned earlier, the fishes measured were subsamples from larger, more extensive collections taken between May 1972 and December 1974. The 1974 catch data are not yet analyzed completely, but the summary of the 1972-73 data (given at the bottom of Table 1) indicates that a total of 17,705 from 261 samples were taken during these two years. Average catches ranged from about 100 fish per haul off Palos Verdes to about 8 fish per haul in Santa Monica Bay and off Catalina Island.

Data on gonad development have not yet been analyzed in detail. However, microscopic confirmation was required for sex determination in fish younger than Age IV. Older fish (to Age VIII) had visible gonads in various stages of development, but few of these specimens appeared ready for spawning, and none had spawned.

We compared the age/length relationships of Dover sole from various local areas and northern California (Hagerman 1952). All southern California fish were shorter for their age than northern California specimens. Within the southern California fish Catalina Island fish were smallest for their age, followed by Palos Verdes fish. Fish from Santa Monica Bay, San Pedro Bay, and the Dana Point and Laguna Beach area were largest for their age -- the age/length curves for these populations were statistically indistinguishable (Figure 1).

The trends in age/body weight ratios were similar to those for age/length: Catalina fish were relatively underweight for their age, Palos Verdes fish were of moderate weight, and Santa Monica Bay, San Pedro Bay, and Dana Point/Laguna Beach specimens were relatively heavy. Palos Verdes and Catalina fish diverged from the other groups at Age II, and Palos Verdes began to differ from Catalina fish at Age III (Figure 2).

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1. Mr. Tom Jow, California Department of Fish and Game, Menlo Park, personal communication.

Table 1. Summary of data on age, length, and body and liver weight of Dover sole from five southern California coastal regions.

	Santa Monica Bay	Palos Verdes	San Pedro Bay	Dana Pt./Laguna Beach	Santa Catalina Island	Total
Years sampled	1972	1972-74	1972-74	1972-74	1972-74	
Depth range (m) of surveys	35-180	60-135	20-150	25-90	60-135	20-150
Age Determinations						
No. of fish	54	328	137	98	64	681
Age range	I-VII	I-VII	I-VII	II-VIII	I-V	I-VIII
Size range (mm TL)	105-315	85-355	55-325	185-335	95-245	55-355
Liver Weight Measurements						
No. of fish	14	121	77	5	30	247
Body weight range (g)	49-291	1.6-273	1.5-275	55-164	8.1-111	1.5-291
Liver weight range (g)	0.5-4.3	0.1-6.7	0.1-5.7	0.5-1.10	0.1-1.2	0.1-6.7
Catch Statistics, 1972-73 <sup>1</sup>						
Total No. of Dover sole	232	13,626	3,313	445	89	17,705
No. of hauls	31	135	56	27	12	261
Catch of Dover sole/ 10-min. trawl <sup>2</sup>	7.4	101	59.2	16.5	7.4	67.8

1. 1974 data on catch statistics have not yet been summarized. The details on the 1972-73 catches are given in Mearns and Sherwood 1974.

2. Direct comparison of catch per unit effort requires corrections for known variations in gear, especially door spread (Mearns and Stubbs 1974): San Pedro Bay and Dana Point/Laguna Beach areas trawled by same methods (Marinovich 25-ft (headrope length) net); Catalina and Palos Verdes trawled by same methods (Wilcox 40- and 25-ft nets); Santa Monica Bay sampled with 25-ft Wilcox net, but slower vessel speed and smaller door spread.

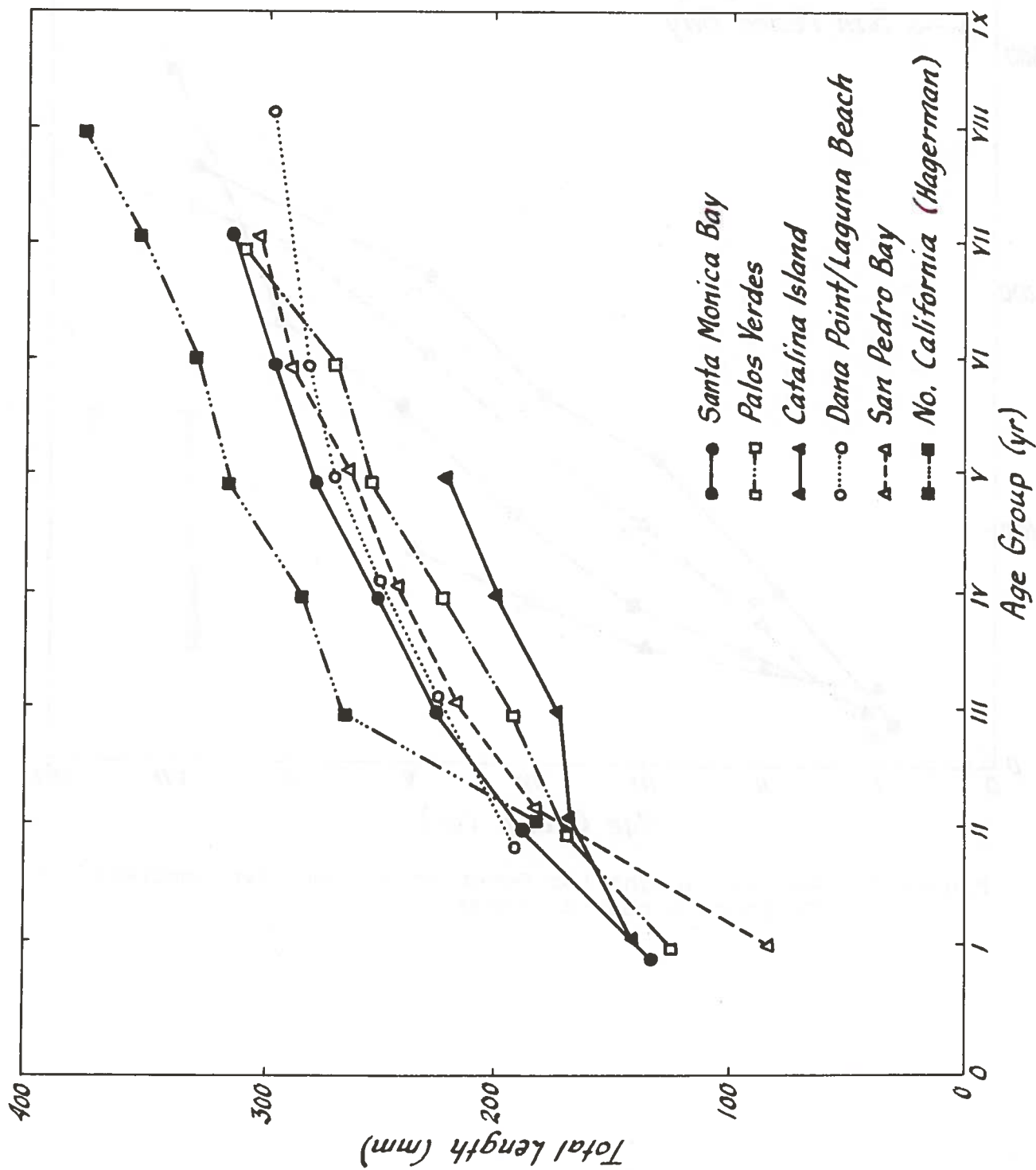


Figure 1. Age vs. length relationships for Dover Sole from five southern California coastal areas and for northern California (Hagerman 1952).

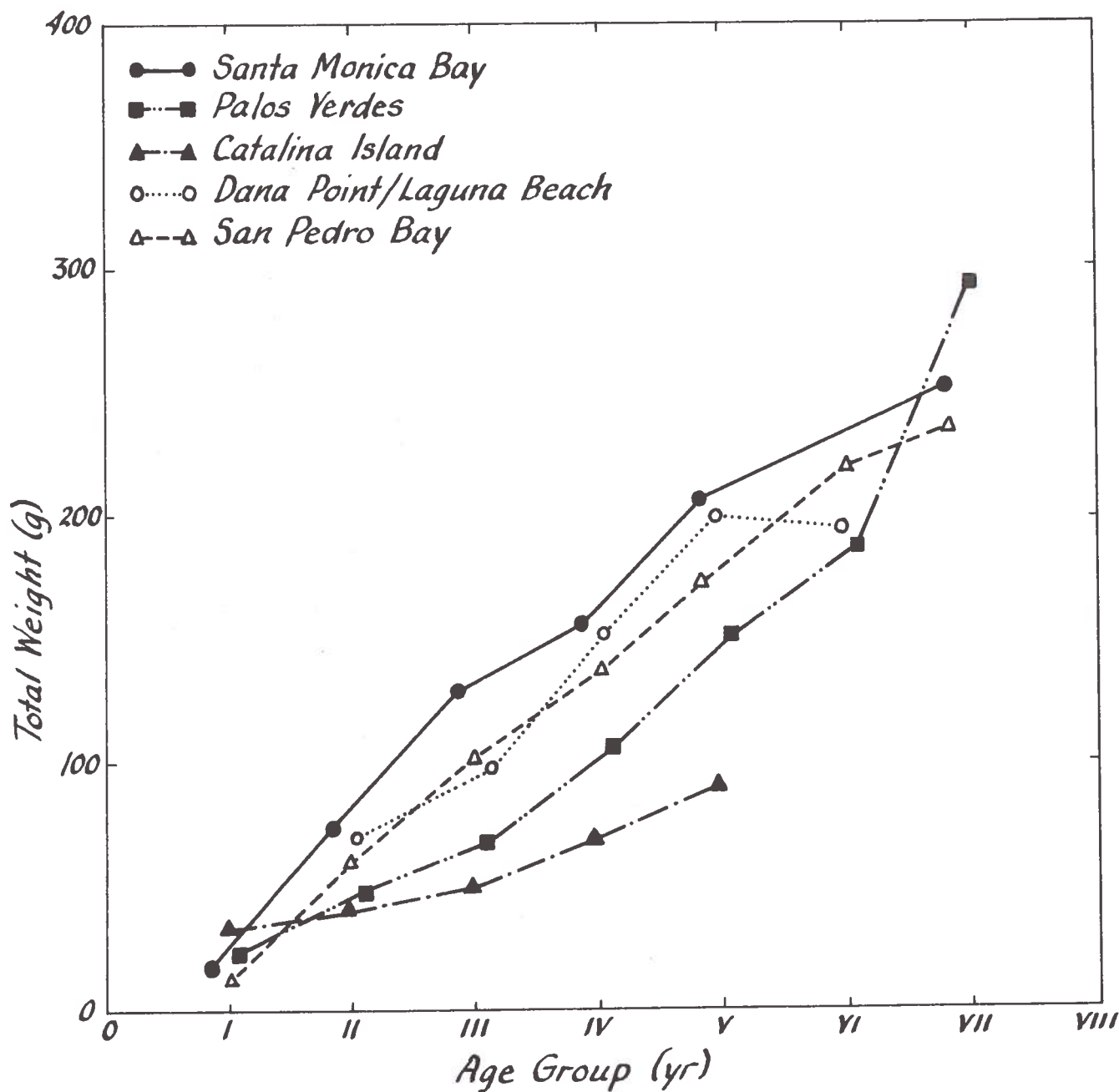


Figure 2. Age vs. weight for Dover sole from five southern California coastal areas.

To normalize the effects of both age and body weight on the liver weight comparison, liver weights were plotted against each of these parameters. Catalina fish had the smallest liver weights for each age group (one Dana Point/Laguna Beach fish of Age VI had a lower liver weight (Figure 3); however as only five of the Dana Point/Laguna fish were measured, this curve is not significant). Palos Verdes fish, which were relatively short and lightweight for their age, had a liver weight curve as a group that was similar to those of the Santa Monica Bay and San Pedro Bay populations, which contained the longest and heaviest specimens. Of particular interest, however, was the trend for diseased fish from Palos Verdes to have larger livers than apparently healthy fish from either Palos Verdes or Catalina (Figure 4); in fact, Dover sole severely affected with fin erosion disease had the largest livers for their age group.

Somewhat different trends appeared when liver weights were compared on the basis of body weight. Santa Monica Bay and Catalina fish had the smallest livers per unit body weight, and Palos Verdes diseased fish had the largest. The regression lines on Figure 5 indicate that livers in diseased Dover sole were some three to five times heavier than those in healthy Catalina or Santa Monica Bay fish.

## DISCUSSION

There appear to be major differences in the growth rates of certain southern California Dover sole populations. Fish from coastal localities that we surveyed appear to grow faster than those from the offshore study area, Santa Catalina Island. However, Palos Verdes fish appear to be growing slower than fish from coastal sites to the north and south. In addition, Palos Verdes Dover sole have enlarged livers, a condition most pronounced in the obviously diseased fishes.

### Sampling Bias and Limitations

The gear and sampling techniques used in collecting the data for this analysis may have biased the data in several ways. First, the small otter trawl gear used in these surveys could not be expected to sample proportionately all size or age ranges of Dover sole present in the population. The species is known to reach at least Ages XV to XX and to measure over 500 mm SL (Demory 1972; Hagerman 1952). The fishes we captured ranged from 30 to 355 mm SL and from Ages I to VIII. In another southern California survey using commercial gear, Jow<sup>2</sup> obtained no fish older than Age XI or over 450 mm TL. Thus, it is possible that southern California Dover sole populations actually are dominated by small young fish.

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2. Mr. Ton Jow, California Department of Fish and Game, Menlo Park, personal communication, and data from California Department of Fish and Game Cruise 69-5-S, 1969.

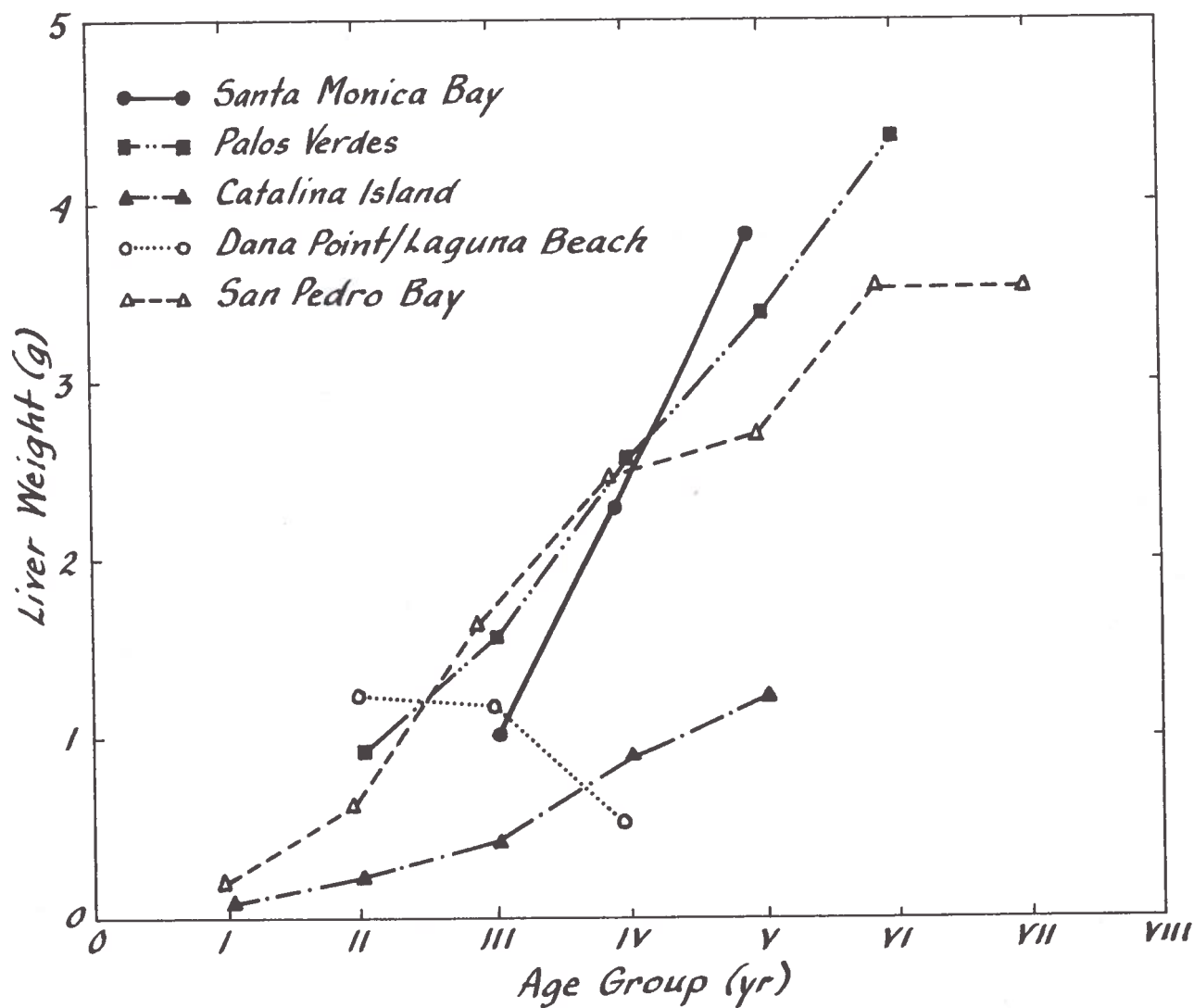


Figure 3. Age vs. liver weight for Dover sole from five southern California coastal areas.

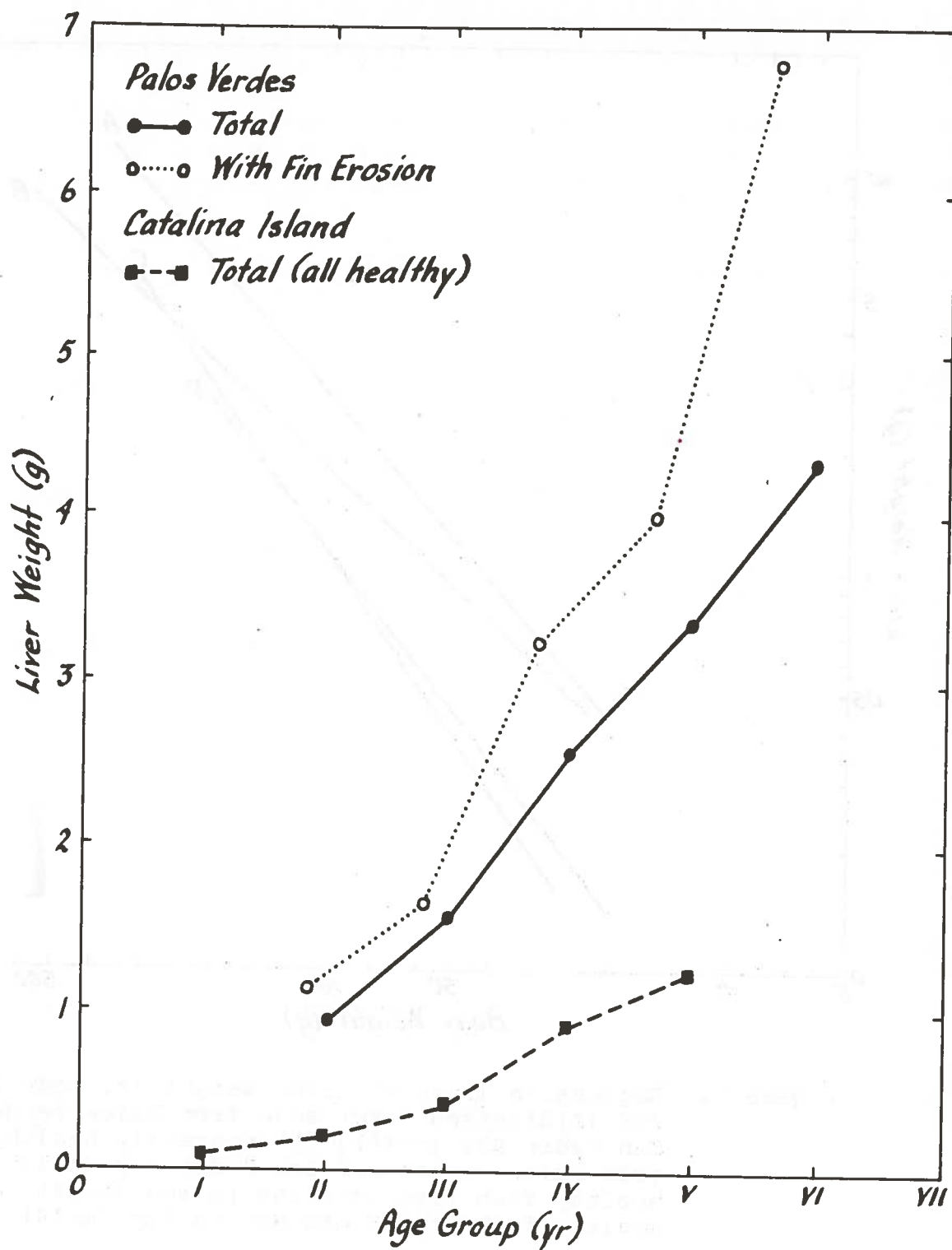


Figure 4. Age vs. liver weight for diseased and total Dover sole from Palos Verdes and for fish from Catalina Island (all healthy).

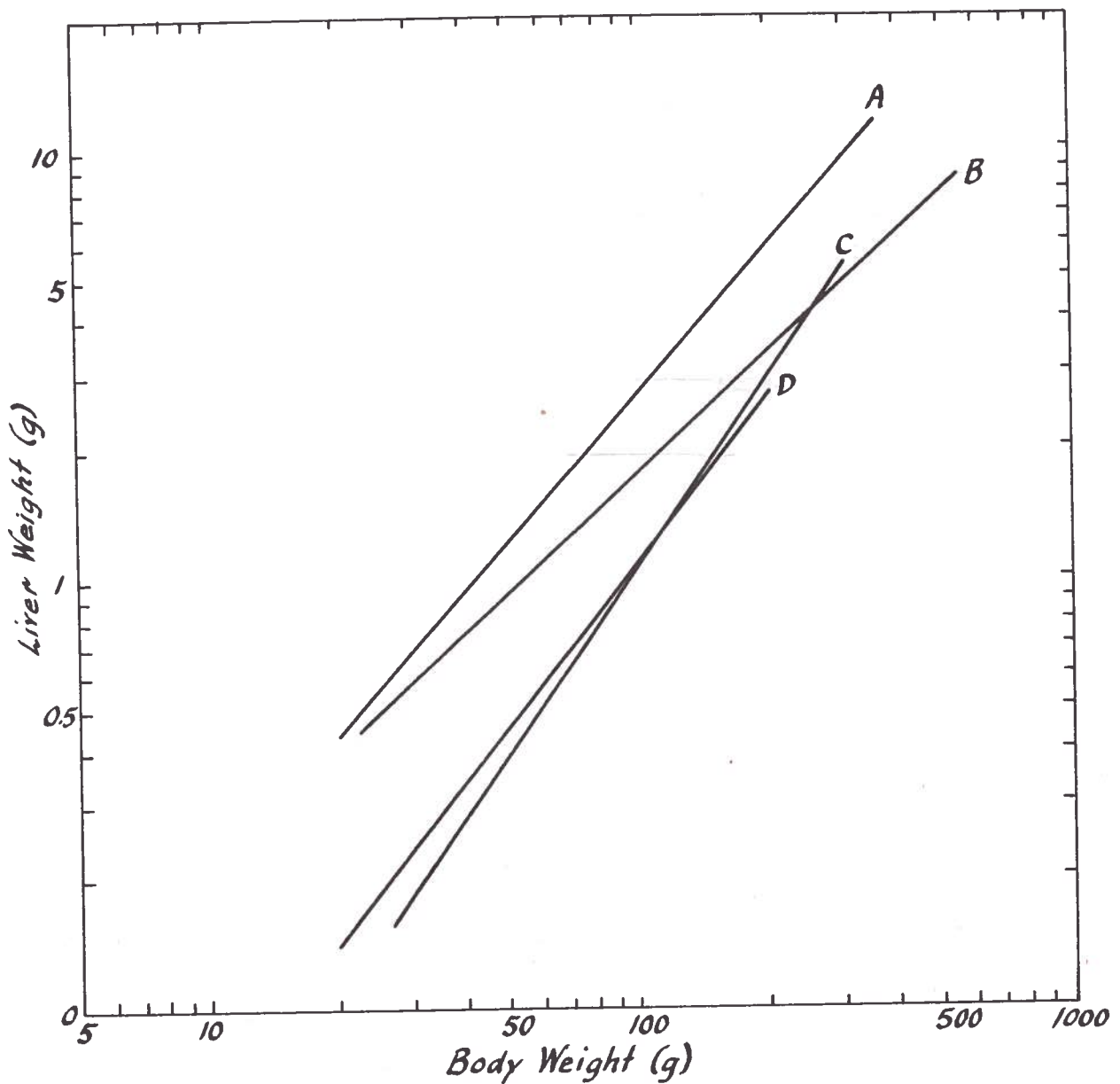


Figure 5. Regression lines of liver weight vs. body length for (A) diseased flounder sole from Palos Verdes and San Pedro Bay ( $n=46$ ); (B) apparently healthy fish from Palos Verdes and San Pedro Bay ( $n=155$ ); (C) healthy fish from Catalina Island ( $n=30$ ); and (D) healthy fish from Santa Monica Bay ( $n=14$ ).

A second type of sampling problem may be more significant: A disproportionately large number of abnormal or diseased fish may be caught in the trawls because these individuals -- especially those with fin erosion diseases or metabolic abnormalities -- probably are less able to avoid or escape the net. The Project has compared data from a few day and night trawl catches, and these do not indicate that diseased Dover sole are less capable of visually avoiding gear; however, sampling by other methods is warranted.

A third type of problem may arise from the nonuniform distribution of the sampling effort by depth and season. Depths beyond 90 m were not sampled off Dana Point and Laguna Beach, and the Santa Monica Bay population is represented by data from only one survey (May-June 1972).

As explained in the methods section, our subsampling of catches was neither random nor quite proportional to the size ranges of fishes available in the samples. Levings (1967) had a similar problem in comparing disproportionate commercial landings and research trawl subsamples from several sites. Nevertheless, his sampling was sufficient to document major regional differences in growth rate of rock sole (Lepidopsetta bilineata).

Examination of otoliths appears to be a reliable way of determining the age of Dover sole. Our age determinations were supported by the other measurements we made -- for example, the weight differences between coastal and Catalina fish would be obvious even with a 5 to 10 percent error in designating Ages III through VIII. Our intercalibration program leads us to believe that we had considerably less error than this.

Our initial data analysis included separation by sex. Males and females were generally equally represented in samples above Age IV; below this age, sex was difficult to determine. In any case, size and age differences with sex were not apparent below Age V or VI, and the sexes were combined for all ages to reduce variances. Age and size differences between sexes would be expected to affect the results for specimens beyond Age VI or VII.

#### Implications of Growth Differences in Southern California Populations

Geographical variation in the growth rate of fish populations is probably a widespread natural phenomenon, dependent on long-term trends in temperature, food availability, and competition for food. Levings (1967) found regional differences in the growth rate of rock sole, which he attributed to differences in bottom temperature and in population density as regulated by fishing pressure: Stocks in warm, intensely fished British Columbia waters grew about 20 percent faster than did those in unfished Bristol Bay and Gulf of Alaska waters. He cited additional data

supporting a relationship between fishing pressure and growth in demersal populations elsewhere.

Because there is no commercial fishery for Dover sole in southern California (below Ventura), fishing pressure cannot be a major factor contributing to the differences in the populations we sampled. However, the sportfishery, which is intense along the coast, may be effective in reducing predators of benthic fish such as juvenile Dover sole. Unfortunately, we have little information on the effect of predation by fishes such as halibut, rockfishes, sculpin, or basses on demersal populations, but predation could have had a substantial impact on the populations when local coastal stocks of predators were more abundant than today.

The Dover sole is a benthic feeding fish; in southern California, the species preys largely on infaunal rather than epifaunal invertebrates. It is possible that the increased numbers of infauna around wastewater discharge sites allows for the development of larger, faster growing populations of Dover sole. Likewise, the lower abundance and growth of Dover sole off Catalina Island may be the result of a limited availability of infaunal items (the infauna may be scarce because the sediments off the island are coarse grained and low in organic content). However, an exception to this pattern in the relationship between growth rate and abundance of infauna occurs at Palos Verdes: Infauna (polychaetes and some pelecypods and gastropods) are extremely abundant around the outfalls, and Dover sole are also abundant but are growing at measurably slower rates than those at other coastal sites. In this case, factors other than food availability must be contributing to the relatively slow growth rates; these factors also must distinguish Palos Verdes from other coastal discharge sites.

The biological indications that Palos Verdes Dover sole are unique include the high incidence of fin erosion and, in the data described here, the relatively large liver sizes, which may be part of the disease syndrome. Chemical indications of uniqueness are the extremely high concentration of DDT and the apparently depressed levels of metals in liver and other tissues of Dover sole at this site (Southern California Coastal Water Research Project 1973, de Goeij et al. 1974). It is therefore possible that chlorinated hydrocarbons, such as DDT, are making metabolic demands on resident fish that result in liver enlargement (perhaps reflecting detoxification activity), at the expense of body growth and fin degradation. Stress from multivalent element imbalance is also a possible explanation for these syndromes. In addition, increased liver volume and growth could account for depressed tissue concentrations of metals if the metals were no more biologically available at the outfall site than elsewhere.

Likewise, the relatively small livers and slow growth rate of Catalina Dover sole may account for the apparently high levels of trace elements in these fish observed by de Goeij et al. (1974). Professor John Isaacs<sup>3</sup> speculates that such a result would not be surprising given the high concentration factors associated with a low rate of conversion of food material. The Project has initiated further studies to determine relationships between fish age, size, and growth and trace element and DDT concentrations.

#### Relative Condition of Southern California Dover Sole Populations

The relatively high abundance of young Dover sole in southern California populations suggests that this area may not be as hospitable a region for the development of mature Dover sole as northern California. Additional comparisons of local age/length data with data from stocks in central and northern California and off the Columbia River in Oregon demonstrate that the divergence in growth rates exists on an even larger geographical scale (Figure 6). When we compared size distributions of Age VI fish<sup>4</sup> from various localities between the Columbia River (Oregon) and Dana Point, we found a gradient of decreasing growth rates beginning somewhere between Morro Bay and Santa Barbara, California (Figure 7). This shift coincides with changes in several significant environmental features, namely (1) a decrease in commercial fishing pressure, (2) an eastward indentation of the coastline and an increase in the distance between the coast and the California Current, and (3) an increase in the proximity of coastal stocks to anaerobic and low-oxygen basins which may harbor larger numbers of predatory fishes (e.g., sablefish), and to the population centers of southern California.

Because, with one exception, proximity to waste discharge sites appears to have an enhancing effect on the growth rate of Dover sole, the other changes in the coastal features in southern California are more likely to cause the general decrease in growth rate in these waters. The anaerobic and low-oxygen basins are at depths (900 to 1800 m) required by Dover sole for spawning, and the fish are known to migrate into such depths during fall and winter (Hagerman 1952; Harry 1959; Westrheim and Morgan 1963). Maturing fish migrating into local basins would face metabolic demands and predation that apparently do not exist at similar depths to the north. The basins, then, may be an effective

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3. Scripps Institution of Oceanography, personal communication.

4. We looked at Age VI fish because data on this size class were available from all areas of interest.

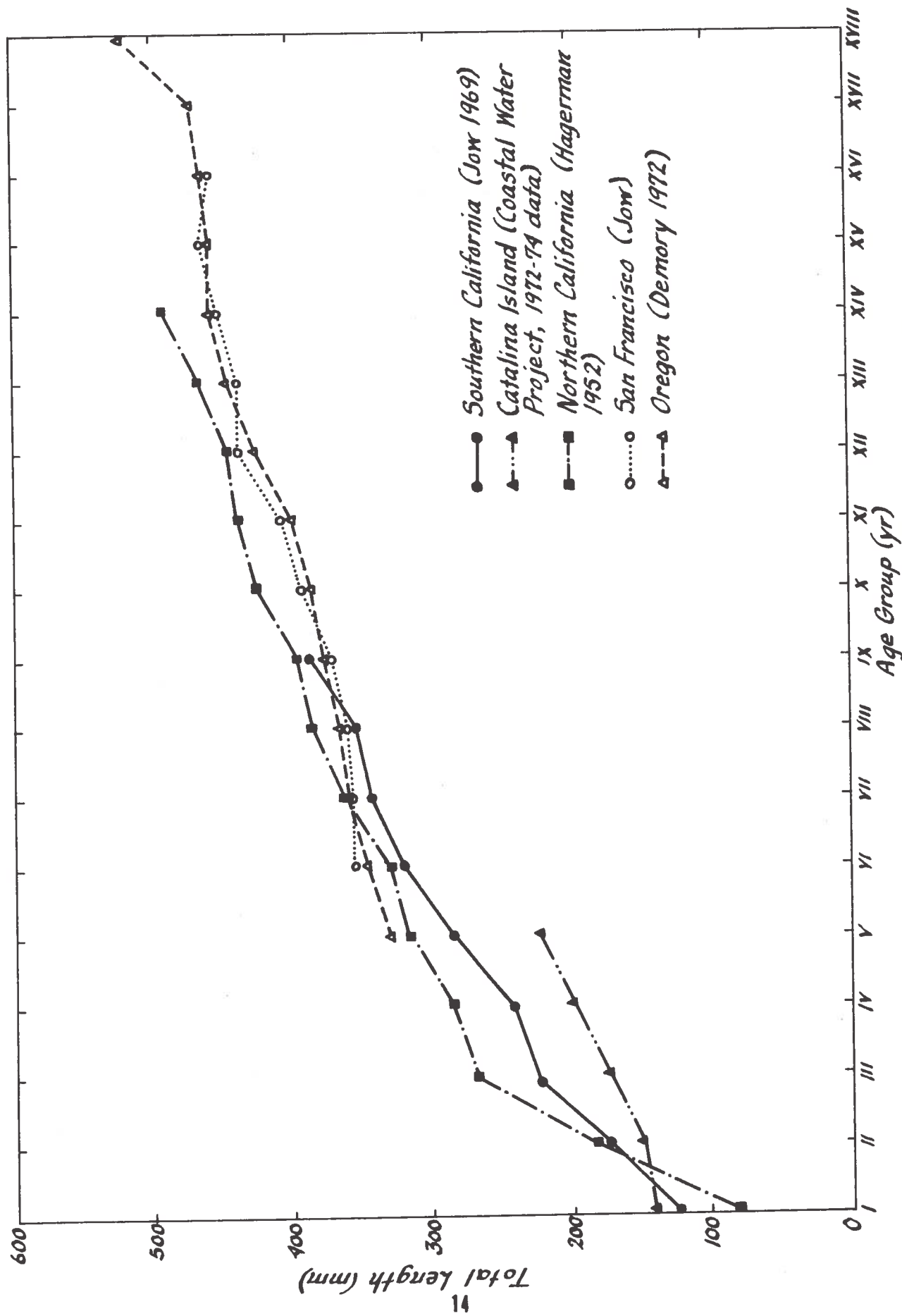


Figure 6. Age vs. length data for Dover sole from five Pacific coastal regions.

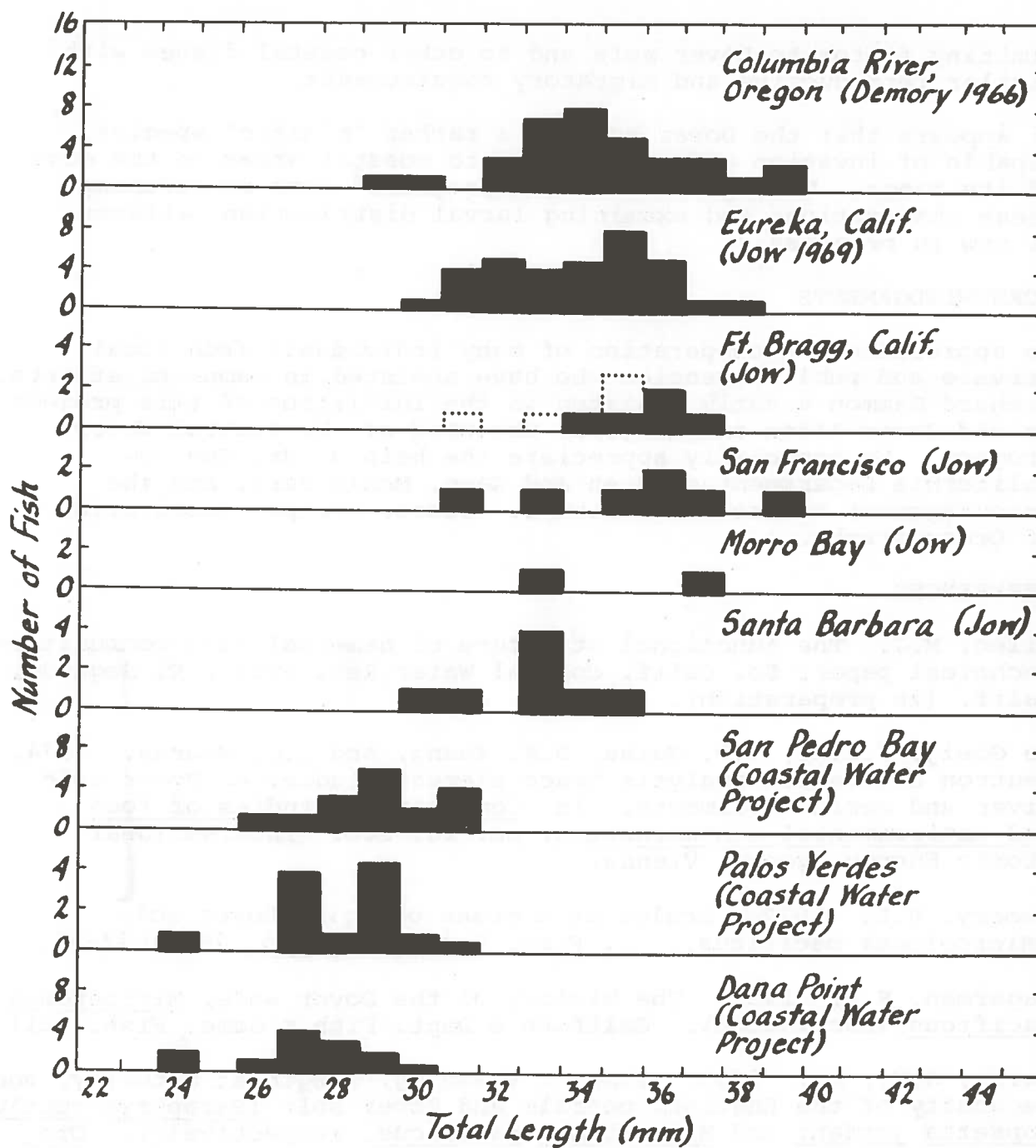


Figure 7. Size distribution of Age VI Dover sole from nine coastal areas between the Columbia River (Oregon) and Dana Point (California).

limiting factor to Dover sole and to other coastal fishes with similar reproductive and migratory requirements.

It appears that the Dover sole is a rather "plastic" species, capable of invasion and expansion into coastal areas on the edge of its range. Through the CalCOFI program,<sup>5</sup> work on refining these observations and examining larval distribution patterns is now in progress.

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#### REFERENCES

- Allen, M.J. The functional structure of demersal fish communities. Technical paper, So. Calif. Coastal Water Res. Proj., El Segundo, Calif. (in preparation).
- de Goeij, J.J.M., V.P. Guinn, D.R. Young, and A.J. Mearns. 1974. Neutron activation analysis trace element studies of Dover sole liver and marine sediments. In Comparative studies of food and environmental contamination, pp. 189-200. International Atomic Energy Agency, Vienna.
- Demory, R.L. 1972. Scales as a means of aging Dover sole (Microstomus pacificus). J. Fish. Res. Bd. Canada. 29: 1647-50.
- Hagerman, F.B. 1952. The biology of the Dover sole, Microstomus pacificus (Lockington). California Dept. Fish & Game, Fish. Bull. 85.
- Harry, G.Y., Jr. 1959. Time of spawning, length at maturity, and fecundity of the English, petrale and Dover sole (Paraphrys vetulus, Eopsetta jordani and Microstomus pacificus, respectively). Oreg. Fish. Comm. Res. Briefs 7:5-13.
- Levings, C.D. 1967. A comparison of growth rates of the rock sole, Lepidopsetta bilineata Ayres, in northeast Pacific waters. Fish. Res. Bd. Canada, Tech. Rept. 36.
- Marine Biological Consultants. 1972. The benthic environment off Orange County Sanitation Districts ocean outfall. Nos. 1 and 2 Annual Trawling Reports No. 1 and 2, August 1970 to May 1971, Costa Mesa, Calif.

5. Dr. Paul Smith, National Marine Fisheries Service, La Jolla, personal communication.

- Mearns, A.J., and M.J. Sherwood. 1974a. Environmental aspects of fin erosion and tumors in southern California Dover sole. Trans. Amer. Fish. Soc. 103:799-810.
- \_\_\_\_\_. 1974b. Ocean waste discharge and tumors in a southern California flatfish. Presented at the Conference of the International Union Against Cancer, 15-17 October 1974, Cork, Ireland.
- Mearns, A.J., and H.H. Stubbs. 1974. Comparison of otter trawls used in southern California coastal surveys. TM 213, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.
- Mearns, A.J., M.J. Allen, and M. Sherwood. 1973a. An otter trawl survey off the central Orange County coast. Rept. TM 201, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.
- \_\_\_\_\_. 1973b. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, May-June 1972. Rept. TM 204, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.
- \_\_\_\_\_. 1974. An otter trawl survey of Santa Monica Bay, May-June 1972. Rept. TM 209, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.
- Mearns, A.J., M.J. Allen, M.J. Sherwood, and R. Gammon. 1973. An otter trawl survey off the Palos Verdes Peninsula and Santa Catalina Island, November-December 1972. Rept. TM 205, So. Calif. Coastal Water Res. Proj., El Segundo, Calif.
- Southern California Coastal Water Research Project. 1973. The ecology of the Southern California Bight: Implications for water quality management, Rept. TR 104, El Segundo, Calif.
- Westrheim, S.J., and A.R. Morgan. 1963. Results from tagging a spawning stock of Dover sole, Microstomus pacificus. Pac. Mar. Fish. Comm. Bull. 4.



