DEMERSAL FISH TRAWLS OFF PALOS VERDES, SOUTHERN CALIFORNIA, 1973–1993

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ABSTRACT

Demersal fish and epibenthic macroinvertebrates were monitored on the Palos Verdes Shelf and upper slope, near Los Angeles, 1973–93. Otter trawls were taken at 12 sites: 4 cross-shore transects with 3 depths (23, 61, and 137 m). Dominant soft-bottom demersal fish were Dover sole (*Microstomus pacificus*), stripetail rockfish (*Sebastes saxicola*), slender sole (*Eopsetta exilis*), Pacific sanddab (*Citharichthys sordidus*), plainfin midshipman (*Porichthys notatus*), yellowchin sculpin (*Icelinus quadriseriatus*), and speckled sanddab (*Citharichthys stigmaeus*). Spatial and temporal abundance patterns are reviewed for 28 representative species.

Two decades of dynamic environmental conditions off Palos Verdes are documented. Specific factors causing fluctuations in fish catches cannot be determined. However, water depth greatly influences distributions, and major temperature shifts and associated biological changes correlate strongest with temporal variations. The extreme 1982–83 El Niño event created the largest changes in community composition. Reduced mass emissions of suspended solids and contaminants from the Los Angeles County Sanitation Districts' submarine outfall system contributed to declining sediment contamination, kelp bed expansion, increased food resource diversity, and greater water clarity. Environmental changes associated with improved wastewater quality stimulated recovery of demersal fish assemblages.

Annual incidence of fin erosion in Dover sole at the outfall station decreased from over 50% in the early 1970s to zero since the mid- to late 1980s. Pseudotumors ranged from 0 to 5% in Dover sole near the outfall.

INTRODUCTION

Our goal is to summarize 21 years of demersal fish trawls at 12 sites off Palos Verdes, and to better understand fluctuations in abundance under changing environmental conditions. We examine monitoring data from the Palos Verdes Shelf and upper slope, 1973–93, and natural and anthropogenic environmental factors. Incidence of fin erosion and pseudotumors among Dover sole is summarized.

The Los Angeles County Sanitation Districts (LACSD) serves the sewage treatment and solid waste management needs of 5 million people in 79 cities, including over 70,000 commercial establishments and industries. Each day, 1.25×10^6 meters^3 (330 million gallons) of partial secondary treated wastewater are discharged into the ocean off Palos Verdes. Municipal wastewaters have been discharged off Palos Verdes for 55 years. The submarine outfall system extends about 3 km offshore from Whites Point to a water depth of 60 m (figure 1). Fish trawl surveys are a Los Angeles Regional Water Quality Control Board permit requirement for the discharge of treated wastewaters.

The demersal fish fauna of the Palos Verdes Shelf and slope was first surveyed in 1911 (Ulrey and Greeley 1928). Palos Verdes trawl sampling was initiated in the early 1970s. The sampling grid consisted of up to 7 cross-shore transects (T0–T6), with stations at 3 depths (23, 61, and 137 m). Seventy-six trawls were taken from May 1970 to February 1972 (SCCWRP 1973), and an additional 29 were taken from May 1972 to March 1973. This 21-station grid was used only until May 1977; thereafter a subset of 12 stations was sampled (figure 1). In fall 1971, net size (headrope length and mesh) and trawl speed were changed (SCCWRP 1973; Mearns and Allen

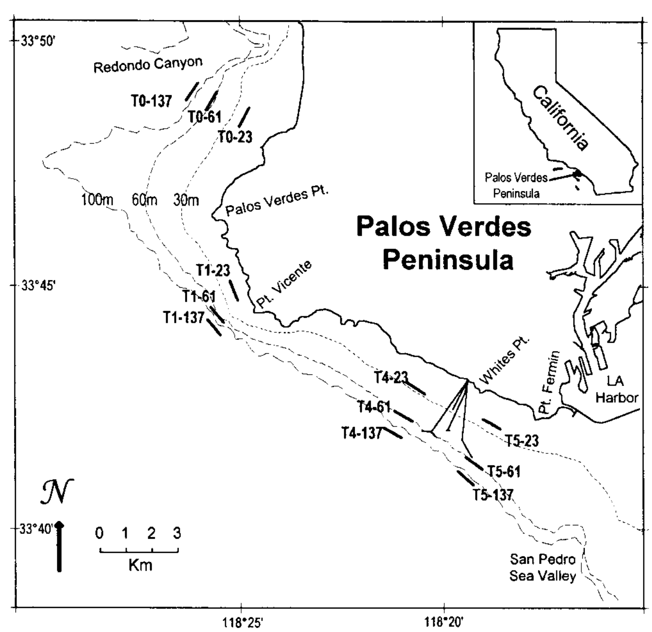

Figure 1. Stations sampled by trawl during Palos Verdes monitoring surveys, 1973–93.

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1978). Therefore we do not use the entire Palos Verdes trawl database in this report because of changes in sampling methods and stations.

This report summarizes LACSD's semiannual and quarterly trawl surveys, 1973–93, at 12 stations (figure 1), along 4 cross-shore transects and 3 isobaths: 23 m (the inner shelf), 61 m (the midshelf), and 137 m (the upper slope). Characteristic fish assemblages have been reported at each of these depths (Mearns et al. 1976; Allen 1982; LACSD 1993; MBC Applied Environmental Sciences and Applied Management and Planning Group 1993; Cross and Allen 1993).

BACKGROUND

The following discussions of environmental conditions and historic fish communities and external anomalies are important background material for the study of long-term changes in Palos Verdes fish assemblages. Methods and results for LACSD's Palos Verdes trawl surveys follow. In the Discussion section, life-history traits for individual fish species will be reviewed with the catch data, and patterns among similar types of species groups will be reported.

Environmental Conditions

The marine environment and its fish assemblages are very dynamic, and much of the variation is not easily explained. We review seven types of environmental factors that can profoundly influence fish recruitment, abundance, and succession. Natural phenomena predominate. Some of the most extreme oceanographic events of the past century occurred during the last two decades. Also, we hypothesize that changes in Palos Verdes fish assemblages demonstrate recovery as a result of decreasing emissions from the LACSD ocean outfalls and the associated ecological improvements.

1. Water temperature and El Niño events. Temperature anomalies measured off Palos Verdes, 1964–93, reveal the major warming (El Niño) trends of 1972–73, 1976–77, 1981–83, 1987, and 1992–93 (figure 2). Waters were considerably cooler in the 1970s than in the 1980s and early 1990s. During El Niño events, species with

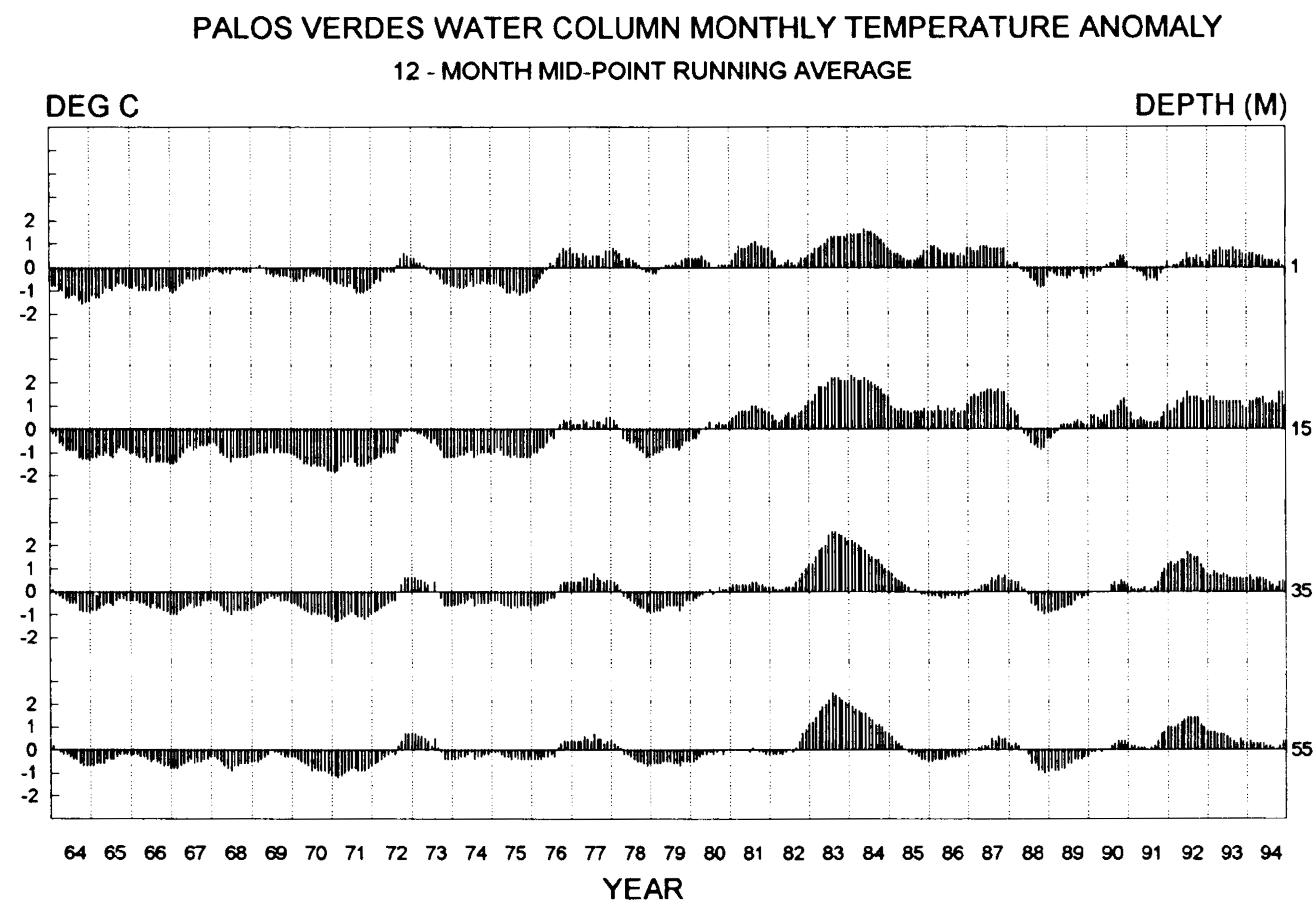

Figure 2. Palos Verdes water column monthly temperature anomaly at water depths 1–55 m from a 60-m near-outfall site. Depth-specific temperature anomaly (12-month midpoint running average) is on left axis; water column depths are on right of figure.

southern distributions are more abundant; shallow-water species occur in deeper waters; and some species with northern distributions become more rare (e.g., Radovich 1961; Mearns 1988). Carlisle (1969) noted major warm water/cold water differences in trawl catches during and after the 1957–59 El Niño. Also, biological productivity in surface waters decreases during El Niño events (e.g., Petersen et al. 1986). Warmer or cooler waters influence spawning, recruitment, and faunal composition for several years (Mearns et al. 1980; Love et al. 1986). Mearns (1979) and Love et al. (1986) report smaller otter trawl fish catches during warm-water events. The major 1982–83 El Niño was accompanied by severe storms, which altered marine habitats substantially (Dayton and Tegner 1984). In 1988, a more intense storm struck the coast, without an associated El Niño (Seymour 1989).

2. Movement of water masses. Variable currents and water masses influence the recruitment and distribution of organisms (e.g., larval fish, Smith and Moser 1988). Also, more northerly species can live in the cooler waters of upwelling areas south of headlands. The Redondo Canyon brings deeper, colder-water species nearer shore, and its walls, currents, and particle flux influence biota.

3. Topography. Demersal fish have habitat preferences. The Palos Verdes Shelf is relatively narrow and steep (2–5 km, 1.7–5.5 degrees); the shelf break is at a water depth of 75^{+} m; and its steeper slope (9–12 degrees) is irregular (figure 1; Emery 1960). The Redondo Canyon to the northwest and the San Pedro Sea Valley to the southeast separate Palos Verdes from adjacent shelves. Silt sediments predominate over much of the shelf and slope, grading to sand in the nearshore and to sandy silt past Palos Verdes Point and at the outfalls. The rocky inshore area is extensive, and outcrops are common northwest of the peninsula.

4. Environmental quality. Water clarity over the Palos Verdes Shelf has increased since the 1970s (Conversi and McGowan 1994). Quality of surface sediments has varied greatly both spatially and temporally. Remarkable reductions in distributions of contaminants, organic matter, and hydrogen sulfide between the 1970s and 1990s relate primarily to improved effluent quality discharged through LACSD's ocean outfalls (figure 3, chromium measured in 1985 at most distant and deepest sites; Stull 1995). However, bioaccumulation of historically discharged chlorinated hydrocarbons (specifically DDT and PCBs) is still a concern on Palos Verdes. A partly buried contaminant reservoir persists in Palos Verdes Shelf and slope sediments; DDT and PCBs are bioaccumulated by marine organisms (Mearns et al. 1991; Stull 1995).

5. Food availability. Sediment-dwelling benthic infauna, especially crustaceans and polychaetes, are favored foods for many demersal fish (Allen 1982). As surface sediment contamination declined over the past two decades, the distribution and composition of benthic assemblages changed dramatically (figure 3; Stull 1995). For example, benthic species diversity, numbers of arthropods, and annelid biomass increased, and mollusc biomass decreased. Pelagic and nektonic benthopelagic prey are favored by some demersal fish, and their availability has also fluctuated (figure 4). Because of the 1982–83 El Niño, extremely large numbers of crustaceans temporarily occupied the Palos Verdes Shelf and slope. Trawl catches of *Pleuroncodes planipes* (pelagic red crab) were highest in 1984 and 1985; the annual average catch from a 10-minute otter trawl at T4-137 in 1985 was 22,000. *Sicyonia ingentis* (ridgeback prawn) densities were highest from 1983 to 1986, with annual 10-minute trawl averages of 14,000 at T0-137 and over 10,000 at T5-137.

6. Kelp coverage. Kelp beds provide food and habitat to fish. Palos Verdes *Macrocystis pyrifera* virtually disappeared by the late 1950s, in part because of wastewater discharge (State Water Quality Control Board 1964). Local recovery began slowly in the mid-1970s, and, since 1978, growth and coverage have been extensive except after severe coastal storms in 1983 and 1988 (Meistrell and Montagne 1983; Wilson and Togstadt 1983; LACSD 1993).

7. Daily and seasonal patterns. Activity patterns vary daily (more fish are caught in night trawls on Palos Verdes; LACSD 1983) and seasonally (e.g., Dover sole feeds on the shelf in summer and reproduces on the slope in winter; Hagerman 1952; Cross 1985).

Community Structure and Function

In the early 1970s the Palos Verdes demersal fish fauna showed distinct effects from wastewater discharge, including low numbers of species, diversity, abundance, and biomass in the immediate vicinity of the outfalls (Mearns et al. 1976; Allen 1977). In addition, important members of southern California fish assemblages were missing (as in Santa Monica Bay; Carlisle 1969), and diseases such as fin erosion were common in some species.

Allen (1982) developed a model of the functional structure of the demersal fish communities of the southern California shelf to aid in studying wastewater effects. The model describes the number and type of feeding guilds represented at different water depths from 10 to 190 m, and the species composition (which species of each guild should dominate at different depths). Feeding guilds include species with similar foraging behavior, based on morphology, diet, and behavior. Palos Verdes trawls were compared to the model to determine which expected species and feeding guilds were present or absent at each depth (LACSD 1988–91). For the most part, the functional structure of Palos Verdes assemblages was similar to structures elsewhere in the bight.

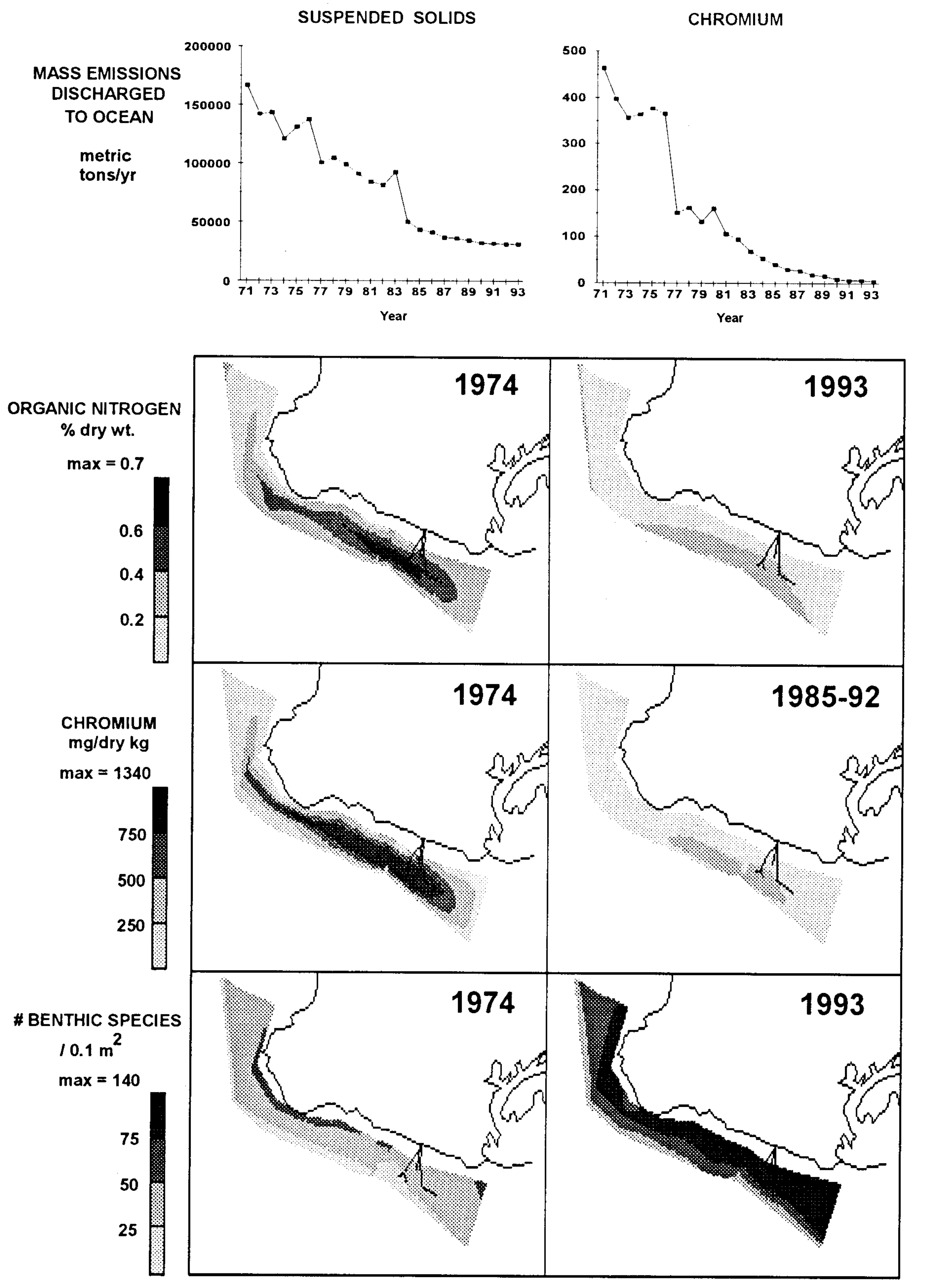

Figure 3. Palos Verdes environmental quality, 1971–93: LACSD effluent emissions of suspended solids and chromium to the ocean; surface-sediment organic nitrogen and chromium concentrations; number of benthic infaunal species per 0.1 m^2.

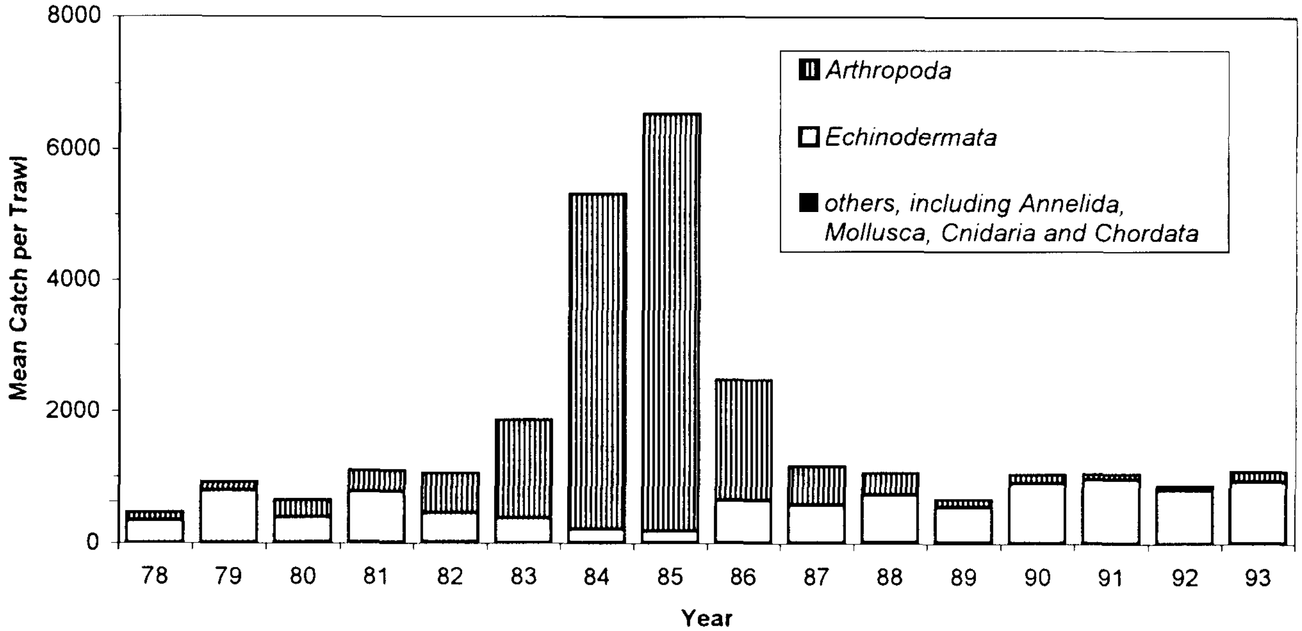

Figure 4. Palos Verdes epibenthic invertebrate abundance, 1978–93. Catch is mean of quarterly 10-minute otter trawls at 12 sites: transects T0, T1, T4, and T5, at depths of 23, 61, and 137 m.

Prager and MacCall (1990) conducted biostatistical modeling of contaminant and climate influences on fish populations of certain Southern California Bight species (northern anchovy, Pacific sardine, Pacific mackerel, Pacific whiting, and California halibut). They could not discern effects of contaminants, but caution that this does not mean that there were no effects. Fish populations are naturally variable, and without multiple events (trends, peaks) it was not statistically possible to distinguish among the numerous potential explanations for changes in abundance or recruitment. Multicollinearity among potential factors was also a complication.

External Anomalies

Dover sole (*Microstomus pacificus*) is typically a deep-water species. Hunter et al. (1990) report 98% of the spawning biomass in central California live in cold, low-oxygen, slope depths (640–1,006 m). Juveniles settle on the shelf and gradually move downslope over their lifetime. Dover sole also migrate seasonally, to the shelf in summer and slope in winter. They feed on benthos (MMS 1987) and may live over 50 years (Hunter et al. 1990).

Among Palos Verdes demersal fish, Dover sole had the greatest frequency of external anomalies, most commonly fin erosion and epidermal pseudotumors. Cross (1988) found fin erosion more common nearer the outfall; 25% to over 30% of the Dover sole exhibited the syndrome in 1971–83. The etiology of fin erosion is unknown, but it has been hypothesized to be related to sediment contamination. Sherwood and Mearns (1977) initiated fin erosion in juvenile Dover sole exposed to contaminated sediments in the laboratory for 13 months.

Epidermal pseudotumors are hypothesized to be a parasitic protozoan condition characterized by unusual mitotic figures (Myers 1981, in press). They are not neoplasms. Per Myers, all fish species with "X-cell epidermal pseudotumors" are in contact with bottom sediments during a large part of their lives. Pseudotumors are most common among flatfish less than a year in age. They are found at both polluted and unpolluted sites. Cross (1988) found frequency higher nearer the LACSD outfalls than elsewhere on Palos Verdes. Incidence as high as 50% was found among juvenile flatfish in the Bering Sea, far from pollutant sources (A. J. Mearns, NOAA, pers. comm., 1990). Younger or previously affected individuals with an immunologic history are more susceptible. The syndrome produces tumorlike lesions on skin, gills, and pseudobranchial glands. Myers postulates that the protozoa exist in marine sediments and that infestation is by contact or feeding. Amoebae morphologically similar to the X-cell are widely distributed.

METHODS

The sampling grid of 12 stations includes 4 transects (T0, T1, T4, and T5), perpendicular to shore and separated by 5 to 8 km, each with 3 water depths (23, 61, and 137 m; figure 1).

Sampling was done with an otter trawl with a 7.6-m headrope, 3.8-cm (stretch) body mesh, and 1.3-cm (stretch) cod-end mesh. The trawl was towed on bottom along the isobath of each station for 10 min at approximately 1 m/sec, thus traversing about 0.6 km. Fish captured during each tow were identified, counted, measured to the nearest cm (standard length for bony fish and total length for cartilaginous fish), examined for external anomalies, and weighed (composites of all individuals of a species) to the nearest 0.1 kg.

RESULTS

Species captured, mean catches, and numbers of occurrences in 1973–93 Palos Verdes trawls are listed in table 1. Common names derive from Robins (1991). Demersal fish populations were highly variable over the 21 years and 73 surveys (876 trawls total).

TABLE 1
Palos Verdes Demersal Fish, 1973–93: All Species Taken, Mean Catches, and Number of Occurrences (Total Number of Fish Taken in 21 Years Was 235,254)

Family name	Scientific name	Common name[a]	Mean number per trawl[b]	% of total abundance	Number of occurrences[c]
Chimaeridae	*Hydrolagus colliei*	Spotted ratfish	1.7	0.05%	51
Heterodontidae	*Heterodontus francisci*	Horn shark	0.2	0.01%	9
Torpedinidae	*Torpedo californica*	Pacific electric ray	0.7	0.01%	49
Rhinobatidae	*Platyrhinoidis triseriata*	Thornback	1.3	0.01%	70
Rajidae	*Raja inornata*	California skate	1.6	0.01%	81
Myliobatidae	*Myliobatis californica*	Bat ray	0.7	0.01%	45
Engraulidae	*Engraulis mordax*	Northern anchovy	18.0	0.56%	19
Argentinidae	*Argentina sialis*	Pacific argentine	5.3	0.17%	88
Synodontidae	*Synodus lucioceps*	California lizardfish	66.7	2.07%	396
Moridae	*Physiculus rastrelligger*	Hundred-fathom codling	0.2	0.01%	9
Gadidae	*Merluccius productus*	Pacific hake	16.8	0.52%	112
Ophidiidae	*Chilara taylori*	Spotted cusk-eel	3.7	0.12%	138
	Ophidion scrippsae	Basketweave cusk-eel	0.2	0.01%	7
Batrachoididae	*Porichthys myriaster*	Specklefin midshipman	1.4	0.01%	76
	Porichthys notatus	Plainfin midshipman	242.9	7.54%	511
Scorpaenidae	*Scorpaena guttata*	California scorpionfish	33.8	1.05%	414
	Sebastes sp.	Unidentified rockfish	0.4	0.01%	15
	Sebastes auriculatus	Brown rockfish	0.5	0.01%	3
	Sebastes chlorostictus	Greenspotted rockfish	1.1	0.01%	31
	Sebastes crameri	Darkblotched rockfish	0.9	0.01%	28
	Sebastes dalli	Calico rockfish	89.9	2.79%	182
	Sebastes diploproa	Splitnose rockfish	132.0	4.10%	261
	Sebastes elongatus	Greenstriped rockfish	3.1	0.10%	105
	Sebastes goodei	Chilipepper	1.2	0.01%	30
	Sebastes hopkinsi	Squarespot rockfish	0.9	0.01%	26
	Sebastes jordani	Shortbelly rockfish	40.6	1.26%	106
	Sebastes levis	Cowcod	1.5	0.01%	56
	Sebastes miniatus	Vermilion rockfish	4.3	0.13%	60
	Sebastes paucispinis	Bocaccio	3.2	0.10%	66
	Sebastes rosenblatti	Greenblotched rockfish	19.5	0.61%	230
	Sebastes rubrivinctus	Flag rockfish	0.3	0.01%	12
	Sebastes saxicola	Stripetail rockfish	289.6	8.99%	452
	Sebastes semicinctus	Halfbanded rockfish	4.9	0.15%	80
	Sebastes serranoides	Olive rockfish	0.2	0.01%	11
	Sebastolobus alascanus	Shortspine thornyhead	4.0	0.12%	67
Anoplopomatidae	*Anoplopoma fimbria*	Sablefish	4.0	0.12%	52
Hexagrammidae	*Zaniolepis frenata*	Shortspine combfish	16.6	0.52%	205
	Zaniolepis latipinnis	Longspine combfish	39.4	1.22%	260
Cottidae	*Chitonotus pugetensis*	Roughback sculpin	19.4	0.60%	176
	Icelinus quadriseriatus	Yellowchin sculpin	222.6	6.91%	287
	Radulinus asprellus	Slim sculpin	0.2	0.01%	9
Agonidae	*Bathyagonus pentacanthus*	Bigeye poacher	0.2	0.01%	4
	Odontopyxis trispinosa	Pygmy poacher	2.3	0.07%	93
	Xeneretmus latifrons	Blacktip poacher	22.6	0.70%	204
	Xeneretmus triacanthus	Bluespotted poacher	0.6	0.01%	27
Serranidae	*Paralabrax clathratus*	Kelp bass	0.2	0.01%	3
	Paralabrax nebulifer	Barred sand bass	2.7	0.08%	80
Malacanthidae	*Caulolatilus princeps*	Ocean whitefish	0.5	0.01%	8
Sciaenidae	*Genyonemus lineatus*	White croaker	132.6	4.12%	147
	Seriphus politus	Queenfish	8.0	0.25%	29
Embiotocidae	*Cymatogaster aggregata*	Shiner perch	33.0	1.02%	75
	Embiotoca jacksoni	Black perch	1.5	0.01%	40
	Hyperprosopon argenteum	Walleye surfperch	0.6	0.01%	9
	Hypsurus caryi	Rainbow seaperch	3.6	0.11%	38

[a]Common names derive from Robins 1991.
[b]Mean of 876 trawls in 73 surveys (2/yr in 1973–77, 3/yr in 1978, and 4/yr in 1979–93).
[c]In 876 trawls.

(Table 1 continues)

TABLE 1 (continued)
Palos Verdes Demersal Fish, 1973–93: All Species Taken, Mean Catches, and Number of Occurrences (Total Number of Fish Taken in 21 Years Was 235,254)

Family name	Scientific name	Common name[a]	Mean number per trawl[b]	% of total abundance	Number of occurrences[c]
Embiotocidae	*Phanerodon furcatus*	White seaperch	6.7	0.21%	61
	Rhacochilus toxotes	Rubberlip seaperch	0.4	0.01%	8
	Rhacochilus vacca	Pile perch	1.7	0.05%	54
	Zalembius rosaceus	Pink seaperch	38.2	1.19%	250
Pomacentridae	*Chromis punctipinnis*	Blacksmith	0.2	0.01%	2
Zoarcidae	*Lycodes cortezianus*	Bigfin eelpout	0.2	0.01%	9
	Lycodopsis pacifica	Blackbelly eelpout	94.0	2.92%	289
Uranoscopidae	*Kathetostoma averruncus*	Smooth stargazer	0.7	0.01%	35
Gobiidae	*Lepidogobius lepidus*	Bay goby	2.6	0.08%	80
Stromateidae	*Peprilus simillimus*	Pacific pompano	0.5	0.01%	13
Bothidae	*Citharichthys fragilis*	Gulf sanddab	39.3	1.22%	257
	Citharichthys sordidus	Pacific sanddab	258.4	8.02%	520
	Citharichthys stigmaeus	Speckled sanddab	202.8	6.30%	311
	Citharichthys xanthostigma	Longfin sanddab	12.7	0.39%	108
	Hippoglossina stomata	Bigmouth sole	20.8	0.64%	397
	Paralichthys californicus	California halibut	13.5	0.42%	297
	Xystreurys liolepis	Fantail sole	11.0	0.34%	272
Pleuronectidae	*Eopsetta exilis*	Slender sole	264.5	8.21%	296
	Eopsetta jordani	Petrale sole	0.4	0.01%	27
	Errex zachirus	Rex sole	54.8	1.70%	204
	Hypsopsetta guttulata	Diamond turbot	1.0	0.01%	57
	Microstomus pacificus	Dover sole	561.2	17.42%	504
	Pleuronectes vetulus	English sole	11.7	0.36%	270
	Pleuronichthys coenosus	C-O sole	5.8	0.18%	141
	Pleuronichthys decurrens	Curlfin sole	10.8	0.34%	165
	Pleuronichthys ritteri	Spotted turbot	4.1	0.13%	88
	Pleuronichthys verticalis	Hornyhead turbot	36.0	1.12%	436
Soleidae	*Symphurus atricauda*	California tonguefish	64.9	2.01%	374

Rare Species Accounting for <0.01% of Total Catch and Taken in <10 of 876 Trawls

Family name	Scientific name	Common name[a]	Family name	Scientific name	Common name[a]
Myxinidae	*Eptatretus stouti*	Pacific hagfish	Hexagrammidae	*Zaniolepis* sp.	Unidentified combfish
Scyliorhinidae	*Cephaloscyllium ventriosum*	Swell shark	Cottidae	*Icelinus cavifrons*	Pit-head sculpin
Carcharhinidae	*Mustelus californicus*	Gray smoothhound		*Icelinus tenuis*	Spotfin sculpin
	Mustelus henlei	Brown smoothhound		*Leptocottus armatus*	Pacific staghorn sculpin
Squalidae	*Squalus acanthias*	Spiny dogfish		*Orthonopias triacis*	Snubnose sculpin
Squatinidae	*Squatina californica*	Angel shark		*Radulinus boleoides*	Darter sculpin
Rhinobatidae	*Rhinobatos productus*	Shovelnose guitarfish		*Scorpaenichthys marmoratus*	Cabezon
Rajidae	*Bathyraja interrupta*	Sandpaper skate	Agonidae	*Agonopsis sterletus*	Southern spearnose poacher
	Raja binoculata	Big skate		*Agonopsis vulsa*	Northern spearnose poacher
Urolophidae	*Urolophus halleri*	Round stingray	Percichthyidae	*Stereolepis gigas*	Giant sea bass
Sternoptychidae	*Argyropelecus sladeni*	Silvery hatchetfish	Serranidae	*Pronotogrammus multifasciatus*	Threadfin bass
Myctophidae	*Stenobrachius leucopsarus*	Northern lampfish	Carangidae	*Trachurus symmetricus*	Jack mackerel
	Triphoturus mexicanus	Mexican lampfish	Sciaenidae	*Sciaenid*	Unidentified croaker
Bythitidae	*Brosmophycis marginata*	Red brotula		*Altractoscion nobilis*	White seabass
Ogcocephalidae	*Zalieutes elater*	Roundel batfish		*Menticirrhus undulatus*	California corbina
Syngnathidae	*Syngnathus* sp.	Unidentified pipefish	Kyphosidae	*Girella nigricans*	Opaleye
	Syngnathus exilis	Barcheek pipefish	Bathymasteridae	*Rathbunella hypoplecta*	Stripedfin ronquil
Scorpaenidae	*Sebastes babcocki*	Redbanded rockfish	Zoarcidae	*Eucryphycus californicus*	Persimmon eelpout
	Sebastes carnatus	Gopher rockfish		*Lyconema barbatum*	Bearded eelpout
	Sebastes caurinus	Copper rockfish	Stichaeidae	*Stichaeid*	Unidentified prickleback
	Sebastes constellatus	Starry rockfish		*Plectobranchus evides*	Bluebarred prickleback
	Sebastes eos	Pink rockfish	Anarhichadidae	*Anarrhichthys ocellatus*	Wolf-eel
	Sebastes macdonaldi	Mexican rockfish	Clinidae	*Heterostichus rostratus*	Giant kelpfish
	Sebastes mystinus	Blue rockfish		*Neoclinus blanchardi*	Sarcastic fringehead
	Sebastes rastrelliger	Grass rockfish	Gobiidae	*Coryphopterus nicholsi*	Blackeye goby
	Sebastes rosaceus	Rosy rockfish	Scombridae	*Scomber japonicus*	Chub mackerel
	Sebastes umbrosus	Honeycomb rockfish	Bothidae	*Citharichthys* sp.	Unidentified sanddab
Hexagrammidae	*Hexagrammos decagrammus*	Kelp greenling	Pleuronectidae	*Pleuronectes bilineatus*	Rock sole
	Ophiodon elongatus	Lingcod		*Pleuronichthys* sp.	Unidentified turbot
	Oxylebius pictus	Painted greenling			

[a]Common names derive from Robins 1991.
[b]Mean of 876 trawls in 73 surveys (2/yr in 1973–77, 3/yr in 1978, and 4/yr in 1979–93).
[c]In 876 trawls.

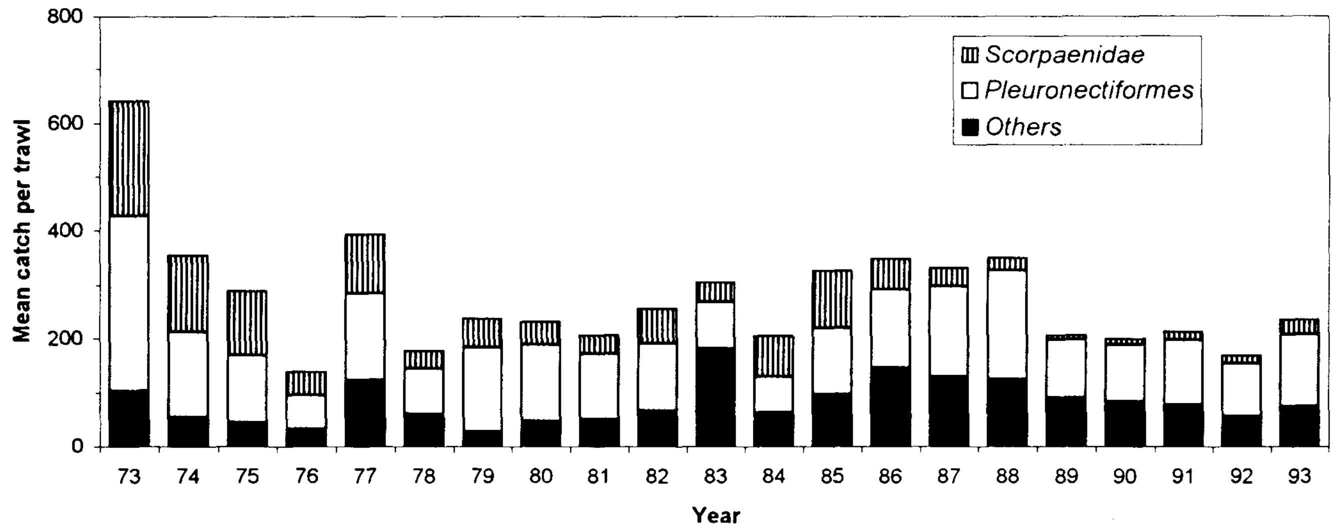

Figure 5. Fish abundance in Palos Verdes trawls, 1973–93. Catch is mean of semiannual or quarterly 10-minute otter trawls at 12 sites: transects T0, T1, T4, and T5 at depths of 23, 61, and 137 m.

Regional History

Pleuronectiformes (flatfish, mostly Pleuronectidae and Bothidae, righteye and lefteye flounders) and Scorpaenidae (scorpionfish, mostly rockfish) dominated the monitored Palos Verdes demersal fish fauna, 1973–93 (figure 5). Mean catch at the 12 sites ranged from 140 in 1976 to 641 in 1973. Flatfish were the most numerous in the 1990s, accounting for 53%–59% of the fish collected; they dominated in all years except 1983–84. The proportion of flatfish increased from 23-m to 137-m water depths. The percentage of rockfish declined over time; they accounted for 4%–12% of the total catch from 1988 to 1993, as compared to over 30% in 1973–76 and 1984–85.

Seven species account for at least 6% of the total number of fish taken in trawls between 1973 and 1993 (table 1): *Microstomus pacificus* (Dover sole, 17%); *Sebastes saxicola* (stripetail rockfish, 9%); *Eopsetta exilis* (slender sole, 8%); *Citharichthys sordidus* (Pacific sanddab, 8%); *Porichthys notatus* (plainfin midshipman, 8%); *Icelinus quadriseriatus* (yellowchin sculpin, 7%); and *Citharichthys stigmaeus* (speckled sanddab, 6%). Together they represent 63% of the 21-year catch. Dominance changed over time.

TABLE 2
Mean Fish Abundance, Biomass, and Number of Species per Trawl, Palos Verdes, 1973–93

	Abundance (mean/trawl)			Biomass (mean kg/trawl)			Species (mean no./trawl)		
Year	23 m	61 m	137 m	23 m	61 m	137 m	23 m	61 m	137 m
1973	538	594	791	5.7	23.9	52.7	10	18	16
1974	197	329	539	2.9	10.5	15.2	10	12	15
1975	125	276	469	2.1	5.6	19.3	8	14	16
1976	37	155	229	2.4	7.2	17.2	7	11	14
1977	179	478	522	13.0	21.6	20.4	13	15	17
1978	44	151	340	6.4	11.7	13.5	8	8	13
1979	99	283	335	6.7	9.0	14.8	11	12	14
1980	77	226	398	3.6	7.7	19.4	7	13	15
1981	71	187	365	8.2	8.9	13.0	9	13	14
1982	133	242	396	8.5	10.9	15.1	10	14	17
1983	199	306	413	19.7	13.9	17.0	13	15	20
1984	45	215	361	4.2	8.0	10.0	9	13	16
1985	156	384	444	8.9	12.8	20.9	11	17	16
1986	101	481	468	10.0	12.3	19.8	10	16	17
1987	148	367	483	12.9	13.2	22.5	11	17	17
1988	100	451	499	9.2	14.2	21.9	10	16	14
1989	77	323	223	8.3	12.8	6.9	9	14	13
1990	61	226	313	8.3	10.9	8.0	10	13	13
1991	66	224	351	5.1	7.7	9.2	9	15	14
1992	39	126	341	4.3	7.1	7.9	8	13	13
1993	58	316	335	5.2	11.8	8.7	9	14	13

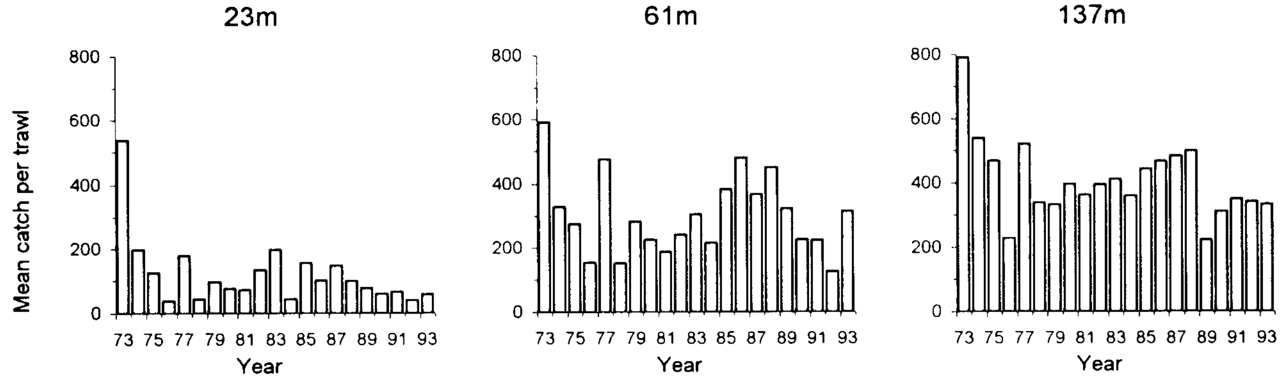

Figure 6. Fish trawled along three Palos Verdes isobaths, 1973–93. Catch is mean of semiannual or quarterly 10-minute otter trawls at 4 sites (T0, T1, T4, and T5) at each depth.

Table 2 lists average abundance, biomass, and number of species at the three depths over time.

Depth and Site Distributions

Fish distributions and abundances are highly depth and habitat dependent. Total abundance increased with depth from 23-m to 137-m isobaths, and abundance and dominance changed over time (figure 6).

In the following material, site-specific distributions are described for abundant fish species, 1973–93 (figures 7–20). The number preceding each species is its rank order in overall abundance for the 21 years. The top 20 fish species and selected other taxa are described. (Data for the other species in table 1 can be provided on request.)

Various life-history traits segregate fish species ecologically. Allen (1982) developed a comprehensive classification of the distributional centers, reproductive modes, refuge requirements, size, morphology, diet, foraging behavior, and relative abundance of southern California soft-bottom fish species. He classifies geographic ranges as warm temperate (San Diegan faunal region, Point Conception to Magdalena Bay); temperate (distribution center north of southern California but ranges to Magdalena Bay); and cold temperate (distribution center north of southern California but ranges to central San Diegan faunal region). Allen (1982) provides detailed specifics, but a brief summary of ranges, feeding habits, refuges (when inactive), and reproductive modes of Palos Verdes dominants is included with the catch histories that follow. The information on life-history traits will be used to show trends in similar types of species groups (Discussion section).

1. *Microstomus pacificus* (Dover sole, figure 7) was the most abundant species trawled off Palos Verdes over the 21 years. It was most common on the slope near the outfalls (T4-137, T5-137) in the 1970s. Numbers declined thereafter. This temperate, upper-slope flatfish is a bottom dweller which stalks benthic infauna such as capitellid polychaetes. When inactive, Dover sole is buried in the sediments. It has pelagic eggs and larvae.

2. *Sebastes saxicola* (stripetail rockfish, figure 7) was a dominant fish at all three depths in the early 1970s. It persisted longer in cooler waters in upper-slope depths (137 m). It was least abundant along the T4 outfall transect, and most common at T0 near Redondo Canyon and at T5-137. At 137 m, catches increased after the 1982–83 El Niño. This temperate, outer-shelf/upper-slope roundfish pursues pelagic prey such as euphausiids. When inactive, the stripetail rockfish is exposed. It has internal eggs and pelagic larvae.

3. *Eopsetta exilis* (slender sole, figure 8) catches at 137 m increased from 1986. It was most abundant near Redondo Canyon (T0-137) and least abundant on transect T4. This cold-temperate, upper-slope flatfish is a bottom dweller which pursues nektonic benthopelagic prey such as shrimp. When inactive, this species buries itself in the sediments. It has pelagic eggs and larvae.

4. *Citharichthys sordidus* (Pacific sanddab, figure 8) has been abundant in 61 and 137 m and nearer the outfall. Smaller catches coincided with El Niño conditions (1976–78, 1983–84, 1989–91). This temperate, outer-shelf/upper-slope flatfish pursues pelagic prey such as euphausiids. When inactive, this species buries itself in the sediments. It has pelagic eggs and larvae.

5. *Porichthys notatus* (plainfin midshipman, figure 9) also prefers outer-shelf/upper-slope habitats, in particular T1-61. Small numbers were caught in the 1970s, and largest catches were at T1-61 following the 1982–83 El Niño. This temperate, outer-shelf/upper-slope roundfish ambushes pelagic prey such as euphausiids. When inactive, its refuge is burial in the sediments. It is nocturnal and has demersal eggs and larvae.

6. *Icelinus quadriseriatus* (yellowchin sculpin, figure 9) peaked at 61 m following the major El Niño (1985–87); it was scarce at T4-61 and common at T1-61. This warm-temperate, outer-shelf roundfish ambushes epibenthic and benthopelagic prey such as gammaridean amphipods.

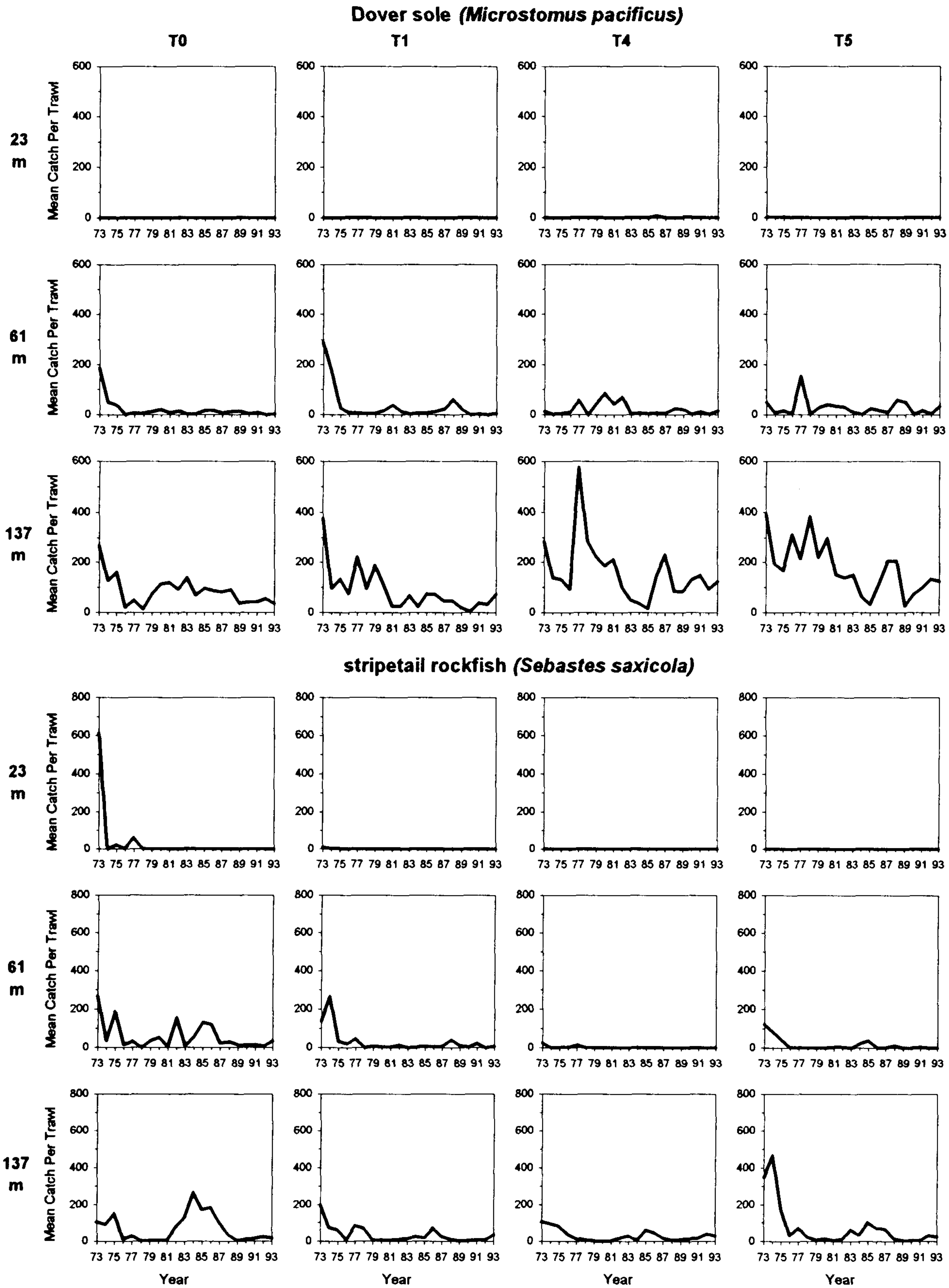

Figure 7. *Microstomus pacificus* (Dover sole) and *Sebastes saxicola* (stripetail rockfish) distributions on Palos Verdes, 1973–93.

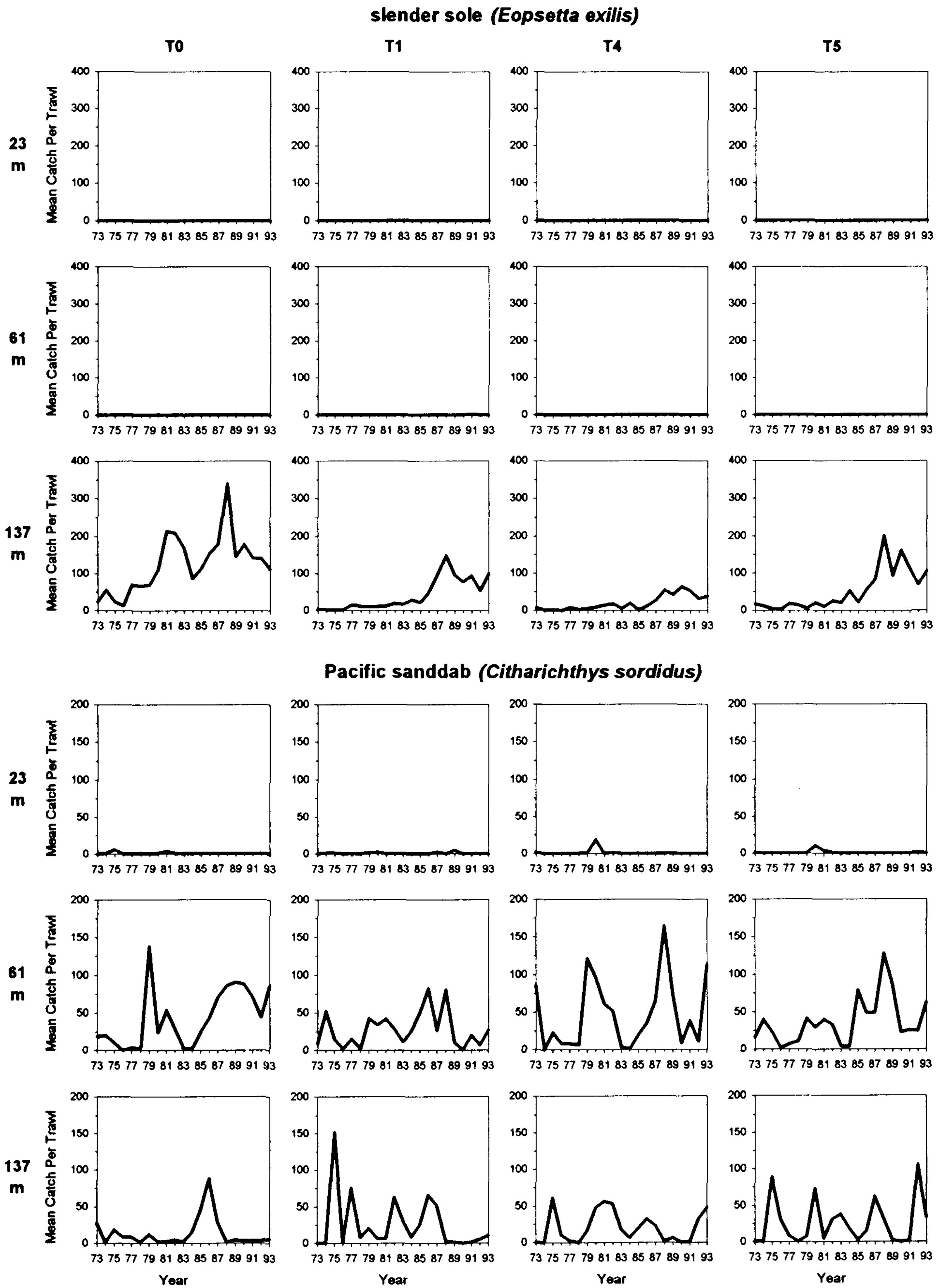

Figure 8. *Eopsetta exilis* (slender sole) and *Citharichthys sordidus* (Pacific sanddab) distributions on Palos Verdes, 1973–93.

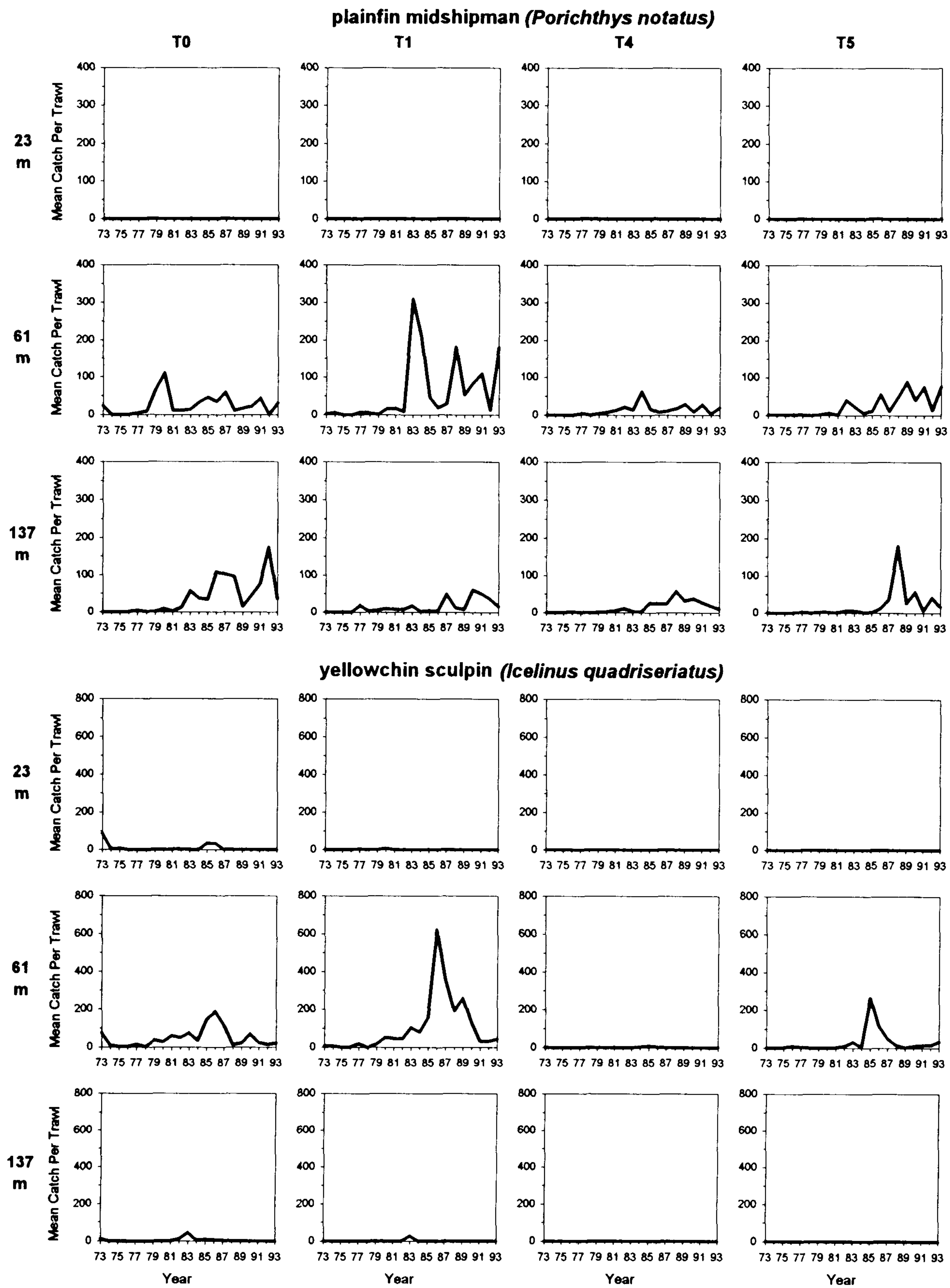

Figure 9. *Porichthys notatus* (plainfin midshipman) and *Icelinus quadriseriatus* (yellowchin sculpin) distributions on Palos Verdes, 1973–93.

When resting, this fish species is exposed. It has demersal eggs and pelagic larvae.

7. *Citharichthys stigmaeus* (speckled sanddab, figure 10) is most common at 23 m (T1-23 and T0-23), and its abundance has decreased substantially since the early 1970s. This temperate, inner-shelf flatfish pursues nekton and benthopelagic organisms such as mysids. When resting, this species is buried in sediments. It has pelagic eggs and larvae.

8. *Genyonemus lineatus* (white croaker, figure 10) is a schooling fish captured sporadically, especially at T4-61 (outfall) and T5-23 and T5-61 (closest to Los Angeles Harbor). Catches were greatest during El Niño events. This temperate, inner-shelf roundfish searches for infauna such as eunicids. Because it is nocturnally active it is most easily caught at night. It has pelagic eggs and larvae. Partyboat and commercial catches of white croaker taken off Palos Verdes are reported in Stull et al. 1987.

9. *Sebastes diploproa* (splitnose rockfish, figure 11) is an upper-slope species, most common at T0-137 and T5-137 and least abundant at T1-137. It decreased in abundance from the early 1970s and was relatively rare from 1986 to 1992. This cold-temperate, upper-slope roundfish species pursues pelagic prey such as euphausiids. At rest, it is exposed. It has internal eggs and pelagic larvae.

10. *Lycodopsis pacifica* (blackbelly eelpout, figure 11) catches are highest at Redondo Canyon T1-137 in El Niño periods. Overall, catches were larger in the 1980s and 1990s than in the 1970s. There was a gradient from north to south along the 137-m isobath. This cold-temperate, upper-slope roundfish searches for epibenthic/benthopelagic prey such as gammarid amphipods. It burrows into sediments. It has demersal eggs and larvae.

11. *Sebastes dalli* (calico rockfish, figure 12) were common in the 1970s at 61 m; populations declined after the 1982–83 El Niño, and they were rare (except at T5-61) in the 1980s and 1990s. This warm-temperate, outer-shelf roundfish pursues pelagic prey such as calanoids. It seeks crevices or is exposed when at rest. Internal eggs and pelagic larvae characterize the species.

12. *Synodus lucioceps* (California lizardfish, figure 12) prefers shelf depths (23-m and 61-m sites); it shows the clearest pattern of high catches during El Niño events (1976–77 and 1982–83), following storm years (e.g., 1988), and at T4-61 and T5-61. This warm-temperate, inner-shelf roundfish ambushes pelagic prey such as anchovies. When inactive, it is buried in sediments. It has pelagic eggs and larvae.

13. *Symphurus atricauda* (California tonguefish, figure 13) has increased steadily at 61 m since the early 1980s, especially at T0-61 and T5-61. Historically, abundances were lower at T4-61 as compared to other 61-m sites. In the 1990s, *Symphurus* catches were not smaller at T4-61. This warm-temperate, outer-shelf flatfish searches for epibenthic/benthopelagic prey such as gammaridean amphipods. At rest it buries itself in sediments. It is nocturnal, and has pelagic eggs and larvae.

14. *Errex zachirus* (rex sole, figure 13) was most abundant in 1973–74, 1979–81, and 1988 at 137 m, especially at T0-137 (Redondo Canyon). It was rare to absent in 1983–84 and 1990–93. This cold-temperate, upper-slope flatfish searches for epibenthic/benthopelagic prey such as gammarid amphipods. When inactive, this species is buried in the sediments. It has pelagic eggs and larvae.

15. *Sebastes jordani* (shortbelly rockfish, figure 14), a cold-temperate, upper-slope neritic roundfish, was more frequent in the 1970s than later. Large numbers were taken at T1-137 in 1985 (1,680 in a single trawl) and 1976 (217 in one trawl).

16. *Zaniolepis latipinnis* (longspine combfish, figure 14) catches were highest at 61 m; they varied considerably. Numbers were lowest nearest the outfall (T4-61) but have increased in the 1990s. This temperate, outer-shelf roundfish pursues epibenthic/benthopelagic prey such as gammarid amphipods. At rest, it is exposed. It has demersal eggs and pelagic larvae.

17. *Citharichthys fragilis* (gulf sanddab, figure 15) were frequently taken at canyon site T0-137, and less frequently off the peninsula face (T1-T5), from 1980. This species is common in the Gulf of California. It is an outer-shelf/upper-slope fish which probably pursues pelagic prey such as euphausiids. When inactive, this species buries itself in the sediments. It has pelagic eggs and larvae.

18. *Zalembius rosaceus* (pink seaperch, figure 15) is common in 61-m catches except at the outfall site (T4-61). This warm-temperate, outer-shelf roundfish searches for epibenthic/benthopelagic prey such as ostracods. At rest it is exposed. It has internal eggs and larvae.

19. *Pleuronichthys verticalis* (hornyhead turbot, figure 16) prefers shelf depths; it was rarest in the 1970s and most common in the mid- to late 1980s, following El Niño. Catches were lower nearer the outfall (T4-61, T5-61). This warm-temperate, inner-shelf flatfish stalks infauna such as polychaete worms (spionids). When inactive, this species is buried in the sediments. It has pelagic eggs and larvae.

20. *Scorpaena guttata* (California scorpionfish, figure 16) was most abundant at 61 m, especially at T4-61. This warm-temperate, outer-shelf roundfish ambushes epibenthic prey such as crabs. It is nocturnal, and at rest adults are usually exposed or in crevices. It has pelagic eggs and larvae.

21. *Cymatogaster aggregata* (shiner perch, figure 17) thrived near the outfall in the 1970s (T4-61, T5-61, T4-23). This cold-temperate, outer-shelf roundfish schools. It pursues pelagic prey such as calanoids. At rest it is exposed. It has internal eggs and larvae.

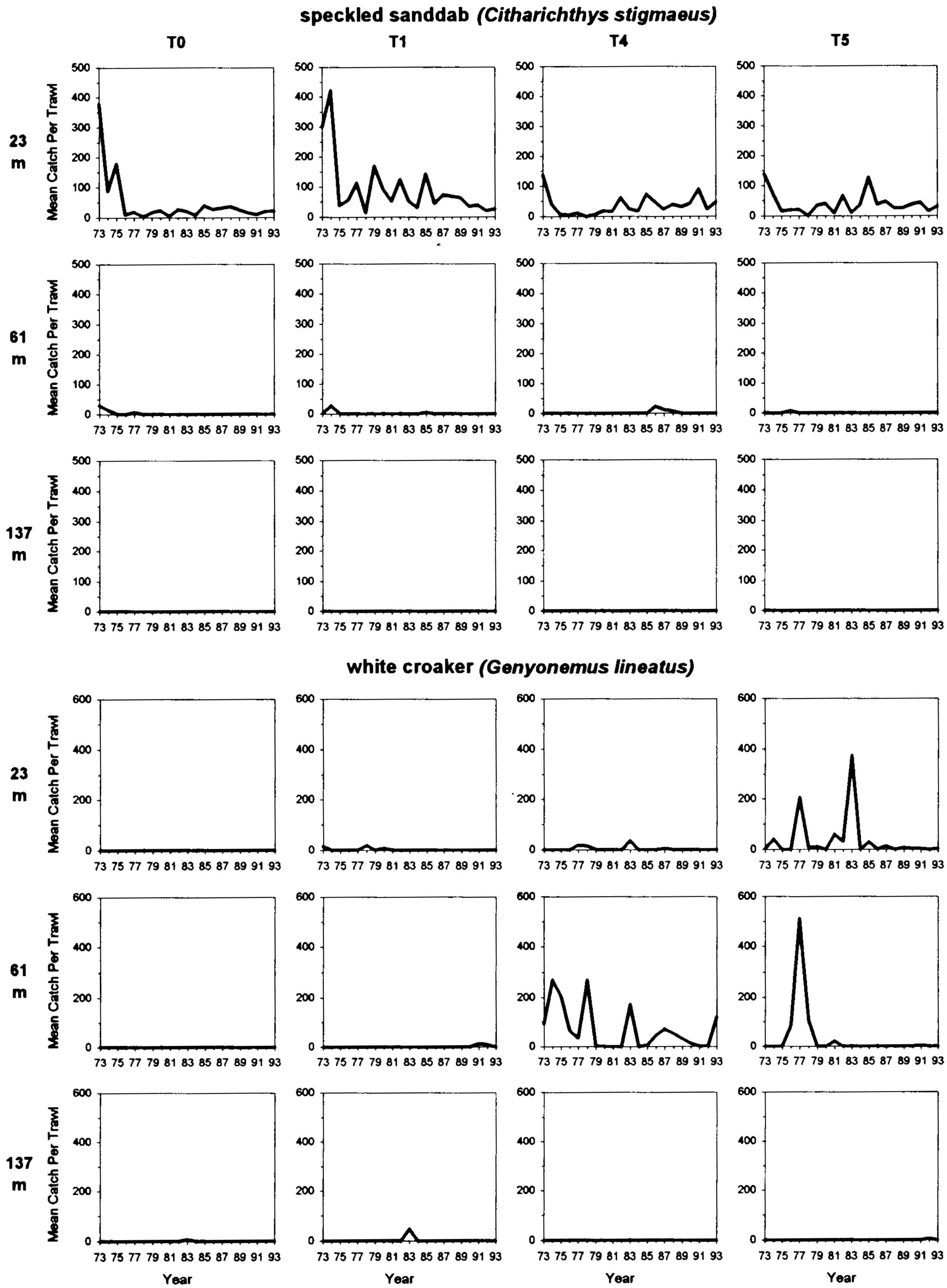

Figure 10. *Citharichthys stigmaeus* (speckled sanddab) and *Genyonemus lineatus* (white croaker) distributions on Palos Verdes, 1973–93.

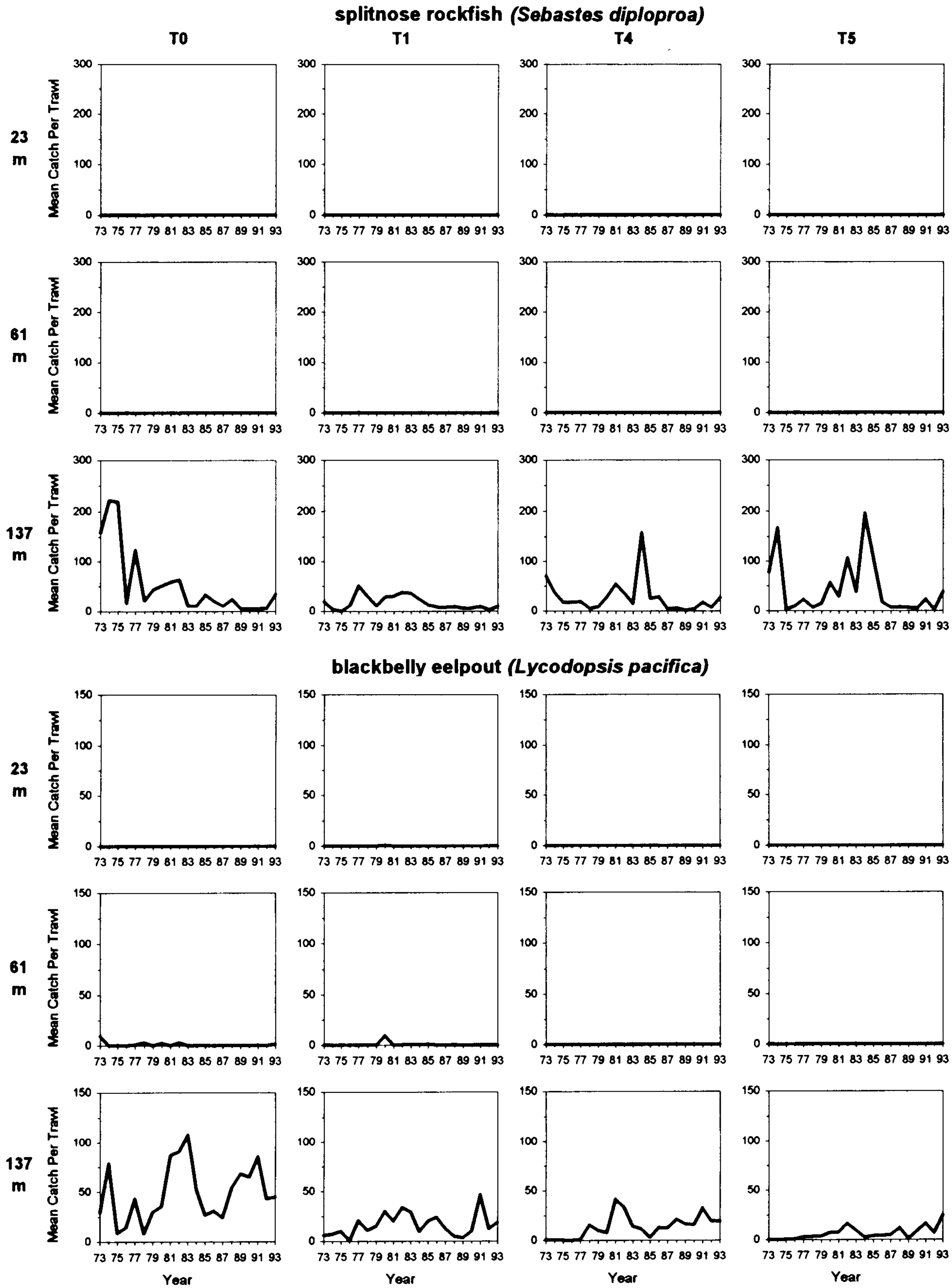

Figure 11. *Sebastes diploproa* (splitnose rockfish) and *Lycodopsis pacifica* (blackbelly eelpout) distributions on Palos Verdes, 1973–93.

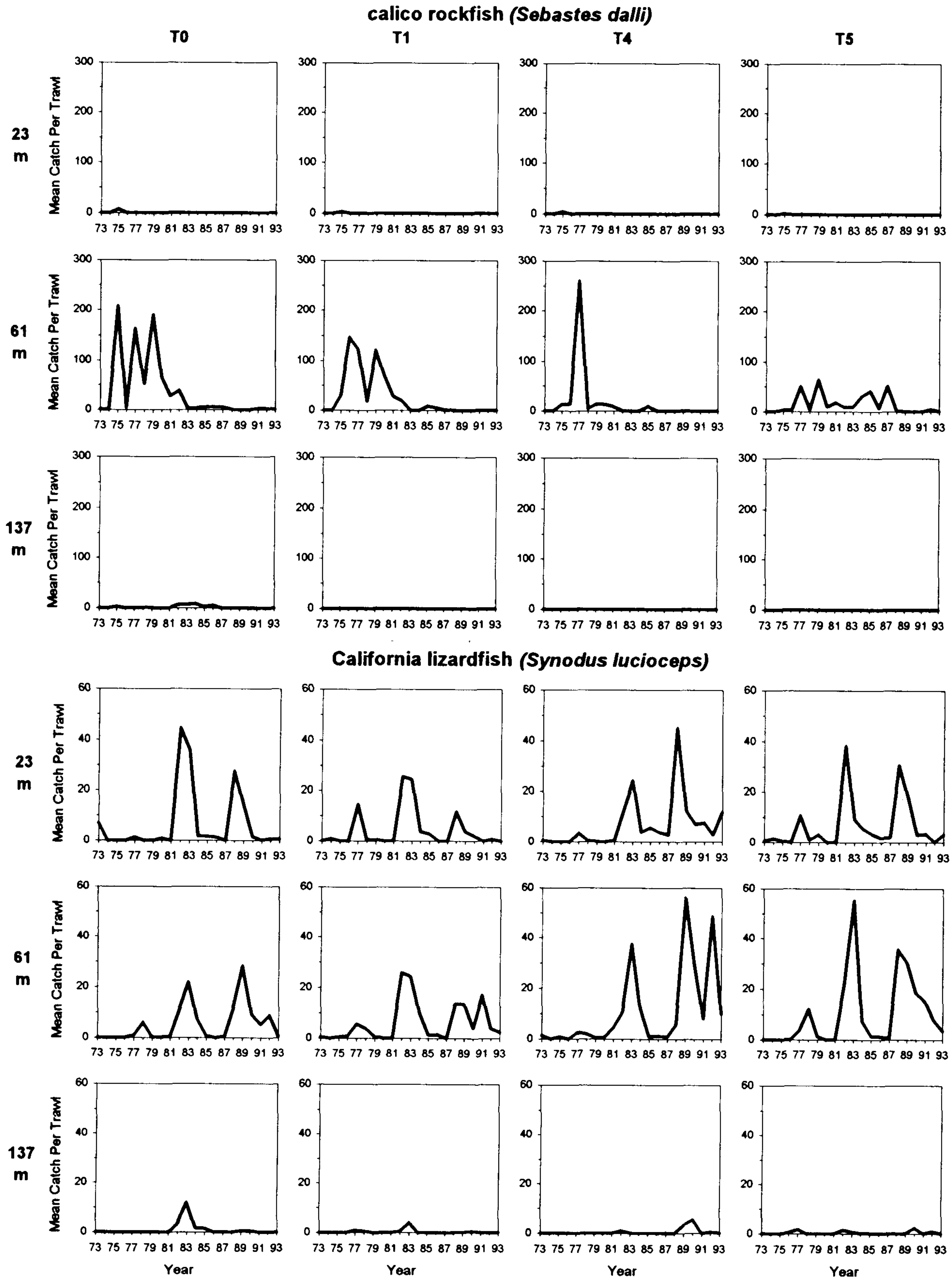

Figure 12. *Sebastes dalli* (calico rockfish) and *Synodus lucioceps* (California lizardfish) distributions on Palos Verdes, 1973–93.

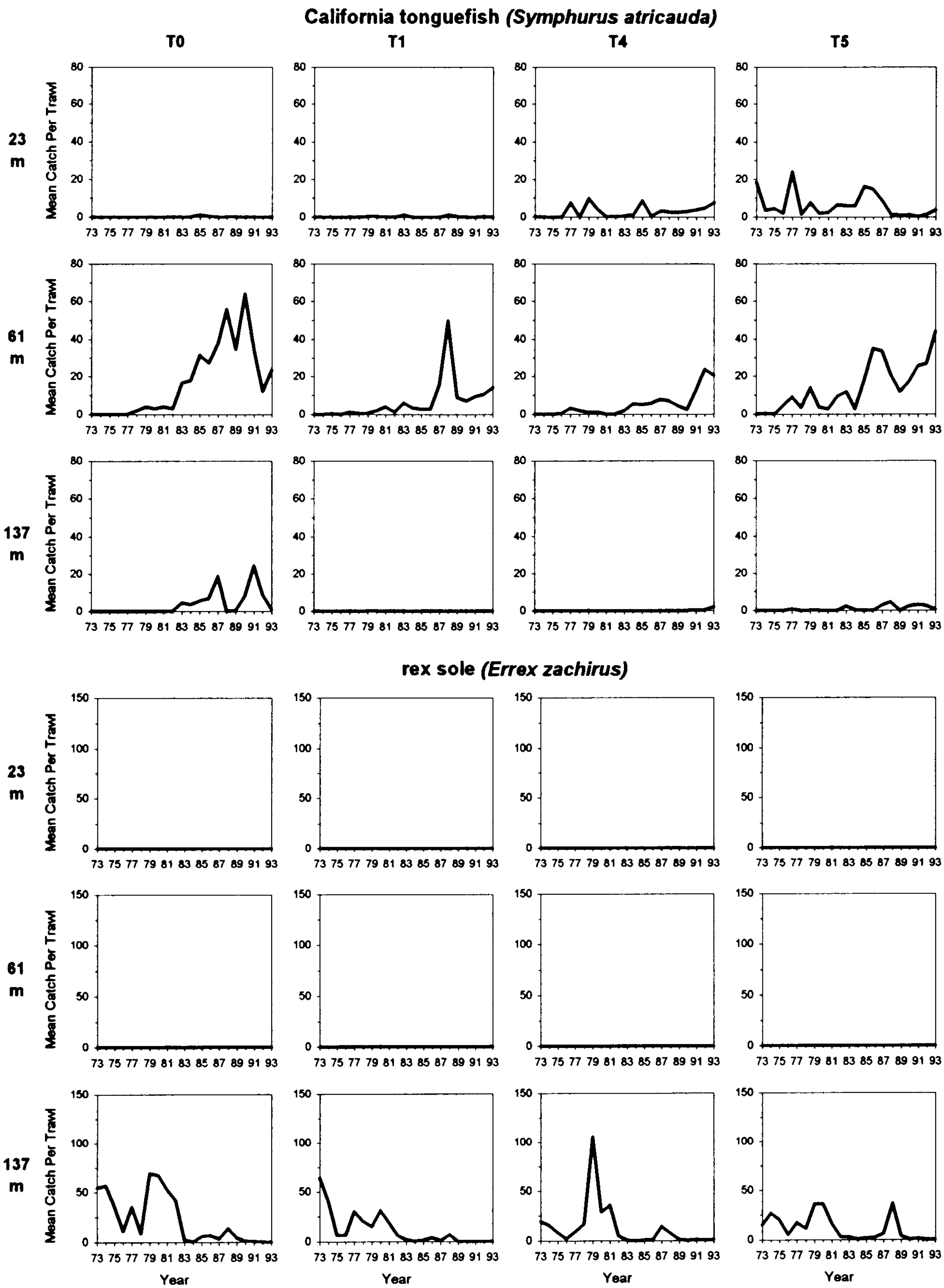

Figure 13. *Symphurus atricauda* (California tonguefish) and *Errex zachirus* (rex sole) distributions on Palos Verdes, 1973–93.

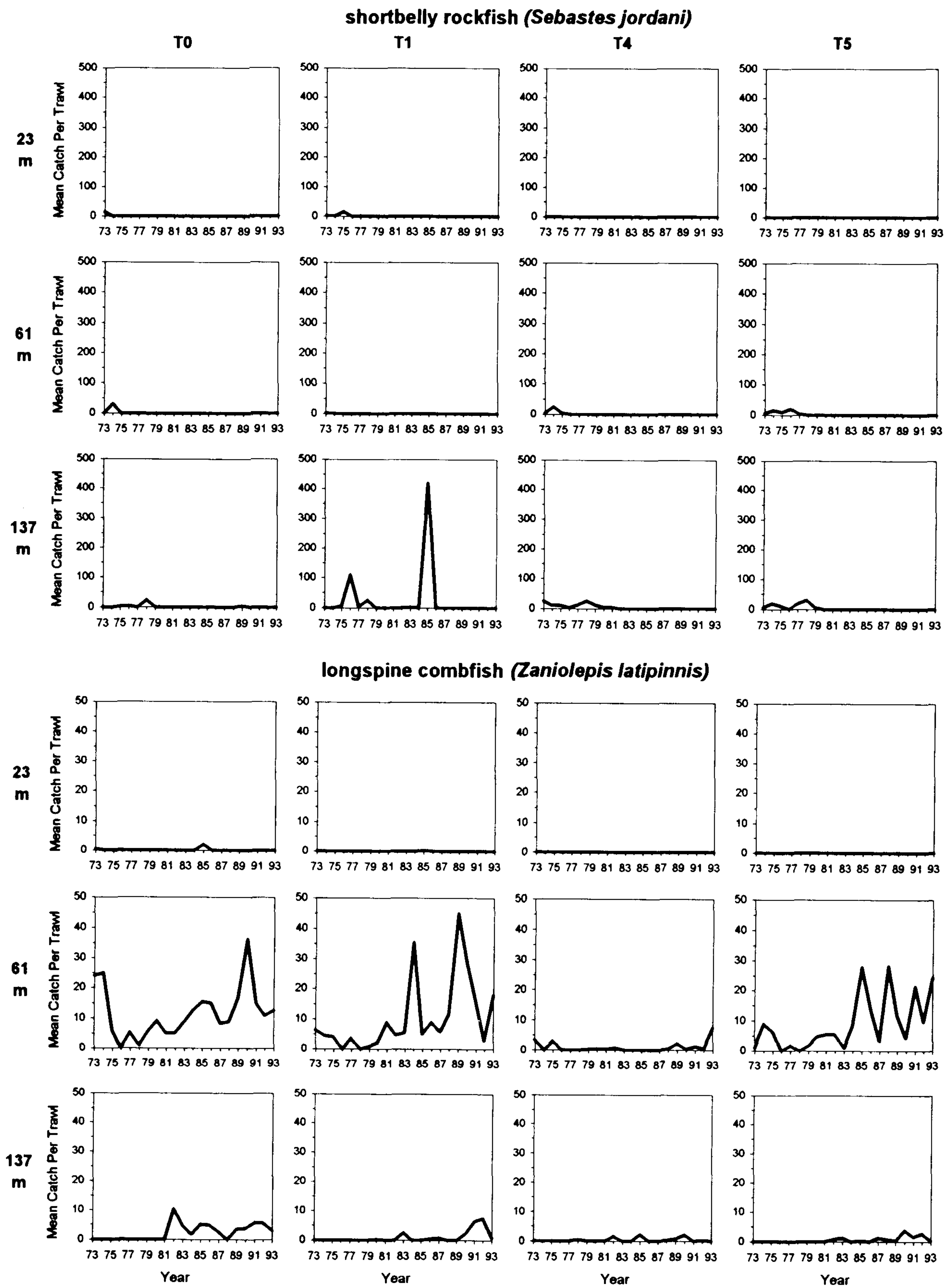

Figure 14. *Sebastes jordani* (shortbelly rockfish) and *Zaniolepis latipinnis* (longspine combfish) distributions on Palos Verdes, 1973–93.

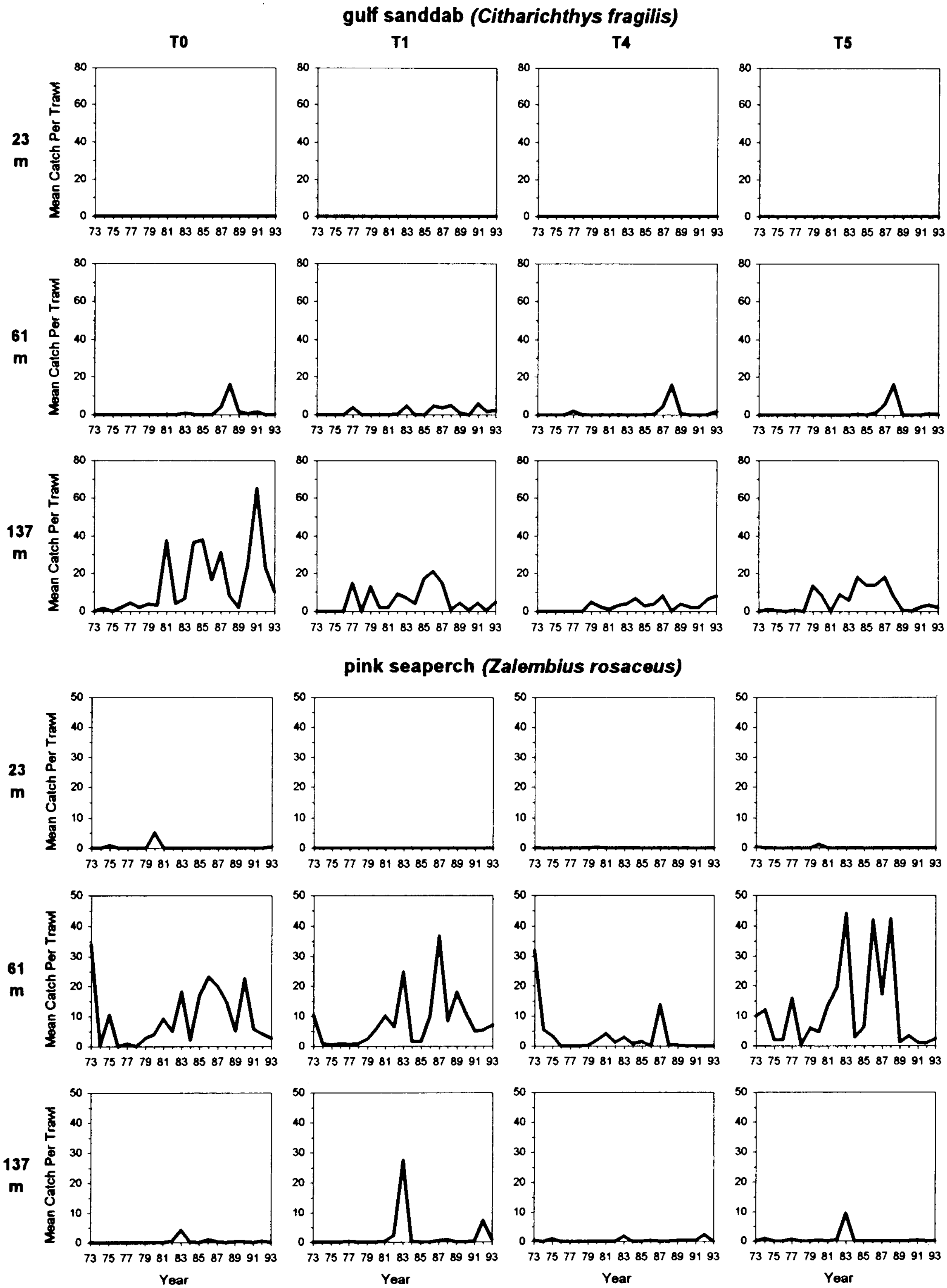

Figure 15. *Citharichthys fragilis* (gulf sanddab) and *Zalembius rosaceus* (pink seaperch) distributions on Palos Verdes, 1973–93.

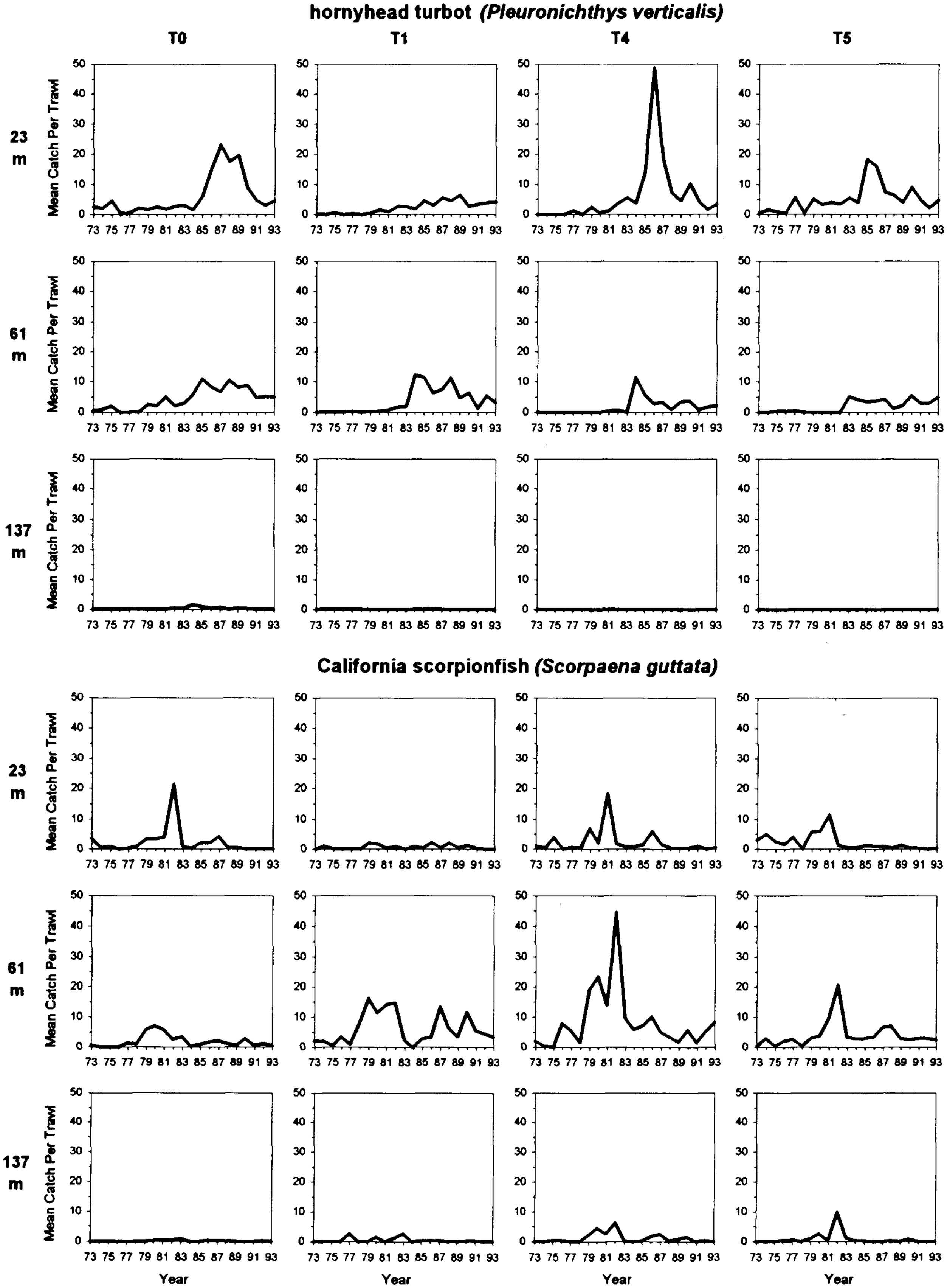

Figure 16. *Pleuronichthys verticalis* (hornyhead turbot) and *Scorpaena guttata* (California scorpionfish) distributions on Palos Verdes at 137 m, 1973–93.

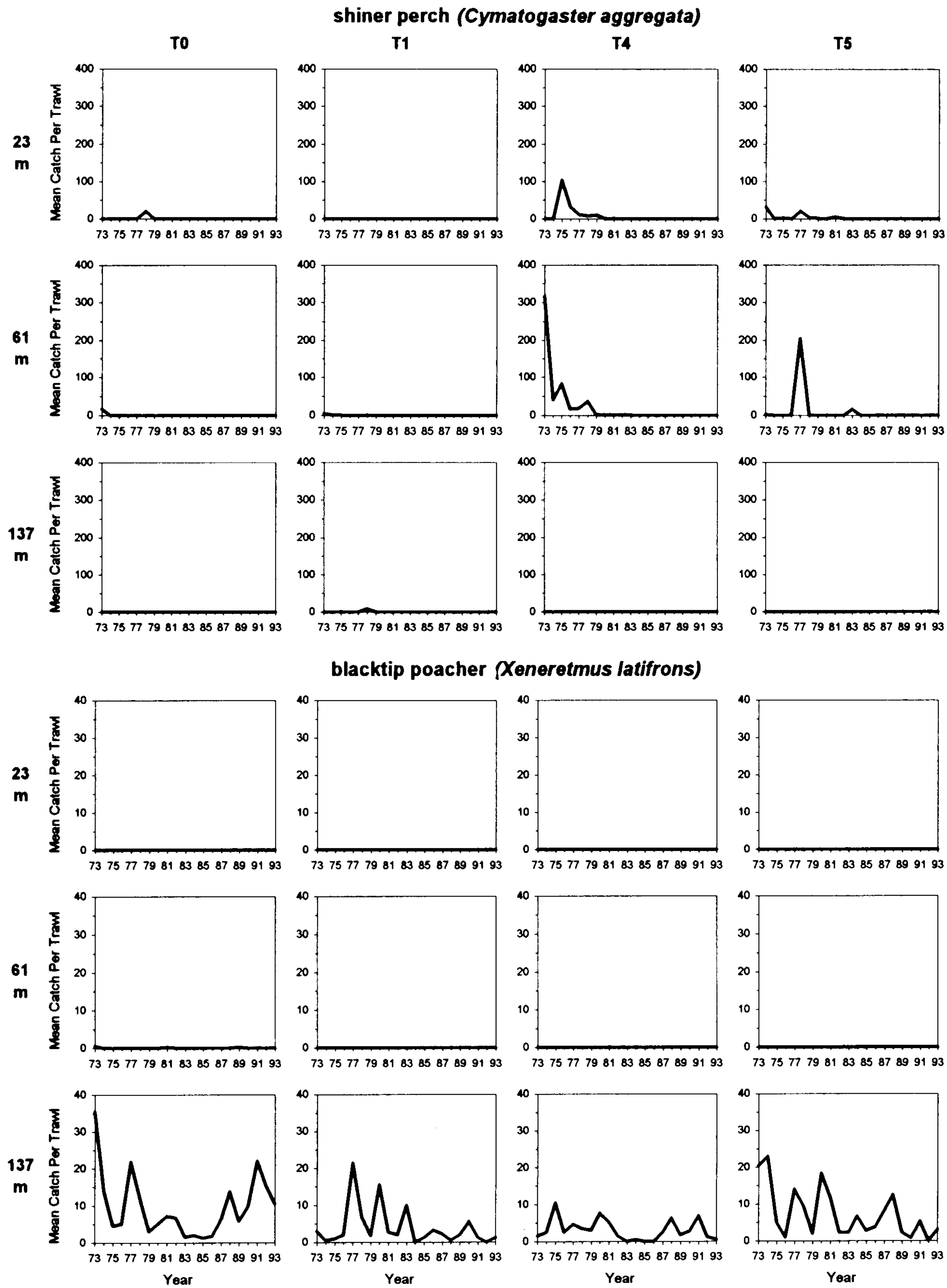

Figure 17. *Cymatogaster aggregata* (shiner perch) and *Xeneretmus latifrons* (blacktip poacher) distributions on Palos Verdes, 1973–93.

22. *Xeneretmus latifrons* (blacktip poacher, figure 17) was frequently taken along the 137-m isobath, but it was less abundant at outfall station T4-137. This cold-temperate, upper-slope roundfish ambushes epibenthic benthopelagic prey such as gammarid amphipods. At rest it is exposed. It has demersal eggs and pelagic larvae.

23. *Hippoglossina stomata* (bigmouth sole, figure 18) was rare in the 1970s, and most common in the mid- to late 1980s, likely in response to El Niño. It was most numerous near Redondo Canyon (T0-61). This warm-temperate, outer-shelf flatfish ambushes nektonic or benthopelagic prey such as mysids. It is buried when at rest. It has pelagic eggs and larvae.

29. *Paralichthys californicus* (California halibut, figure 18) was most common at 23 m in the 1980s, especially at T1-23; it was rare in the 1970s. This temperate, inner-shelf flatfish ambushes pelagic prey such as anchovies. It buries itself in sediments when at rest, and has pelagic eggs and larvae.

31. *Pleuronectes vetulus* (English sole, figure 19) was most abundant in the early 1970s at scattered sites, 23–137 m. In the 1980s and 1990s it was most often caught at outfall station T4-61. This temperate, outer-shelf flatfish searches for infaunal prey such as eunicid polychaetes. It is buried when at rest and has pelagic eggs and larvae.

32. *Xystreurys liolepis* (fantail sole, figure 19) was most common along the 23-m isobath from the 1980s and was abundant only in the mid-1980s at 61 m. This warm-temperate, inner-shelf flatfish ambushes epibenthic prey such as crabs. It is buried when at rest, and has pelagic eggs and larvae.

33. *Pleuronichthys decurrens* (curlfin sole, figure 20) is a shelf species which was most prevalent in the early 1970s at T4-23, T1-23, and T4-61. This cold-temperate, outer-shelf flatfish stalks benthic infauna such as echiurans. At rest it is buried. It has pelagic eggs and larvae.

35. *Phanerodon furcatus* (white seaperch, figure 20) is another inshore species, most numerous in the 1970s at T5-23 and T4-23. This cold-temperate, inner-shelf roundfish searches for epibenthic/benthopelagic prey such as gammarid amphipods. At rest, it is exposed. It has internal eggs and larvae.

Among the species not portrayed, *Sebastes rosenblatti* (greenblotched rockfish), *Zaniolepis frenata* (shortspine combfish), and *Chitonotus pugettensis* (roughback sculpin) were less common near the outfall.

External Anomalies

Dover sole dorsal and anal fins, which are in frequent contact with the sediment surface, showed most fin erosion; the ventral pectoral fin was more affected than the dorsal. Near total losses of most fins were observed in the early 1970s, but the severity of the syndrome declined over time. Data from the 1980s are conservative; very minor fin anomalies were observed, and it was sometimes difficult to distinguish if the damage was from the trawl net or some other source.

Most Dover sole were taken along the 137-m isobath. Figure 21 (dotted line) shows the mean number of Dover sole of four size classes taken annually at the four Palos Verdes 137-m sites. Dover sole were remarkably abundant in the early 1970s, particularly in summer; they were less common from 1980 to 1993.

Figure 21 (bars) also shows the mean annual percentage of Dover sole of the four size classes with fin erosion. Fin erosion was a function of sampling site and fish size. Most frequent and most severe fin erosion incidences were found at near-outfall stations (T4 and T5) in the 1970s. The syndrome was rare at the most distant transect, T0, and infrequent at T1. Frequency has been very low at all sites from the mid- to late 1980s.

Fin erosion declined first among smaller sole; the syndrome has not been observed in the smallest size class since 1980. The syndrome persisted longer in larger individuals; it was rarely observed in the mid-1980s, and not observed in the 1990s.

Historically, fewer Dover sole had X-cell epidermal pseudotumors than fin erosion (figures 21 and 22). But there has not been the same relative reduction in pseudotumors as in fin erosion. Incidence was highest (0–5%) nearest the outfall (T4-137), and lowest among larger specimens (>14 cm standard length).

DISCUSSION

Demersal fish that live both in the water column and on the bottom are commonly taken over Palos Verdes' soft-bottom habitat. Allen's (1982) descriptions of functional aspects of southern California soft-bottom fish communities indicate that the Palos Verdes fish eat pelagic, benthopelagic, epibenthic, infaunal, and other prey. Arthropods are a preferred food, especially euphausiids, gammarids, shrimp, mysids, and crabs. Many fish taken in the 1980s and 1990s bury themselves in the sediments when inactive; others are exposed. The most common reproductive strategy includes pelagic eggs and larvae, although a few dominants have internal or demersal eggs or larvae. For the entire 21 years, total abundances and numbers of species tend to be only slightly lower at outfall station T4 as compared to the other 61-m sites.

It is difficult to establish the causes of the observed spatial and temporal changes in demersal fish catches on Palos Verdes, 1973–93. A multiplicity of hydrodynamic and biological processes influence fish populations on various spatial or temporal scales. Parallel long-term regional data that might serve as a reference are unavailable. Also, the geomorphology of Palos Verdes is unique

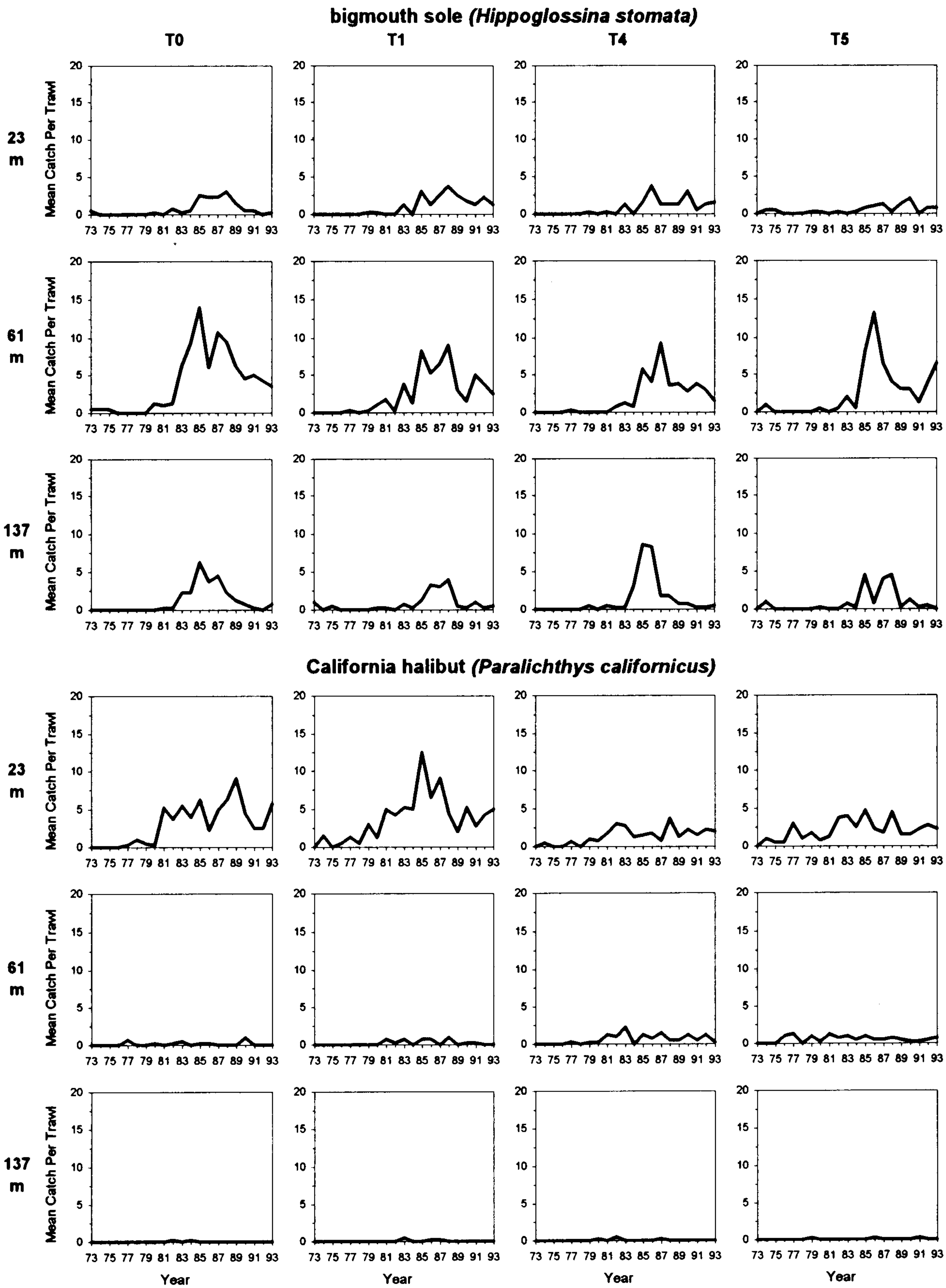

Figure 18. *Hippoglossina stomata* (bigmouth sole) and *Paralichthys californicus* (California halibut) distributions on Palos Verdes, 1973–93.

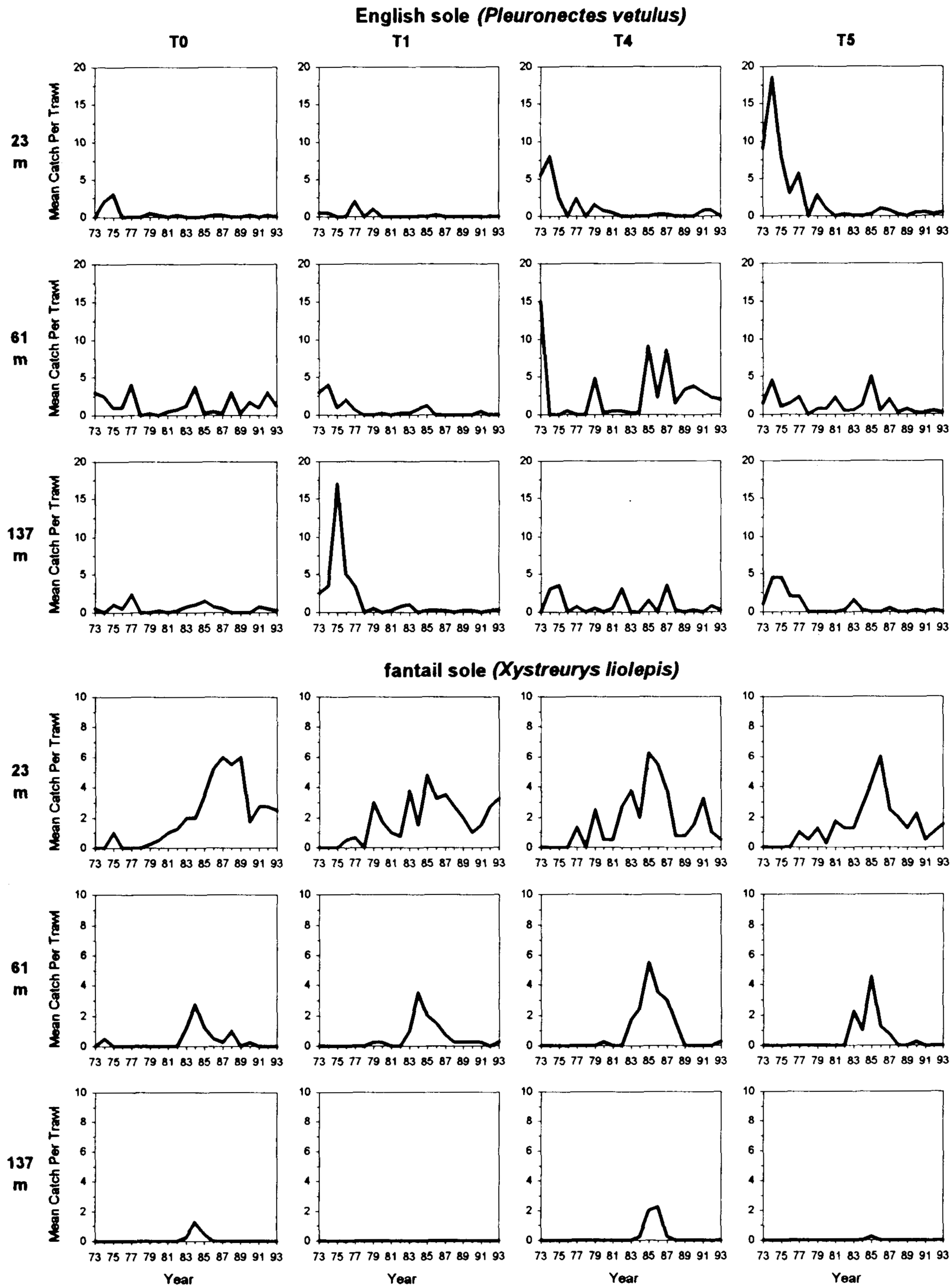

Figure 19. *Pleuronectes vetulus* (English sole) and *Xystreurys liolepis* (fantail sole) distributions on Palos Verdes, 1973–93.

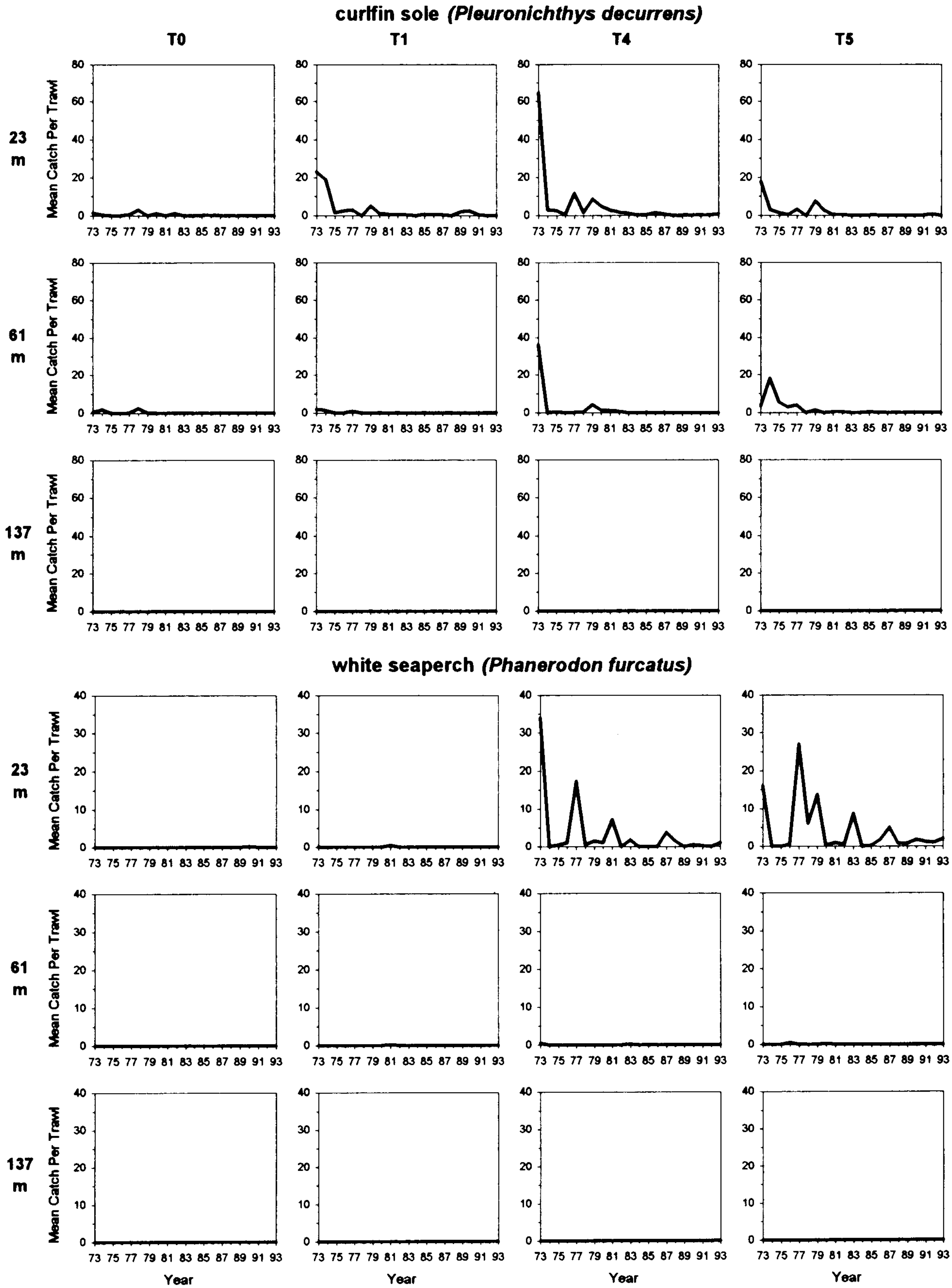

Figure 20. *Pleuronichthys decurrens* (curlfin sole) and *Phanerodon furcatus* (white seaperch) distributions on Palos Verdes, 1973–93.

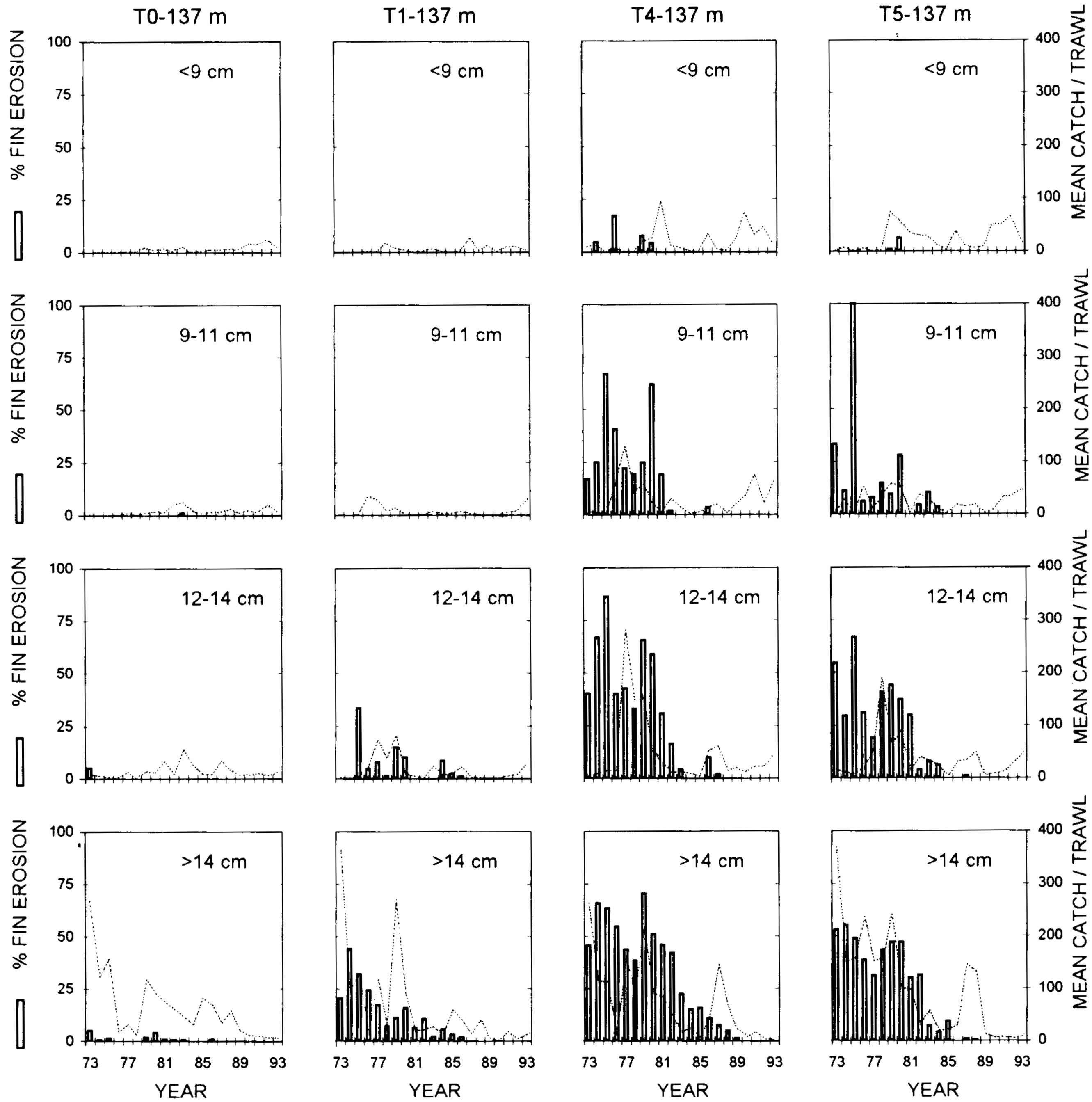

Figure 21. Percentage of fin erosion and number of Dover sole caught at Palos Verdes 137-m sites, by size class, 1973–93.

relative to its regional setting. Moreover, many demersal fish species have pelagic eggs and larvae which can be widely dispersed; thus correlations between local environmental factors and catch data are difficult. Also, fish populations can reflect both present environmental conditions and conditions at the time of settlement from the plankton. Despite these difficulties, one can speculate on the important processes from correlations with specific perturbations or from physical/biological habitat characteristics.

Water depth created the dominant spatial distribution pattern. Species exhibit depth preferences from inner shelf (23 m) and outer shelf (61 m) to upper slope (137 m). Other habitat features that probably influenced fish distributions include sediment type and quality (substrate, and levels of contaminants and organic matter), and topography (coastal promontory with narrow shelf, steep slope, canyons, outfall structure, and seasonal upwelling).

Stochastic natural events appear to play a major role

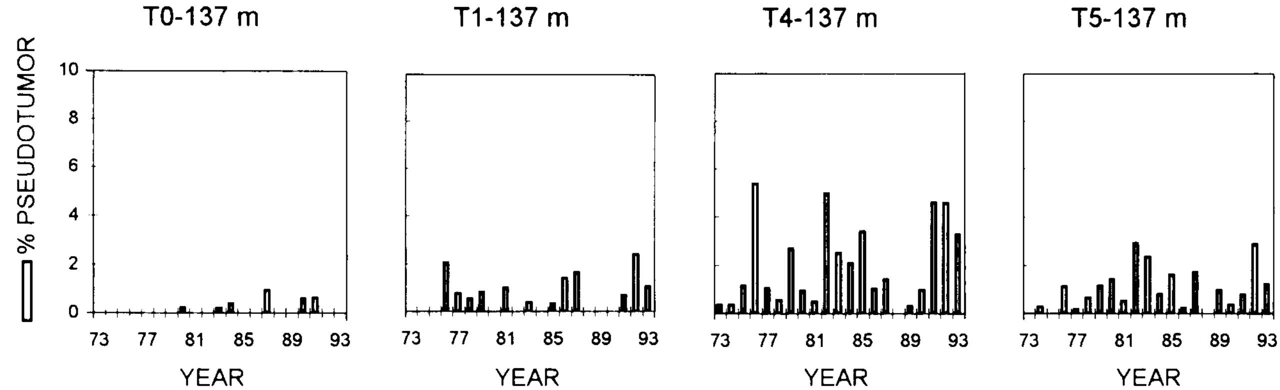

Figure 22. Percentage of pseudotumors in Dover sole caught at Palos Verdes 137-m sites, 1973–93.

in shaping community structure. Most of the changes in species composition and abundance occurred over the entire Palos Verdes study area, and may have been region- or bightwide.

Temperature shifts had the greatest effect on Palos Verdes fish populations. El Niño events, which are related to the strength of the California Countercurrent, were a key factor. Residual effects from the most extreme El Niño (1982–83) persisted in the fish assemblage for several years. The warmer waters of 1982–83, and of the 1980s and 1990s, brought southerly (mostly warm-temperate) species northward, changed recruitment patterns, and displaced some fish farther offshore or to the north.

Species whose catches increased during or after the 1982–83 El Niño include *Merluccius productus* (Pacific hake), *Xystreurys liolepis* (fantail sole), *Seriphus politus* (queenfish), *Chitonotus pugettensis* (roughback sculpin), *Sebastes rosenblatti* (greenblotched rockfish), *Hippoglossina stomata* (bigmouth sole), *Pleuronichthys verticalis* (hornyhead turbot), *Citharichthys fragilis* (gulf sanddab), *Zalembius rosaceus* (pink seaperch), *Zaniolepis latipinnis* (longspine combfish), *Symphurus atricauda* (California tonguefish), *Synodus lucioceps* (California lizardfish), *Sebastes diploproa* (splitnose rockfish), *Genyonemus lineatus* (white croaker), *Porichthys notatus* (plainfin midshipman), and *Icelinus quadriseriatus* (yellowchin sculpin). During this period, there were fewer *Xeneretmus latifrons* (blacktip poacher) and *Errex zachirus* (rex sole), both cold-temperate species.

Most of the fish species whose catches increased during or after the 1982–83 El Niño consume crustaceans such as shrimp, mysids, euphausiids, crabs, gammarids, ostracods, or calanoids (Allen 1982). The prey are primarily benthopelagic or pelagic, and are taken from the bottom or from the water column. During and following the largest El Niño (1983–86), extremely large numbers of *Sicyonia ingentis* (ridgeback shrimp) and *Pleuroncodes planipes* (pelagic red crab) occurred on the shelf and upper slope. It is hypothesized that these were a very important food resource for the fish that flourished during those years.

Following are several other examples of distribution patterns and possible environmental correlates. Some of the changes in catches relate to declining wastewater emissions (solids, trace contaminants) and associated ecological improvements such as better sediment quality, more diverse food resources (e.g., more microcrustacea and fewer small polychaetes), increased kelp, and greater water clarity. The large and ongoing natural variability alters effects from wastewater discharges and tends to confound interpretations.

At 23 m, *Citharichthys stigmaeus* (speckled sanddab), *Pleuronectes vetulus* (English sole), *Pleuronichthys decurrens* (curlfin sole), and *Phanerodon furcatus* (white seaperch) decreased, and *Paralichthys californicus* (California halibut) and *Xysteurys liolepis* (fantail sole) increased. Warmer waters in the 1980s and 1990s were likely a factor; sediment quality and food resources may have played a role.

At 61 m, *Sebastes saxicola* (stripetail rockfish), *Genyonemus lineatus* (white croaker), *Sebastes dalli* (calico rockfish), and *Cymatogaster aggregata* (shiner perch) decreased. These are water-column fish; many are exposed when at rest. The rockfish and shiner perch have internal eggs. *Symphurus atricauda* (California tonguefish), *Zaniolepis latipinnis* (longspine combfish), *Pleuronichthys verticalis* (hornyhead turbot), *Hippoglossina stomata* (bigmouth sole), and *Citharichthys xanthostigma* (longfin sanddab) increased. These have pelagic or demersal eggs, and pelagic larvae. Most are bottom-living fish which bury themselves during periods of inactivity. The increase in bottom dwellers may relate in part to improvements in sediment quality, such as lowered trace contaminants, organic matter, and hydrogen sulfide. Bottom dwellers themselves play a major role in redistributing contaminants by disturbing the sediments.

At 137 m, *Microstomus pacificus* (Dover sole), *Sebastes saxicola* (stripetail rockfish), *Sebastes diploproa* (splitnose rockfish), *Errex zachirus* (rex sole), and *Anoplopoma* *fimbria* (sablefish) decreased. *Eopsetta exilis* (slender sole), *Porichthys notatus* (plainfin midshipman), *Lycodopsis pacifica* (blackbelly eelpout), *Sebastes rosenblatti* (greenblotched rockfish), and *Zaniolepis frenata* (shortspine combfish) increased. Some species with a more northerly distribution were more common in the 1970s, whereas some with a more southern or temperate distribution increased in the 1980s and 1990s.

Nearshore fish appear to have moved offshore during perturbations. *Synodus lucioceps* (California lizardfish) catches at 23 m correspond directly with El Niño and storm events (increases in 1973, 1977, 1982–83, 1988, and 1992). *Cymatogaster aggregata* (shiner perch) decreased steadily, but the largest 61-m populations were also recorded in El Niño years 1973, 1977, and 1983. *Genyonemus lineatus* (white croaker) tended to be more abundant in 61-m catches in El Niño years (1977, 1983, and 1993).

At 137 m, *Porichthys notatus* (plainfin midshipman) was most abundant on the upper slope after the 1988 storms. Two waves of *Sebastes saxicola* (stripetail rockfish) recruitment came with El Niño events.

Some species characteristic of the Palos Verdes outfall area in the early 1970s decreased thereafter, including *Cymatogaster aggregata* (shiner perch), *Pleuronichthys decurrens* (curlfin sole), *Phanerodon furcatus* (white seaperch), *Pleuronectes vetulus* (English sole), and *Microstomus pacificus* (Dover sole). These have cold-temperate and temperate distributions; many prey on various benthic infauna.

Other species that had been absent or rare became more abundant near the outfall, including *Symphurus atricauda* (California tonguefish), *Pleuronichthys verticalis* (hornyhead turbot), *Paralichthys californicus* (California halibut), *Zaniolepis latipinnis* (longspine combfish), and *Lycodopsis pacifica* (blackbelly eelpout). Many are warm-temperate or temperate species, and microcrustaceans such as gammarids are a common food preference.

Some species, such as *Icelinus quadriseriatus* (yellowchin sculpin) and *Zaniolepis latipinnis* (longspine combfish) are rare near the outfall. Both prey on gammarid amphipods, which are less abundant in soft sediments nearer the outfall system. Persistent differences in fish assemblages near the outfall may be due to the nature of the substrate (fine-grained, organically enriched sediments with trace contaminants), topography (e.g., outfall structure), food resources, or the discharge of treated wastewaters. Also, historically discharged contaminants such as DDT and PCBs persist in a partly buried sediment reservoir on Palos Verdes (Stull et al. 1988). These may influence the condition of some fish species (Cross and Hose 1988).

Fin erosion was common in Dover sole near the outfall. But it has not been induced in Palos Verdes Dover sole for many years: in smallest sole (<9 cm) it has not been observed since 1980, and in larger specimens (>14 cm) it was last observed in the mid-1980s (figure 21). Absence of the syndrome may result from improved sediment quality and reduced emissions of effluent solids and contaminants (figure 3).

Pseudotumors were more prevalent in Dover sole nearer the outfall, as reported by Cross (1988). Historically the incidence of pseudotumors was lower than that of fin erosion. Although fin erosion virtually disappeared, pseudotumors continue to occur on Palos Verdes, with lowest frequency in larger Dover sole (>14 cm). The overall incidence ranges from 0–2% at stations distant from the outfall (T0, T1), and 0–5% near the outfall.

CONCLUSIONS

1. Palos Verdes demersal fish catches varied greatly from 1973 to 1993. Spatial and temporal patterns are described, and inferences are made on potentially important environmental processes that influence fish assemblages.

2. Water depth was the primary determinant of spatial distributions. Species exhibited particular preferences for inner-shelf (23-m), outer-shelf (61-m), or upper-slope (137-m) habitats. Wastewater discharge, substrate type, topography, and food resources also influenced distributions.

3. Temperature shifts induced more changes in fish assemblages over time than did any other natural or anthropogenic factors. The 1970s were several degrees cooler than the 1980s and 1990s. The major warming trend of the 1982–83 El Niño, and associated physical and biological perturbations, had the most dramatic effects on demersal fish. Warmer waters, large populations of crustaceans, and more southern fish species were observed. Catches of many fish species increased substantially, while a few decreased. The largest changes persisted for several years.

4. Many other factors also helped shape the fish populations over time, including smaller-scaled oceanographic events, natural hydrodynamic and biological fluctuations, disturbances such as storms, and anthropogenic activities.

5. Fish assemblages recovered in concert with decreasing emissions of wastewater solids and contaminants from the outfalls, and with associated ecological improvements in Palos Verdes habitats. Some species that were abundant near the outfalls in the early 1970s declined; some that had been rare increased. Bottom fish, which bury themselves in sediments during periods of inactivity, became more common, as did species which prey on crustaceans. Several species are still reduced near the outfall as compared to other Palos Verdes sites.

6. The incidence and severity of fin erosion among Palos Verdes Dover sole decreased from the 1970s; it has not been observed since the mid-1980s. Dover sole

epidermal pseudotumors, believed to be a parasitic condition and not a neoplasm, are more frequent (<5%) near the outfall than elsewhere on Palos Verdes. They have also been observed in flatfish distant from pollutant sources.

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