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Relative abundance and health of demersal fish species on the southern California shelf in 1994

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ABSTRACT

Numerous local studies of demersal fish populations have been conducted off the southern California coast during the last 25 years, but the populations have not been described synoptically. This study describes the distribution, relative importance, and health of dominant fish species in the first synoptic survey of the southern California mainland shelf. Fish were collected by 7.6-m head rope semiballoon otter trawls from 114 stations at depths of 10-200 m from Point Conception, California, to the United States-Mexico international border in July-August 1994. Species were identified, counted, measured (length), examined for anomalies, and weighed. Eighty-seven fish species from 34 families were collected; rockfishes and flatfishes were most diverse. More species were common (i.e., widely distributed) than were abundant or high in biomass. Overall, Pacific sanddab (*Citharichthys sordidus*), plainfin midshipman (*Porichthys notatus*), California halibut (*Paralichthys californicus*), slender sole (*Lyopsetta (=Eopsetta) exilis*), Dover sole (*Microstomus pacificus*), and white croaker (*Genyonemus lineatus*) were among the top three species in either areal coverage, total abundance, or total biomass. Pacific sanddab was the most widespread and abundant species, and was second (after California halibut) in biomass. Species rankings varied by areal coverage, abundance, and biomass for the entire mainland shelf, geographic regions, depth zones, and wastewater influence areas. Anomalies were found in 197 of 18,912 fish, with pigment anomalies and parasites being most prevalent; epidermal tumors, lesions, and fin erosion occurred in 17 fish. In the 1970s, tumors, fin erosion, lesions and skeletal deformities were prevalent in locally contaminated areas, but these anomalies were rare and scattered along the mainland shelf in 1994. The 1% anomaly rate likely represents background conditions. Regionwide, demersal fish populations were relatively healthy, with notable decreases in anomalies since the 1970s.

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INTRODUCTION

Southern California is one of the most rapidly changing coastal environments in the country. The human population in the coastal basin has increased from 11 million (SCCWRP 1973) to 17 million (CDF,DRU 1995) during the past 25 years, with urbanization of the coast increasing in proportion to this change. With this increase, recreational, commercial, and industrial uses of the southern California coastal ocean have generally increased. Recreational fishing in the area has increased during this period, but commercial fishing has varied as the importance of the pelagic wet fish fishery varied (Schiff *et al.* 2000). Stormwater runoff has increased in importance as a source of pollution while wastewater discharge, although increasing in volume, has decreased in mass emissions of contaminants by more than 80% (Raco-Rands

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1999, Schiff *et al.* 2000). In addition to a rapidly changing environment of human activities in the area, the ocean climate in the area has changed greatly during the past 25 years. The cool, productive waters of the 1960s and 1970s were replaced largely by the warmer waters of the 1980s and 1990s, due to El Niños and general ocean warming (Smith 1995).

Fish populations are frequently monitored locally, but not for the region as a whole. Demersal fishes (which live on or near the seafloor, are sedentary, and are widely distributed on Southern California Bight [SCB] mainland shelf soft-bottom habitats) have been the subject of most of the studies of human impact to the area. Local areas have been studied extensively for more than 25 years (e.g., Carlisle 1969, MBC 1987, SCCWRP 1992, CLAEMD 1994, CSDMWWD 1995, Stull 1995, CSDOC 1996, Stull and Tang 1996, CSDLAC 1997), but less is known about spatial and temporal variability throughout the SCB. Past regional studies compiled trawl data from various times, places, and purposes (SCCWRP 1973, Mearns *et al.* 1976, Allen and Voglin 1976, Allen 1977, Allen 1982) or collected data in reference surveys of limited scope (Allen and Mearns 1977; Word *et al.* 1977; Love *et al.* 1986; Thompson *et al.* 1987, 1993). However, demersal fish populations have not been examined synoptically along the entire mainland shelf of the southern California coast at any time in the past 25 years.

In 1994 we conducted the first regional synoptic trawl survey of the entire southern California mainland (Allen *et al.* 1998). The objective of this report is to describe the distribution, relative importance (areal coverage, abundance, and biomass), population structure (size and age), and health of dominant fish species on the southern California mainland shelf. We compare these attributes among predetermined geographic, depth, and wastewater influence subpopulations, and to previous, less extensive, regional studies of the area. Although not discussed in this article, this information will also provide a context for understanding local population patterns. Previous studies from this survey describe variability in trawl catch parameters (Allen and Moore 1996), recurrent groups (Allen and Moore 1997), and assemblages (Allen *et al.* 1999). However, the distribution, relative importance, population structure, and health of the populations have not been reported.

METHODS

Trawl samples were collected at 114 randomly selected stations from Point Conception, California, to the United States-Mexico international border at depths of 9 to 215 m (Figure 1). Samples were collected from July 12 to August 22, 1994, with 7.6-m head-rope semiballoon otter trawls with 1.25-cm cod-end mesh. Trawls were towed for 10 min at 1 m/sec (2 kn) along isobaths. Fish were identified to species, counted, measured, examined for anomalies, and weighed by species to the nearest 0.1 kg. Lengths of individual fish were measured by centimeter size class: total length (TL) for cartilaginous fish and maximum (board) standard length (SL) for bony fish. Each fish was examined for external anomalies, including fin erosion, tumors, parasites, ambicoloration, albinism, diffuse pigmentation, skeletal deformities, and lesions. Fish parasites that were not on the fish when they were examined were reported with the trawl invertebrates.

Stations were selected using a stratified random design (Stevens 1997, Allen *et al.* 1998). Three subpopulation categories were defined: (1) Regions — northern (Point Conception to Point Dume), central (Point Dume to Dana Point), and southern (Dana Point to United States-Mexico international border); (2) Depth zones — inner shelf (10-25 m), middle shelf (26-100 m), and outer shelf (101-200 m); and (3) Typical of area - publicly owned treatment work (POTW) and non-POTW areas (Figure 2). The POTW areas were broad regions encompassing much or all of the area monitored around outfalls of the four major POTWs: City of Los Angeles, Hyperion Treatment Plant outfall at 60 m in Santa Monica Bay; County Sanitation Districts of Los Angeles County, Joint Water Pollution Control Plant outfall at 60 m off Palos Verdes; County Sanitation Districts of Orange County outfall at 60 m on the San Pedro Shelf; and City of San Diego, Point Loma Wastewater Treatment Facility outfall at 100 m off Point Loma. The non-POTW area was the remaining area (even though additional sources discharge into shallow waters). Sample numbers from these strata were not equal, with the following numbers of samples by subpopulation: Regions – northern (45), central (41), and southern (28); Depth zones – inner shelf (30), middle shelf (53), and outer shelf (31); and Typical of area - POTW (23) and non-POTW (30) (Allen *et al.* 1998). Further, the distribution of sampling effort by 10-m depth intervals was also uneven, with the highest number of samples collected at the 15-, 25-, and 45-m depth classes (Figure 1).

Data Analysis

Area-weighted means were calculated using a ratio estimator (Thompson 1992, Allen *et al.* 1998). Weighting factors for each station are given in Allen *et al.* (1998). The distribution by abundance and biomass of the top three dominant species for occurrence, abundance, and biomass were mapped. Length frequency and occurrence by depth were plotted for these species. Length-frequency plots of dominant species were compared to the maximum reported size for that species. Percent occurrence was defined as

FIGURE 1. Map of 114 fish population stations sampled by trawl on the mainland shelf of southern California at depths of 10-200 m, July-August 1994, with inset of number of stations sampled per 10 m depth classes.

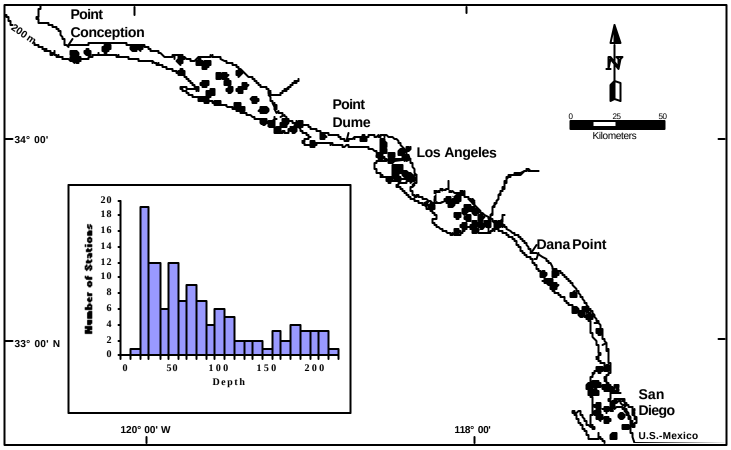
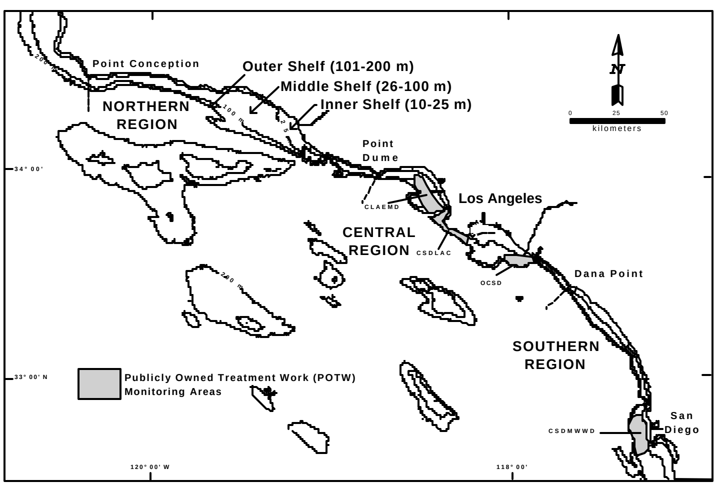


FIGURE 2. Distribution of subpopulations for regions, depth zones, and publicly owned treatment work (POTW) monitoring areas used in the regional trawl survey of the mainland shelf of southern California, July-August 1994. CLAEMD = City of Los Angeles Environmental Monitoring Division; CSDLAC = County Sanitation Districts of Los Angeles County; CSDMWWD = City of San Diego, Metropolitan Wastewater Department; CSDOC = County Sanitation Districts of Orange County.



the percent of the total occurrence of a species that was found within 10 m depth intervals.

RESULTS

The survey collected 87 species of fish, representing 3 classes and 34 families (Table 1). There were 80 species of ray-finned fish (Actinopterygii), 6 species of cartilaginous fishes (Chondrichthyes), and 1 species of hagfish (Myxini). The most diverse families were Scorpaenidae (scorpionfishes) with 21 species; Pleuronectidae (righteye flounders) with 9 species; and Paralichthyidae (whiffs) with 7 species. Equitability curves for occurrence, abundance, and biomass indicate that more species occurred frequently than abundantly or with a high biomass (Figure 3).

Occurrence

Nineteen species occurred individually in 20% or more of the area sampled (Table 2). Pacific sanddab (*Citharichthys sordidus*), Dover sole (*Microstomus pacificus*), plainfin midshipman (*Porichthys notatus*), California lizardfish (*Synodus lucioceps*), hornyhead turbot (*Pleuronichthys verticalis*), and yellowchin sculpin (*Icelinus quadriseriatus*) occurred in over half of the total area.

Geographically, Pacific sanddab was the most common species in the northern and southern regions, whereas California lizardfish was the most common species in the central region (Table 3). Bathymetrically, speckled sanddab (*Citharichthys stigmaeus*) was the most common species on the inner shelf, Pacific sanddab on the middle shelf, and Dover sole on the outer shelf. Bigmouth sole (*Hippoglossina stomata*) was the most common species in the POTW areas, whereas Pacific sanddab inhabited the most area in the non-POTW areas. However, Pacific sanddab occupied a higher percentage of area in the POTW area than in the non-POTW area. No species occurred in more than 50% of the area in all of the subpopulations. The most widespread species (Pacific sanddab and Dover sole) inhabited more than 50% of the area in all subpopulations except the central region and inner shelf zone. Depth zone specificity occurred in shortspine combfish (*Zaniolepis frenata*), slender sole (*Lyopsetta =Eopsetta] exilis*), blacktip poacher (*Xeneretmus latifrons*), rex sole (*Glyptocephalus [=Errex] zachirus*), and Pacific hake (*Merluccius productus*) — outer shelf; bay goby (*Lepidogobius lepidus*) — middle shelf; and California halibut (*Paralichthys californicus*) and fantail sole (*Xystreurys liolepis*) — inner shelf.

Abundance

The 26 most abundant species together accounted for 95% of the survey catch (Table 4). Together, Pacific sanddab, plainfin midshipman, slender sole, yellowchin sculpin, and speckled sanddab accounted for half of the catch.

Pacific sanddab was the most abundant species in all subpopulations except the inner shelf (where speckled

TABLE 1. Taxonomic list of demersal fish species collected in the regional survey

Taxon/Species	Author	Common Name
MYXINI		HAGFISHES
— MYXINIFORMES		
Myxinidae		HAGFISHES
Eptatretus stoutii	(Lockington 1878)	Pacific hagfish
CHONDRICHTHYES		CARTILAGINOUS FISHES
— CARCHARHINIFORMES		
Scyliorhinidae		CAT SHARKS
Cephaloscyllium ventriosum	(Garman 1880)	swell shark
— SQUATINIFORMES		
Squatinidae		ANGEL SHARKS
Squatina californica	Ayres 1859	Pacific angel shark
— RAJIFORMES		
Rhinobatidae		GUITARFISHES
Platyrhinoidis triseriata	(Jordan & Gilbert 1880)	thornback
Rajidae		SKATES
Raja inornata	Jordan & Gilbert 1881	California skate
Raja stellulata	(Jordan & Gilbert 1880)	starry skate
Myliobatidae		EAGLE RAYS
Myliobatis californica	Gill 1865	bat ray
ACTINOPTERYGII		RAY-FINNED FISHES
— CLUPEIFORMES		
Engraulidae		ANCHOVIES
Engraulis mordax	Girard 1854	northern anchovy
Clupeidae		HERRINGS
Sardinops sagax	(Jenyns 1842)	Pacific sardine
— OSMERIFORMES		
Argentinidae		ARGENTINES
Argentina sialis	Gilbert 1890	Pacific argentine
— AULOPIFORMES		
Synodontidae		LIZARDFISHES
Synodus lucioceps	(Ayres 1855)	California lizardfish
—OPHIDIIFORMES		
Ophidiidae		CUSK-EELS
Chilara taylori	(Girard 1858)	spotted cusk-eel
Bythitidae		VIVIPAROUS BROTULAS
Brosmophycis marginata	(Ayres 1854)	red brotula
— GADIFORMES		
Merlucciidae		MERLUCCID HAKES
Merluccius productus	(Ayres 1855)	Pacific hake
— BATRACHOIDIFORMES		
Batrachoididae		TOADFISHES
Porichthys myriaster	Hubbs & Schultz 1939	specklefin midshipman
Porichthys notatus	Girard 1854	plainfin midshipman
— GASTEROSTEIFORMES		
Syngnathidae		PIPEFISHES
Syngnathus exilis	(Osburn & Nichols 1916)	barcheek pipefish
— SCORPAENIFORMES		
Scorpaenidae		SCORPIONFISHES
Scorpaena guttata	Girard 1854	California scorpionfish
Sebastes auriculatus	Girard 1854	brown rockfish
Sebastes caurinus	Richardson 1845	copper rockfish
Sebastes chlorostictus	(Jordan & Gilbert 1880)	greenspotted rockfish
Sebastes constellatus	(Jordan & Gilbert 1880)	starry rockfish
Sebastes dallii	(Eigenmann & Beeson 1894)	calico rockfish
Sebastes diploproa	(Gilbert 1890)	splitnose rockfish
Sebastes elongatus	Ayres 1859	greenstriped rockfish
Sebastes eos	(Eigenmann & Eigenmann 1890)	pink rockfish
Sebastes hopkinsi	(Cramer 1895)	squarespot rockfish
Sebastes jordani	(Gilbert 1896)	shortbelly rockfish
Sebastes levis	(Eigenmann & Eigenmann 1889)	cowcod
Sebastes miniatus	(Jordan & Gilbert 1880)	vermilion rockfish
Sebastes pinniger	(Gill 1864)	canary rockfish
Sebastes rosaceus	Girard 1854	rosy rockfish
Sebastes rosenblatti	Chen 1971	greenblotched rockfish
Sebastes rubrivinctus	(Jordan & Gilbert 1880)	flag rockfish

Table 1 (continued)

Taxon/Species	Author	Common Name
Sebastes saxicola	(Gilbert 1890)	stripetail rockfish
Sebastes semicinctus	(Gilbert 1897)	halfbanded rockfish
Sebastes umbrosus	(Jordan & Gilbert 1882)	honeycomb rockfish
Sebastolobus alascanus	Bean 1890	shortspine thornyhead
Triglidae		SEAROBINS
Prionotus stephanophrys	Lockington 1881	lumptail searobin
Hexagrammidae		GREENLINGS
Ophiodon elongatus	Girard 1854	lingcod
Oxylebius pictus	Gill 1862	painted greenling
Zaniolepis frenata	Eigenmann & Eigenmann 1889	shortspine combfish
Zaniolepis latipinnis	Girard 1857	longspine combfish
Cottidae		SCULPINS
Chitonotus pugetensis	(Steindachner 1876)	roughback sculpin
Icelinus filamentosus	Gilbert 1890	threadfin sculpin
Icelinus fimbriatus	Gilbert 1890	fringed sculpin
Icelinus quadriseriatus	(Lockington 1880)	yellowchin sculpin
Icelinus tenuis	Gilbert 1890	spotfin sculpin
Agonidae		POACHERS
Odontopyxis trispinosa	Lockington 1880	pygmy poacher
Xeneretmus latifrons	(Gilbert 1890)	blacktip poacher
Xeneretmus triacanthus	(Gilbert 1890)	bluespotted poacher
— PERCIFORMES		
Serranidae		SEA BASSES
Paralabrax clathratus	(Girard 1854)	kelp bass
Paralabrax nebulifer	(Girard 1854)	barred sand bass
Carangidae		JACKS
Trachurus symmetricus	(Ayres 1855)	jack mackerel
Sciaenidae		DRUMS
Genyonemus lineatus	(Ayres 1855)	white croaker
Seriphus politus	Ayres 1860	queenfish
Embiotocidae		SURFPERCHES
Phanerodon furcatus	Girard 1854	white seaperch
Rhacochilus toxotes	Agassiz 1854	rubberlip seaperch
Zalembius rosaceus	(Jordan & Gilbert 1880)	pink seaperch
Labridae		WRASSES
Halichoeres semicinctus	(Ayres 1859)	rock wrasse
Bathymasteridae		RONQUILS
Rathbunella alleni	Gilbert 1904	stripedfin (=rough) ronquil
Rathbunella hypoplecta	(Gilbert 1890)	bluebanded (=stripedfin) ronquil
Zoarcidae		EELPOUTS
Lycodes cortezianus	(Gilbert 1890)	bigfin eelpout
Lycodopsis pacifica	(Collett 1879)	blackbelly eelpout
Lyconema barbatum	Gilbert 1896	bearded eelpout
Stichaeidae		PRICKLEBACKS
Plectobranchus evides	Gilbert 1890	bluebarred prickleback
Uranoscopidae		STARGAZERS
Kathetostoma averruncus	Jordan & Bollman 1890	smooth stargazer
Gobiidae		GOBIES
Coryphopterus nicholsii	(Bean 1882)	blackeye goby
Lepidogobius lepidus	(Girard 1858)	bay goby
Stromateidae		BUTTERFISHES
Peprilus simillimus	(Ayres 1860)	Pacific pompano
— PLEURONECTIFORMES		
Paralichthyidae		WHIFFS
Citharichthys fragilis	Gilbert 1890	gulf sanddab
Citharichthys sordidus	(Girard 1854)	Pacific sanddab
Citharichthys stigmaeus	Jordan & Gilbert 1882	speckled sanddab
Citharichthys xanthostigma	Gilbert 1890	longfin sanddab
Hippoglossina stomata	Eigenmann & Eigenmann 1890	bigmouth sole
Paralichthys californicus	(Ayres 1859)	California halibut
Xystreurys liolepis	Jordan & Gilbert 1880	fantail sole

(Table 1 continued)

Taxon/Species	Author	Common Name
Pleuronectidae		RIGHTEYE FLOUNDERS
Eopsetta jordani	(Lockington 1879)	petrale sole
Glyptocephalus (=Errex) zachirus	Lockington 1879	rex sole
Lyopsetta (=Eopsetta) exilis	(Jordan & Gilbert 1880)	slender sole
Microstomus pacificus	(Lockington 1879)	Dover sole
Parophrys vetula (=Pleuronectes vetulus)	Girard 1854	English sole
Pleuronichthys decurrens	Jordan & Gilbert 1880	curlfin sole
Pleuronichthys guttulatus (=Hypsopsetta guttulata)	Girard 1856	diamond turbot
Pleuronichthys ritteri	Starks & Morris 1907	spotted turbot
Pleuronichthys verticalis	Jordan & Gilbert 1880	hornyhead turbot
Cynoglossidae		TONGUEFISHES
Symphurus atricauda	(Jordan & Gilbert 1880)	California tonguefish

Taxonomic arrangement (Nelson 1994); scientific and common names generally from Robins *et al*. (1991). = means that name is changed since Allen *et al*. (1998). Pleuronectid names follow Cooper and Chapleau (1998); bathymasterid common names from Matarese (1991).

FIGURE 3. Equitability curves of fish occurrence, abundance, and biomass by species on the mainland shelf of southern California at depths of 10-200 m, July-August 1994. x = 87th species.

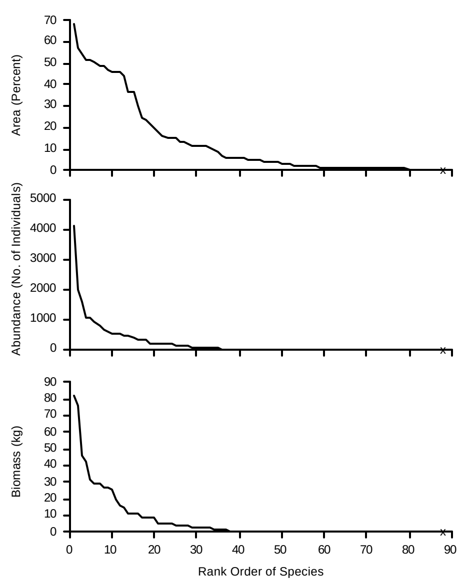


TABLE 2. Demersal fish species occurring in 20% or more of the area of the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

Species	No. of Stations	Percent Stations	Percent Area
Pacific sanddab	75	66	68
Dover sole	65	57	57
plainfin midshipman	57	50	54
California lizardfish	58	51	52
hornyhead turbot	60	53	51
yellowchin sculpin	51	45	51
bigmouth sole	56	49	49
longfin sanddab	55	48	49
English sole	50	44	47
stripetail rockfish	50	44	47
longspine combfish	44	39	46
California tonguefish	49	43	45
pink seaperch	44	39	44
bay goby	36	32	37
speckled sanddab	47	41	36
slender sole	37	33	30
shortspine combfish	32	28	25
California skate	25	22	23
fantail sole	27	24	21

Total stations = 114.
Total area = 3,075 km^2.
Based on area-weighted frequency of occurrences.

TABLE 3. Demersal fish species comprising 50% or more of the area by subpopulation in the regional survey of the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

	Percent Area							
	Region			Shelf Depth Zone			Middle Shelf	
Species	Northern	Central	Southern	Inner	Middle	Outer	POTW	NPOTW
Pacific sanddab	79	-	73	-	84	86	87	83
Dover sole	68	-	56	-	64	97	70	63
plainfin midshipman	62	-	66	-	71	59	61	73
California lizardfish	-	68	58	72	57	-	61	57
hornyhead turbot	53	62	-	72	60	-	78	57
yellowchin sculpin	59	-	-	-	80	-	83	80
pink seaperch	67	-	-	-	66	-	65	67
longspine combfish	67	-	-	-	71	-	57	73
English sole	65	-	-	-	54	-	-	57
stripetail rockfish	59	-	-	-	54	73	-	57
speckled sanddab	-	65	-	93	-	-	52	-
California tonguefish	-	58	-	-	63	-	78	60
bigmouth sole	-	54	64	-	69	-	96	63
longfin sanddab	-	-	71	-	67	-	87	63
shortspine combfish	-	-	-	-	-	86	-	-
slender sole	-	-	-	-	-	86	-	-
blacktip poacher	-	-	-	-	-	65	-	-
rex sole	-	-	-	-	-	60	-	-
Pacific hake	-	-	-	-	-	52	-	-
bay goby	-	-	-	-	59	-	57	60
California halibut	-	-	-	67	-	-	-	-
fantail sole	-	-	-	60	-	-	-	-

"-" = Species absent or not occurring in at least 50% of the area.
POTW = Publicly owned treatment work monitoring areas; NPOTW = non-POTW areas.
Total area (km^2) by subpopulation: N = 1,561; C = 820; S = 694; IS = 676; MS = 1,709; OS = 689; P = 290; NP = 1,419; SCB = 3,075.

sanddab was dominant) and outer shelf (where slender sole had a higher mean abundance) (Table 5). The second most abundant species was more variable. Geographically, plainfin midshipman was second in abundance in the northern and southern regions; slender sole was second in the central region. Bathymetrically, hornyhead turbot was second on the inner shelf, yellowchin sculpin on the middle shelf, and Pacific sanddab on the outer shelf. Yellowchin sculpin was also second in POTW areas; bay goby was second in non-POTW areas.

Biomass

Twenty-eight species together accounted for the top 95% of biomass in the survey (Table 6). Together, California halibut, Pacific sanddab, white croaker (*Genyonemus lineatus*), plainfin midshipman, Dover sole, and slender sole accounted for half of the total biomass.

Geographically, Pacific sanddab was the biomass dominant in the northern region and, California halibut in the central region (Table 7); in the south, Pacific sanddab accounted for the highest percentage of the total biomass, but California lizardfish had a higher mean biomass. California halibut was dominant on the inner shelf, white croaker on the middle shelf, and Pacific sanddab on the outer shelf. On the middle shelf, white croaker was biomass dominant in POTW areas (occurring almost entirely at one site), whereas California lizardfish was dominant in non-POTW areas.

Size (Length) Distribution

Fish ranged in size from 1.5 cm (midpoint of size class 2) to 104.5 cm (Figure 4). Most were small, with approximately 95% ranging from 2.5 to 18.5 cm in length. The modal size class of 6.5 cm comprised 10.3% of the catch. The length frequency distribution was skewed to the right and strongly truncated to the left at 3.5 cm. The smallest individuals (2 cm) included yellowchin sculpin, bay goby, and unidentified rockfish (*Sebastes* sp.), and the largest were a California halibut (104 cm), and a bat ray (*Myliobatis californica*) and Pacific angel shark (*Squatina californica*) (both 85 cm).

Species Distributions

Pacific Sanddab

Pacific sanddab is a middle and outer shelf species that occurred in 68% of the area and accounted for 22% of the

TABLE 4. Demersal fish species comprising 95% or more of the total fish abundance in the regional survey of the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

Species	No. of Individuals Mean/Haul*	No. of Individuals Total	Percent Total	Percent Cumulative
Pacific sanddab	34.8	4,125	21.8	21.8
plainfin midshipman	15.6	1,996	10.6	32.4
slender sole	11.5	1,569	8.3	40.7
yellowchin sculpin	8.2	1,079	5.7	46.4
speckled sanddab	8.9	1,067	5.6	52.0
Dover sole	7.8	961	5.1	57.1
longfin sanddab	6.3	776	4.1	61.2
stripetail rockfish	6.0	658	3.5	64.7
California tonguefish	3.5	584	3.1	67.8
splitnose rockfish	3.9	522	2.8	70.5
white croaker	2.3	510	2.7	73.2
bay goby	7.3	509	2.7	75.9
longspine combfish	6.0	481	2.5	78.4
pink seaperch	5.4	466	2.5	80.9
Pacific hake	2.8	398	2.1	83.0
shortspine combfish	2.3	316	1.7	84.7
northern anchovy	2.4	308	1.6	86.3
blackbelly eelpout	1.9	304	1.6	87.9
hornyhead turbot	1.7	221	1.2	89.1
bigmouth sole	1.8	203	1.1	90.2
blacktip poacher	1.5	191	1.0	91.2
English sole	1.7	186	1.0	92.2
halfbanded rockfish	1.8	172	0.9	93.1
California lizardfish	1.5	171	0.9	94.0
rex sole	1.1	143	0.8	94.7
Pacific argentine	1.3	136	0.7	95.4

Total abundance = 18,912 fish.
Total area = 3,075 km^2.
*Area-weighted mean.

fish abundance and 13% of the biomass (Figure 5; Tables 2, 4 and 6). By depth, it occurred in 50% or more of the stations at all depths greater than 50 m, occurring at 100% of the stations at all depths from 51 to 200 m, except 71-80 m and 141-150 m (Figure 5). Pacific sanddab occurred in 50% of the area of all subpopulations, except the central region and inner shelf zone (Table 3). It was the most common species in the northern and southern regions, middle shelf zone, and non-POTW areas. It was the numerical dominant in all subpopulations except the inner shelf and outer shelf zones (Table 5), and was among the top three biomass contributors in all but the inner shelf and central regions (Table 7). It accounted for 32% of the catch in the southern region (Table 5). Over 200 Pacific sanddab were taken at each of four 90-110 m trawls off San Diego and Orange County. Maximum biomass, greater than 6 kg, occurred at a station near Mugu Submarine Canyon off Ventura. Size distributions were strongly bimodal, with the primary mode at 5 cm and the secondary mode at 11 cm; most were less than 15 cm in length.

Plainfin Midshipman

Plainfin midshipman is a middle shelf species that occurred in 54% of the area, and accounted for 11% of the abundance and 7% of the biomass (Figure 6; Tables 2, 4 and 6). By depth, it occurred in 50% or more of the stations at all depths between 51 and 200 m, occurring at 100% of the stations at all depths from 91-160 m, except for 101-110 m and 141-150 m (Figure 6). It occurred in more than 50% of the area in all subpopulations except the central region and inner shelf zone (Table 3). In the southern and northern regions, it ranked second in abundance (Table 5). It ranked second in biomass in the southern region (Table 7). The largest catch (571 specimens) occurred off Oceanside. Over 150 were collected at two sites, in Santa Monica Bay and off Santa Barbara. Size distributions were weakly bimodal, with the primary mode at 10 cm and the secondary mode at 13 cm; most were less than 17 cm in length.

Dover Sole

Dover sole is a middle and outer shelf species that occurred in 57% of the area. It was the most common species on the outer shelf and second most common species in the northern region (Figure 7; Table 2). By depth, it occurred in 50% or more of the stations at all depths greater than 60 m and was found at 100% of the stations from 71 to 215 m, except for 81-90 m and 141-150 m (Figure 7). This species accounted for 5% of the total abundance and biomass (Tables 4 and 6). It occurred in more than 50% of the area in all subpopulations, except the central region and inner shelf zone (Table 3). Exceptionally large numbers (136 fish weighing 6 kg) were taken at a 162 m station offshore of the Orange County outfall. The length frequency distribution was slightly bimodal, with modes at 7 and 12 cm; most were less than 27 cm.

Slender Sole

Slender sole is an outer shelf species that occurred in 30% of the area and was tied with shortspine combfish and Pacific sanddab for second most common species in the outer shelf zone (Figure 8; Tables 2 and 3). By depth, it occurred in 50% or more of the stations at all depths greater than 110 m, being found at 100% of the stations from 131 to 215 m, except for 141-150 m and 161-170 m (Figure 8). Overall, this species represented 8% of the catch and 5% of the biomass (Tables 4 and 6). It was the most abundant species in the outer shelf zone (Table 5).

TABLE 5. Demersal fish species comprising 80% or more of the fish abundance by subpopulation on the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

	Abundance															
	Region						Shelf Depth Zone						Middle Shelf			
	Northern		Central		Southern		Inner		Middle		Outer		POTW		NPOTW	
Species	M	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%
Pacific sanddab	27	**20**	31	**16**	57	**32**	-	**-**	43	**28**	47	**19**	58	**27**	40	**28**
plainfin midshipman	13	**10**	11	**8**	27	**15**	-	**-**	11	**8**	43	**16**	19	**9**	9	**6**
slender sole	6	**6**	23	**13**	11	**6**	-	**-**	-	**-**	49	**19**	-	**-**	-	**-**
yellowchin sculpin	7	**4**	12	**10**	7	**2**	-	**-**	15	**12**	-	**-**	32	**15**	11	**8**
speckled sanddab	-	**-**	19	**9**	7	**4**	20	**41**	8	**5**	-	**-**	9	**4**	8	**5**
Dover sole	8	**6**	6	**4**	10	**6**	-	**-**	-	**-**	20	**8**	-	**-**	6	**4**
longfin sanddab	-	**-**	5	**4**	17	**8**	2	**5**	10	**8**	-	**-**	19	**9**	8	**6**
stripetail rockfish	7	**5**	4	**3**	7	**3**	-	**-**	-	**-**	13	**5**	-	**-**	-	**-**
California tonguefish	-	**-**	9	**7**	-	**-**	2	**4**	5	**6**	-	**-**	19	**9**	-	**-**
splitnose rockfish	-	**-**	-	**-**	13	**7**	-	**-**	-	**-**	17	**6**	-	**-**	-	**-**
white croaker	-	**-**	8	**7**	-	**-**	2	**4**	3	**5**	-	**-**	20	**9**	-	**-**
bay goby	12	**7**	-	**-**	-	**-**	-	**-**	13	**5**	-	**-**	-	**-**	15	**11**
longspine combfish	11	**6**	-	**-**	-	**-**	-	**-**	10	**4**	-	**-**	-	**-**	11	**8**
pink seaperch	9	**6**	-	**-**	-	**-**	3	**6**	8	**4**	-	**-**	-	**-**	9	**6**
northern anchovy	4	**5**	-	**-**	-	**-**	-	**-**	-	**-**	-	**-**	-	**-**	-	**-**
Pacific hake	3	**4**	-	**-**	-	**-**	-	**-**	-	**-**	13	**5**	-	**-**	-	**-**
shortspine combfish	3	**3**	-	**-**	-	**-**	-	**-**	-	**-**	10	**4**	-	**-**	-	**-**
blackbelly eelpout	-	**-**	3	**2**	-	**-**	-	**-**	-	**-**	-	**-**	-	**-**	-	**-**
hornyhead turbot	-	**-**	-	**-**	-	**-**	4	**7**	-	**-**	-	**-**	-	**-**	-	**-**
California halibut	-	**-**	-	**-**	-	**-**	3	**7**	-	**-**	-	**-**	-	**-**	-	**-**
California lizardfish	-	**-**	-	**-**	-	**-**	2	**4**	-	**-**	-	**-**	-	**-**	-	**-**
English sole	-	**-**	-	**-**	-	**-**	2	**4**	-	**-**	-	**-**	-	**-**	-	**-**

M = area-weighted mean; units — number of individuals/haul
"-" = Species absent or not included in the top 80%.
POTW = Publicly owned treatment work monitoring areas; NPOTW = non-POTW areas.
Total catch abundance (no. of individuals) by subpopulation: N = 6,131; C = 7,064; S = 5,717; IS = 1,515; MS = 9,271; OS = 8,126; P = 4,887; NP = 4,384; SCB = 18,912.

Over 200 slender sole, weighing more than 3.5 kg, were taken at each of three Santa Monica Bay sites. Size distributions were strongly bimodal, with the primary mode at 11 cm and a small secondary mode at 4 cm; most were less than 17 cm in length.

California Halibut

California halibut is an inner shelf species that was the most important contributor of biomass (14% of the total biomass, Figure 9, Table 6), although it occurred in only 16% of the area and was not numerically important (0.5%). By depth, it was found in 50% or more of the stations at depths from 11-40 m, occurring at 100% of the stations from 11 to 20 m (Figure 9). This species was typically collected on coarser sediments (<30% fines). At a 13 m site off Seal Beach, 37 halibut, weighing 22 kg total, were taken. A single specimen off the Orange County outfall was over 1 m in length and weighed 17.5 kg. Size distributions were bimodal, with modes at 26 and 32 cm; most were less than 36 cm.

White Croaker

White croaker is an inner shelf species that occurred in 4% of the area, and represented 3% of the total abundance and 8% of the biomass (Figure 10, Tables 4 and 6). By depth, this species was collected from 21-40 m and it occurred at 25% of the stations in the 21-30 m depth class (Figure 10). This species was rarely taken (6 occurrences) in the central region's inner and middle shelf. The largest catch (449 individuals weighing 43.5 kg) was from a 30 m station near the Orange County outfall. This catch was the largest biomass for a single species taken at any site in the survey. The second largest white croaker catch was 39 specimens (2 kg) at a station inside Long Beach Harbor; a few specimens were taken at 4 other sites (Figure 10). The size- frequency distribution was slightly bimodal, with modes at 17 and 12 cm; most were less than 22 cm in length.

Anomalies and Parasites

The prevalence of fish anomalies and parasites was low and incidences were scattered throughout the SCB (Figure

TABLE 6. Demersal fish species comprising 95% or more of the total fish biomass in the regional survey of the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

Species	Biomass (kg) Mean/Haul*	Biomass (kg) Total	Percent Total	Percent Cumulative
California halibut	0.55	81.6	13.5	13.5
Pacific sanddab	0.60	76.1	12.6	26.1
white croaker	0.20	46.5	7.7	33.8
plainfin midshipman	0.32	42.8	7.1	40.9
Dover sole	0.25	31.9	5.3	46.2
slender sole	0.22	29.6	4.9	51.1
longfin sanddab	0.24	29.5	4.9	55.9
California lizardfish	0.29	27.1	4.5	60.4
hornyhead turbot	0.21	26.3	4.4	64.8
English sole	0.23	25.6	4.2	69.0
California scorpionfish	0.20	19.3	3.2	72.2
stripetail rockfish	0.12	16.0	2.6	74.9
bigmouth sole	0.12	15.1	2.5	77.4
California skate	0.10	11.7	1.9	79.3
longspine combfish	0.13	11.2	1.9	81.1
fantail sole	0.09	10.8	1.8	82.9
greenblotched rockfish	0.05	9.3	1.5	84.5
California tonguefish	0.05	9.2	1.5	86.0
shortspine combfish	0.06	8.5	1.4	87.4
speckled sanddab	0.07	8.4	1.4	88.8
Pacific angel shark	0.09	5.8	1.0	89.8
pink seaperch	0.07	5.6	0.9	90.7
rex sole	0.03	5.4	0.9	91.6
spotted turbot	0.04	4.9	0.8	92.4
halfbanded rockfish	0.04	4.6	0.8	93.1
yellowchin sculpin	0.03	3.9	0.6	93.8
petrale sole	0.03	3.6	0.6	94.4
splitnose rockfish	0.03	3.6	0.6	95.0

Total biomass = 621.8 kg.
Total area = 3,075 km^2.
* Area-weighted mean.

11). Of the 18,912 fish and 87 species taken, 197 fish (1.0%) and 15 species (17%) had identified syndromes, including parasites (penellid eye copepods, *Phrixocephalus cincinnatus*; cymothoid isopods; and leeches), epidermal tumors, lesions, fin erosion, a skeletal deformity, albinism, ambicoloration, or diffuse pigmentation (Table 8). Pigmentation anomalies and parasites were most abundant. In the survey, 74 fish (mostly Dover sole) had diffuse pigmentation, 69 (mostly Pacific sanddab) had parasites, and 41 flatfish had ambicoloration. Ten Dover sole had epidermal tumors and seven fish had lesions, four hornyhead turbot had albinism, one Dover sole had fin erosion, and one spotted turbot (*Pleuronichthys ritteri*) had a skeletal deformity. Fish with lesions included three hornyhead turbot, and one each of Dover sole, California tonguefish (*Symphurus atricauda*), plainfin midshipman, and slender sole.

Anomalies were most prevalent in California halibut (26% of 102 individuals), Dover sole (8% of 961 individuals), and hornyhead turbot (8% of 221 individuals). Highest anomaly incidences occurred in Dover sole (75), and Pacific sanddab (47) and California halibut (26). Most afflicted species had a single type of anomaly; however, Dover sole, hornyhead turbot, and California tonguefish had five, four, and three anomaly types, respectively, and California halibut, spotted turbot, and rex sole each had two types. Nine individual fish had two types of anomalies, and typically at least one was a pigment anomaly; however, one Dover sole from the Santa Barbara Channel had an epidermal tumor and fin erosion.

External parasites were the most widely distributed anomaly, followed by diffuse pigmentation, and ambicoloration (Table 8, Figures 11 and 12). Parasites were found throughout the mainland shelf, often in San Pedro Bay and off Point Loma. The parasite was identified in 22 of 69 fish with parasites; one was a fish louse (*Elthusa* (=*Livoneca*) sp.) on a California lizardfish, and 21 were eye copepods (20 on Pacific sanddab and one on a bay goby).

Other anomalies were relatively rare (Table 8, Figure 11). Epidermal tumors occurred in Dover sole off Santa Barbara and Ventura, near Redondo Canyon, and off Mission Bay. Lesions occurred off the Santa Clara River, on the Palos Verdes Shelf, in San Pedro Bay, and off Point Loma. A skeletal deformity (an abnormal gill cover on the eyed side of the head) was found in a spotted turbot on the inner shelf near Long Beach Harbor.

DISCUSSION

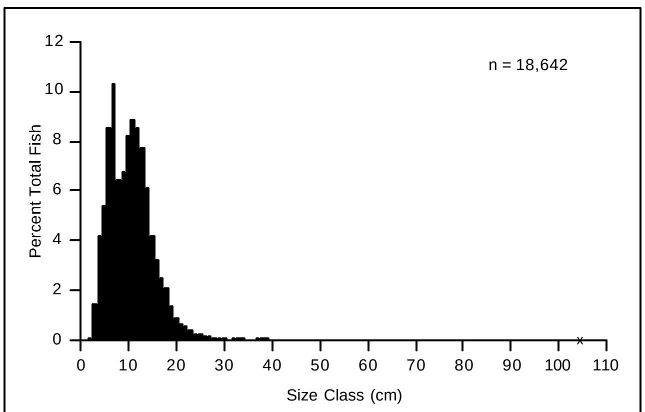
Some changes in the fish populations have occurred since the early 1970s. Although no earlier synoptic survey was conducted of the southern California mainland shelf (from 10 to 200 m), the species composition of fish populations on the shelf in 1994 can be compared to the most comprehensive regional study of this fauna in the past (i.e., Allen 1982). That study compiled trawl data collected during 1972-1973 (but not synoptically) by the same methods and over similar depths (but only within the central SCB). More fish species occurred in 50% of the stations in 1972-1973 (7) than in 1994 (5) (Table 2). In 1972-1973 Dover sole, Pacific sanddab, stripetail rockfish (*Sebastes saxicola*), plainfin midshipman, pink seaperch (*Zalembius rosaceus*), English sole (*Parophrys vetula (=Pleuronectes*

TABLE 7. Demersal fish species comprising 80% or more of the fish biomass by subpopulation on the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

	Biomass															
	Region						Shelf Depth Zone						Middle Shelf			
	Northern		Central		Southern		Inner		Middle		Outer		POTW		NPOTW	
Species	M	%	M	%	M	%	M	%	M	%	M	%	M	%	M	%
California halibut	0.11	**4**	1.71	**23**	0.15	**4**	2.11	**45**	0.15	**7**	-	-	0.86	**12**	-	-
Pacific sanddab	0.67	**21**	0.41	**6**	0.68	**16**	-	-	0.51	**12**	1.40	**21**	0.81	**11**	0.44	**12**
white croaker	-	-	0.72	**15**	-	-	-	-	0.32	**16**	-	-	1.89	**26**	-	-
plainfin midshipman	0.27	**9**	0.29	**4**	0.48	**10**	-	-	0.30	**4**	1.05	**15**	0.35	**5**	0.12	**3**
Dover sole	0.20	**6**	0.29	**5**	0.30	**6**	-	-	0.16	**3**	0.70	**12**	-	-	0.16	**4**
slender sole	0.13	**5**	0.39	**5**	0.23	**4**	-	-	-	-	0.96	**14**	-	-	-	-
longfin sanddab	0.10	**3**	0.23	**4**	0.55	**9**	0.16	**4**	0.36	**9**	-	-	0.66	**9**	0.30	**8**
California lizardfish	0.11	**3**	0.16	**3**	0.86	**9**	0.19	**4**	0.42	**7**	-	-	-	-	0.46	**12**
hornyhead turbot	0.10	**2**	0.50	**7**	0.12	**2**	0.45	**10**	0.19	**5**	-	-	0.34	**5**	0.16	**4**
English sole	0.35	**11**	-	-	-	-	0.28	**6**	0.20	**4**	0.23	**3**	0.20	**3**	0.20	**5**
California scorpionfish	-	-	0.16	**2**	0.64	**8**	0.14	**4**	0.30	**5**	-	-	0.21	**3**	0.31	**8**
stripetail rockfish	0.08	**3**	-	-	0.23	**4**	-	-	-	-	0.42	**7**	-	-	-	-
bigmouth sole	-	-	0.18	**3**	0.19	**3**	-	-	0.16	**4**	-	-	0.28	**4**	0.14	**4**
California skate	-	-	-	-	0.20	**3**	-	-	-	-	-	-	-	-	0.12	**3**
longspine combfish	0.23	**5**	-	-	-	-	-	-	0.22	**3**	-	-	-	-	0.24	**6**
fantail sole	-	-	0.17	**2**	-	-	0.24	**5**	-	-	-	-	-	-	-	-
Pacific angel shark	0.18	**3**	-	-	-	-	-	-	-	-	-	-	-	-	0.19	**5**
pink seaperch	0.13	**3**	-	-	-	-	-	-	-	-	-	-	-	-	0.13	**4**
shortspine combfish	0.07	**3**	-	-	-	-	-	-	-	-	0.27	**4**	-	-	-	-
California tonguefish	-	-	0.15	**3**	-	-	-	-	0.07	**3**	-	-	0.31	**4**	-	-
greenblotched rockfish	-	-	-	-	0.10	**2**	-	-	-	-	0.17	**4**	-	-	-	-
speckled sanddab	-	-	-	-	-	-	0.15	**3**	-	-	-	-	-	-	-	-
rex sole	-	-	-	-	-	-	-	-	-	-	0.15	**3**	-	-	-	-
bat ray	0.09	**2**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
splitnose rockfish	-	-	-	-	0.09	**2**	-	-	-	-	-	-	-	-	-	-

M = area-weighted mean; units — kilograms/haul.
"-" = Species absent or not included in the top 80%.
POTW = Publicly owned treatment work monitoring areas; NPOTW = non-POTW areas
Total catch biomass (kg) by subpopulation: N = 170.5; C = 301.8; S = 149.5; IS = 137.0;
MS = 277.1; OS = 207.7; P = 165.4; NP = 111.7; SCB = 621.8.

FIGURE 4. Length-frequency distribution of all fish collected by trawl on the mainland shelf of southern California at depths of 10-200 m, July-August 1994. n = number of fish measured; x = largest fish (size class 104). Numbers of samples by depth class are shown in Figure 1.



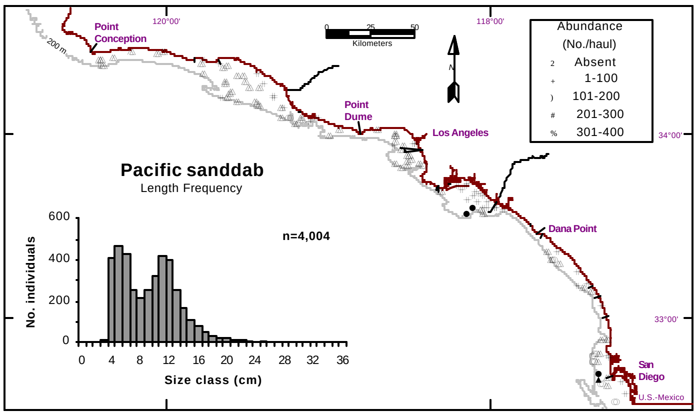
vetulus)), and yellowchin sculpin all occurred in more than half of the samples. In 1994, Pacific sanddab, Dover sole, plainfin midshipman, California lizardfish, and hornyhead turbot occurred in more than half the samples. Thus, stripetail rockfish, pink seaperch, English sole, and yellowchin sculpin became less common during the intervening two decades whereas California lizardfish and hornyhead turbot became more common.

Similarly, fewer fish species cumulatively accounted for 50% of the fish abundance in 1972-1973 (Allen 1982) than in 1994 (4 and 5, respectively (Table 4). In 1972-1973, these species were stripetail rockfish, Dover sole, speckled sanddab, and Pacific sanddab. In 1994, these species were Pacific sanddab, plainfin midshipman, slender sole, yellowchin sculpin, and speckled sanddab (Table 4). Hence, stripetail rockfish and Dover sole became relatively less abundant and plainfin midshipman, slender sole, and yellowchin sculpin more abundant during the intervening two decades.

Although the shifts in abundance and occurrence between the two periods are likely due at least in part to a

FIGURE 5. Distribution of Pacific sanddab (*Citharichthys sordidus*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.

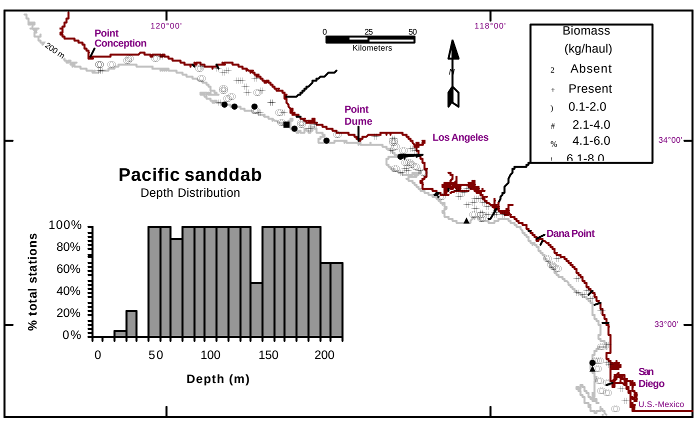
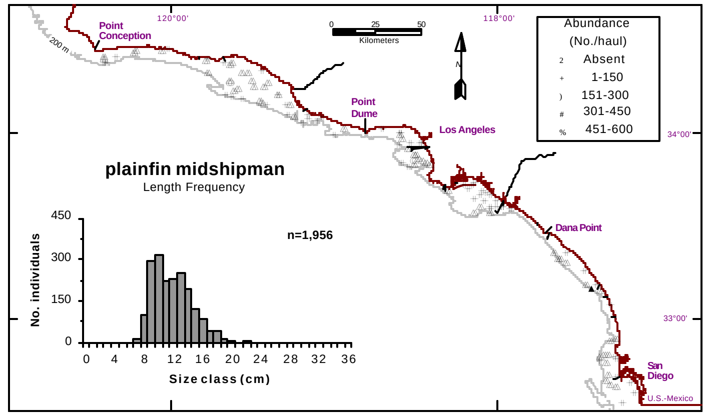
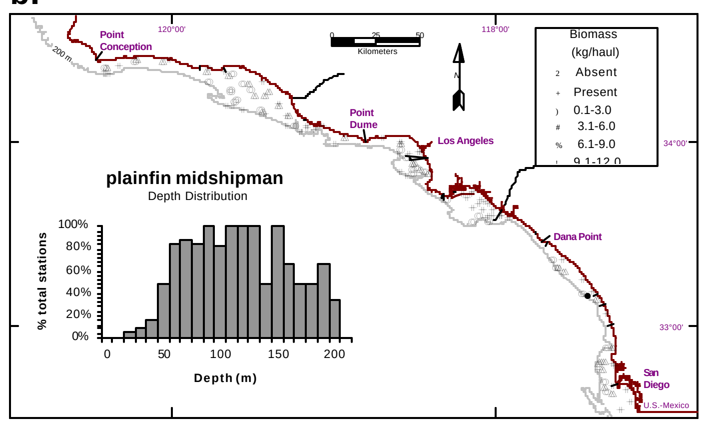


FIGURE 6. Distribution of plainfin midshipman (*Porichthys notatus*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.



warming of the oceanic environment during the 1980s (Smith 1995), a difference in the distribution of samples between the 1972-1973 and 1994 surveys may also play a role. Both data sets cover 10-200 m water depths; however, the 1972-1973 survey sampled only the central region (with many samples in POTW areas) whereas the 1994 survey also included northern and southern regions of the SCB mainland shelf and relatively fewer samples from POTW areas.

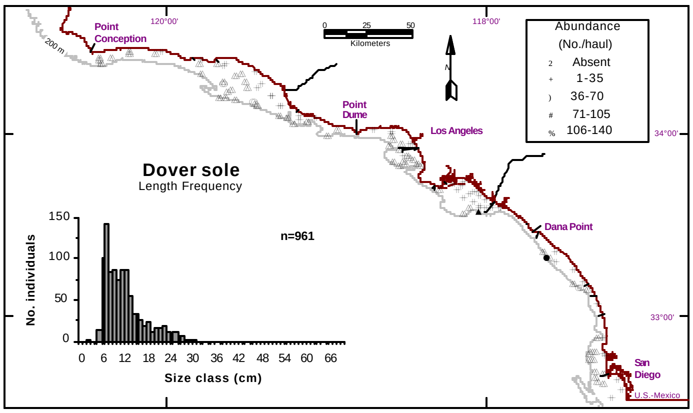
During the 1994 surveys, only 19 species (22% of the total) occurred in 20% or more of the area, suggesting that most of the species caught were rare. However, Allen (1982) found that a high proportion of the species on the soft-bottom habitat of the mainland shelf of southern California are either incidental to the habitat or region, or are inadequately sampled by trawl. Of 126 fish species collected in the early 1970s, 26% formed recurrent groups, 68% were incidental (being more commonly found in other habitats or biogeographic zones), and 6% were characteristic of the area but ineffectively sampled by trawl. A similar relationship continued to occur in 1994, as only 32% of the 87 species formed recurrent groups (Allen and Moore 1997). All species collected in 1994 had also been collected in previous trawl surveys of southern California.

Size (Length) Distributions

The length-frequency distribution of fish collected in the 1994 survey (Figure 4) was almost identical to that of the 1972-1973 survey (Allen 1982). In both surveys, fish ranged from 1.5 cm to approximately 1 m in length with modal sizes of 6.5 cm (but also 5.5 cm in the 1972-1973 survey). Ninety-five percent of the fish were between 2.5 to 18.5 cm in 1994 and between 3.5 to 21.5 cm in 1972-1973. The strong truncation of the distributions at 2.5 to 3.5 cm

FIGURE 7. Distribution of Dover sole (*Microstomus pacificus*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.

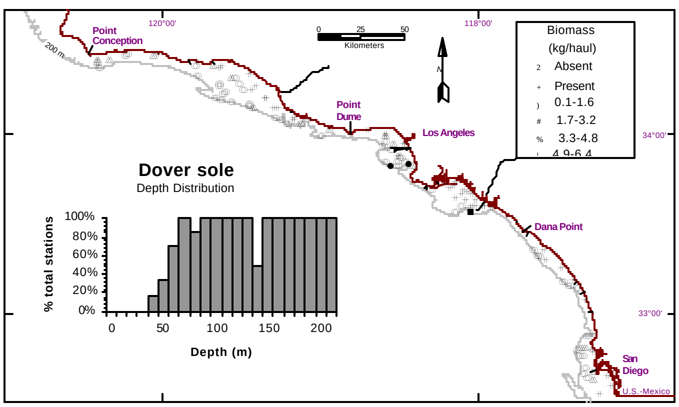
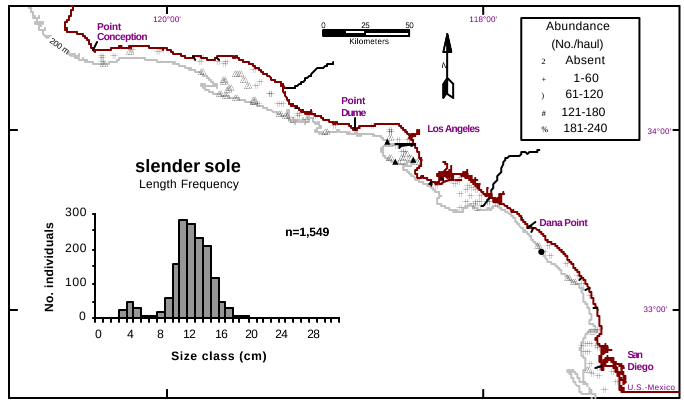
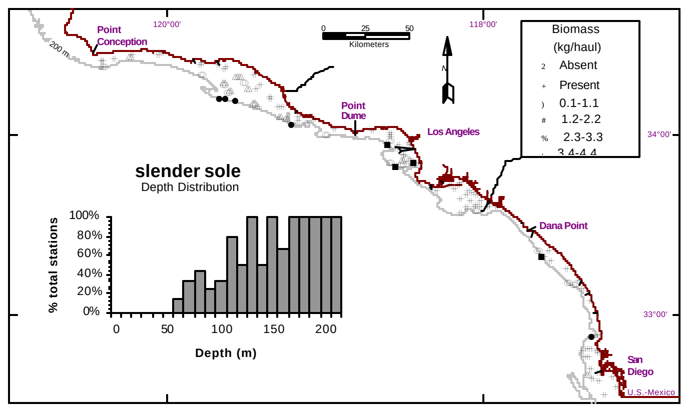


FIGURE 8. Distribution of slender sole (*Lyopsetta (=Eopsetta) exilis*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.



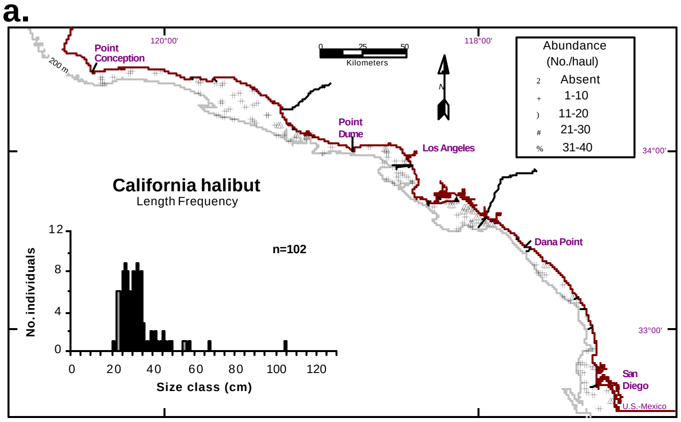
probably reflects both a net-related sampling bias (due to the 1.25 cm cod-end mesh) and the size at which many species recruit to the bottom. The skewness to the right of the distributions was probably due to increased net avoidance and decreased density of larger fish (Allen 1982). Based upon information on the growth rates of the most abundant species, it can be assumed that most of the fish collected were juveniles. Depending upon the species, this result may be due to sampling bias from net size and type (in which case, mature adults live in the area but escaped the net) or because the study area represents a nursery area for the species (and the adult lives in a non-sampled habitat or depth) (Allen and Mearns 1977). The adults would include species with small maximum sizes (e.g., yellowchin sculpin and speckled sanddab).

Pacific sanddab has a pelagic larval stage that lasts several months before the fish transforms into a juvenile and settle to the bottom at approximately 2.5-4.0 cm (Moser and Sumida 1996). Pacific sanddab matures at approximately 19 cm (3 years) (Hart 1973). It is 10 cm at 1 year and 15 cm at 2 years. Hence, almost all of the fish taken were juveniles (Figure 5). The primary mode at 5 cm represents Age 0 fish and the secondary mode at 11 cm represents Age 1 fish. Few Age 2 fish were collected and even fewer Age 3 fish were collected (which may have been mature).

Plainfin midshipman has demersal young that detach from sessile eggs and settle inshore near the nesting sites at 1.6 to 1.9 cm in length (Fitch and Lavenberg 1971, Watson 1996). This species lives 3 or 4 years (until they are approximately 18-20 cm long) and most probably die after spawning (Fitch and Lavenberg 1971). Plainfin midshipman may mature at 11 cm and 2 years (Love 1996); if so, then the bimodal distribution (Figure 6) with modes at 10 (Age 1)

FIGURE 9. Distribution of California halibut (*Paralichthys californicus*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.

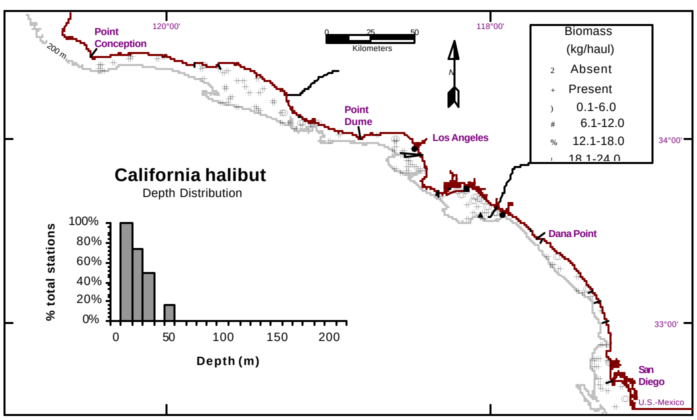
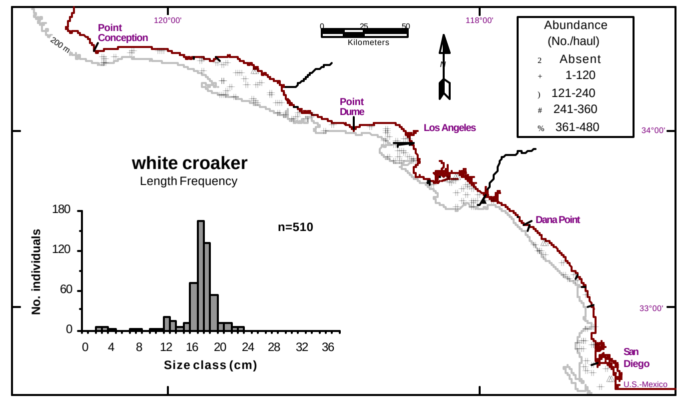
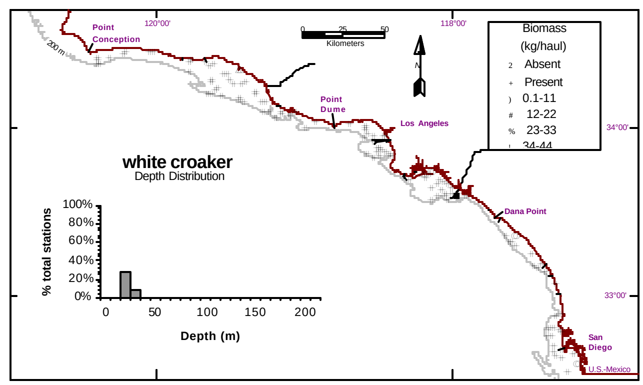


FIGURE 10. Distribution of white croaker (*Genyonemus lineatus*) on the mainland shelf of southern California at depths of 10-200 m, July-August 1994: (a) map of abundance with inset graph of length frequency distribution (x = maximum standard length); and (b) map of biomass with inset graph of frequency of occurrence by depth. Numbers of samples by depth class are shown in Figure 1. (X = maximum length of species).

a.



b.



and 13 cm (probably Age 2) suggest that both juveniles and adults were collected in this survey. However, if midshipmen do not mature until spawning and die after spawning, all fish were immature and the decrease in numbers in the upper tail of the distribution may reflect a movement of individuals inshore to spawning grounds at this size.

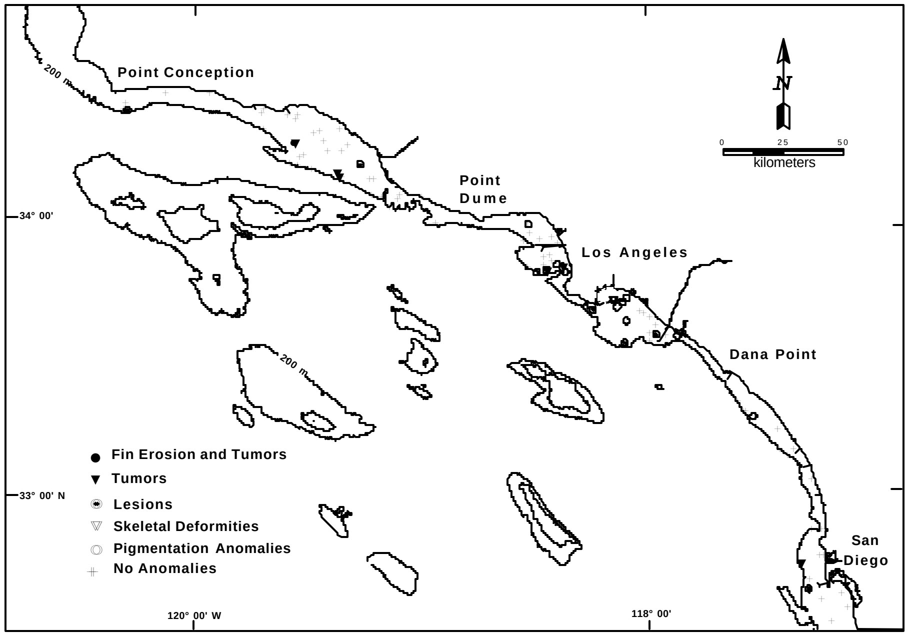
Dover sole has a prolonged pelagic larval stage which lasts 2 years (Markle *et al*. 1992) before settling to the bottom at 4-7 cm (Allen and Mearns 1976, Markle *et al*. 1992). As previous estimates for larval duration was 9 months, age estimates in the literature should be increased by 1 year (MBC 1990). Therefore, Dover sole mature at approximately 39-45 cm (Hart 1973) and 6 years (5 years in Fitch and Lavenberg (1971), corrected by +1 year). All Dover sole collected in this survey were juveniles (Figure 7). The primary mode at 7 cm probably represents Age 2 fish and the secondary mode at 12 cm probably represents Age 3 fish subpopulations. The truncation at 5 cm reflects the actual size of settlement to the bottom and hence susceptibility to being caught by otter trawl.

Slender sole has a long-lived pelagic larva that settles to the bottom at 1.5 to 2.5 cm in length (Charter and Moser 1996). This species matures at 15 cm and 3 years (Hart 1973, Love 1996). The primary mode in this survey was at 11 cm and only a few were above 15 cm (Figure 8). Hence, most of the fish were juveniles of Age 1 and Age 2. A small mode at 4 cm represents Age 0 fish, recently recruited from the plankton; this recruitment occurred primarily in the outer shelf of the central region.

California halibut has a short-lived pelagic larva that settles to the bottom at 0.8 to 0.9 cm in length (Ahlstrom *et al*. 1984, Allen 1990). This species matures at 20 to 43 cm (males 20 to 23 cm, females 38 to 43 cm) and 2 to 5 years (males 2 to 3 years, females 4 to 5 years) (Fitch 1965, Fitch and Lavenberg 1971, Haaker 1975, Allen 1990). The primary modes in this survey were at 26 cm and 32 cm, with only a few above 36 cm but one at 104 cm (Figure 9). Adjusting these standard lengths to total length (using an estimate of SL = 0.85 TL), these sizes would be 31, 38, 42, and 123 cm, respectively. These probably represent Ages 2, 3, 3, and >15, respectively (Pattison and McAllister 1990). No fish less than 20 cm was taken; fish of this size generally occur in estuaries and lagoons rather than on the open coast (Haaker 1975, Allen 1990).

White croaker has a short-lived pelagic larva that transforms to the juvenile stage at 1.7 cm in length (Moser 1996). This species matures at 14 to 15 cm and 1 to 4 years (Love *et al.* 1984, Moore 1998). The primary mode in this survey was at 17 cm, secondary at 12 cm, and only a few were above 22 cm (Figure 10). The primary mode represents 6-year-old fish and secondary mode represents 1-year-old fish; few fish are older than 10 years (Moore 1998). A small cluster at 2 to 3 cm represents Age 0 fish, recently recruited from the plankton; this recruitment occurred on the inner shelf of the central region.

FIGURE 11. Distribution of fish anomalies on the mainland shelf of southern California at depths of 10-200 m, July-August 1994. Numbers of samples by depth class are shown in Figure 1.



Anomalies

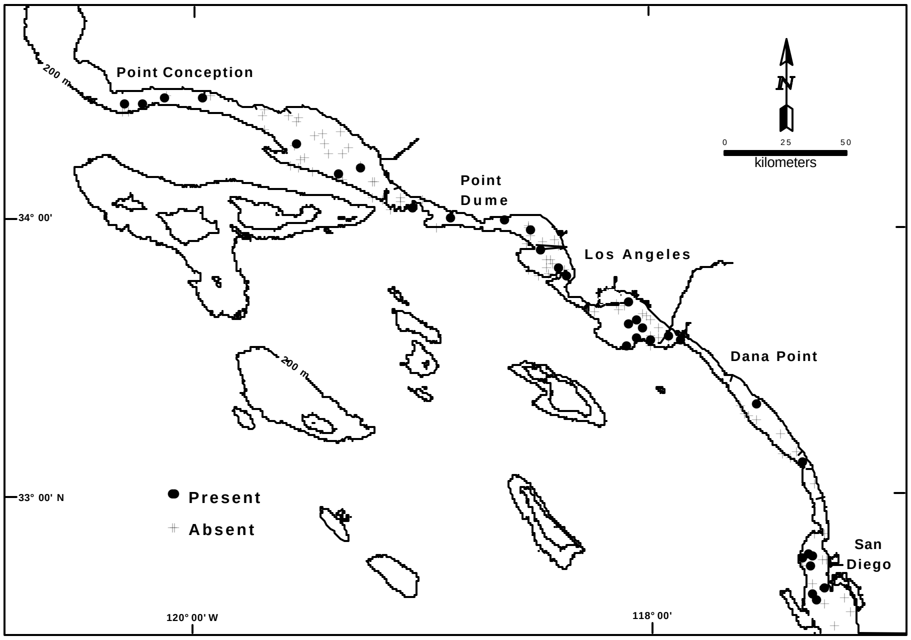
The low prevalence of anomalies (1.0%) in demersal fish from the SCB mainland shelf in 1994 was similar to background anomaly rates in mid-Atlantic (0.5%) and Gulf Coast (0.7%) estuaries (Fournie *et al.* 1996). Hence, it is likely that the anomaly levels in the 1994 survey represent background levels. However, the 1969-1976 SCB mainland

TABLE 8. Number of fish by species with different anomaly types collected in the regional survey of the mainland shelf of southern California at depths of 10-200 m, July-August 1994.

						Pigmentation			Total		
Species	Par.	Tum.	Les.	FE	SD	Alb.	Amb.	DP	Anom.	Fish	%Anom.
California halibut	5	-	-	-	-	-	22	-	26[a]	102	25.5
Dover sole	-	10	1	1	-	-	2	67	75[a]	961	7.8
hornyhead turbot	8	-	3	-	-	4	2	5	17	221	7.7
spotted turbot	-	-	-	-	1	-	3	-	3[a]	43	6.7
California skate	2	-	-	-	-	-	-	-	2	33	6.1
rex sole	-	-	-	-	-	-	1	5	5[a]	143	3.5
California tonguefish	-	-	1	-	-	-	10	2	13	584	2.2
fantail sole	-	-	-	-	-	-	1	-	1	64	1.6
bigmouth sole	3	-	-	-	-	-	-	-	3	203	1.5
Pacific sanddab	47	-	-	-	-	-	-	-	47	4,123	1.1
California lizardfish	1	-	-	-	-	-	-	-	1	171	0.6
speckled sanddab	2	-	-	-	-	-	-	-	2	1,067	0.2
bay goby	1	-	-	-	-	-	-	-	1	509	0.2
plainfin midshipman	-	-	1	-	-	-	-	-	1	1,996	0.1
slender sole	-	-	1	-	-	-	-	-	1	1,569	0.1
Total	69	10	7	1	1	4	41	74	197[a]	18,912[b]	1.0

[a]Total reflects number of fish with anomalies. Nine fish had two anomalies.
[b]Total of all fish in survey.
Alb. = Albinism; Amb. =Ambicoloration; Anom. = anomalous; DP = Diffuse Pigmentation;
FE = Fin Erosion; Les. = Lesion; Par. = Parasite; Skel. = Skeletal Deformity

FIGURE 12. Distribution of fish with external parasites on the mainland shelf of southern California at depths of 10-200 m, July-August 1994. Numbers of samples by depth class are shown in Figure 1.



shelf levels were higher (5%) (Mearns and Sherwood 1977). Thus, anomaly prevalence decreased by 80% between the 1970s and 1994.

Fin erosion was the most frequently observed anomaly, between 1972-1976 (Mearns and Sherwood 1977). It occurred in 33 species of fish on the shelf, with 60% of the species being flatfishes (Pleuronectidae, Paralichthyidae, and Cynoglossidae) and rockfishes. The disease was very prevalent on the Palos Verdes Shelf and was found at a low frequency in Santa Monica Bay, San Pedro Bay, and Dana Point. Approximately 39% of the Dover sole from the Palos Verdes Shelf and 30% of those from the SCB had fin erosion in 1972-1976. Fin erosion in Dover sole decreased as sediment contamination levels decreased between the early 1970s and the mid-1980s and was virtually absent on the Palos Verdes Shelf by 1990 (Stull 1995). In this 1994 survey, only 1 of 18,912 fish had fin erosion; this was a Dover sole from off Santa Barbara with an epidermal tumor. The fin erosion in this specimen did not have the dark edges found in fin erosion on the Palos Verdes Shelf in the 1970s.

Epidermal tumors occurred in 126 (1.4%) of 8,733 Dover sole collected from Santa Monica Bay to Point Loma, California, in 1972-1975 (Mearns and Sherwood 1977). Most of these individuals were less than 12 cm in length. Epidermal tumors (which are x-cell lesions thought to be caused by an amoebic parasite; Dawe *et al.* 1979) have been found in Dover sole from Point Arguello, California, to off Cedros Island, Baja California Sur, Mexico (Sherwood and Mearns 1976). The prevalence of epidermal tumors in Dover sole on the Palos Verdes Shelf decreased with increasing distance from the Whites Point outfall and also with time from 1971 to 1983 (Cross 1988). In 1994, epidermal tumors were found in 10 (1%) of 961 Dover sole from Santa Barbara to Mission Bay (Figure 11). This rate of occurrence probably represents the background prevalence for this disease in the SCB.

Ambicoloration has been found in bigmouth sole, California halibut, diamond turbot (*Pleuronichthys guttulatus (=Hypsopsetta guttulata)*), Dover sole, English sole, curlfin sole (*Pleuronichthys decurrens*), hornyhead turbot, and California tonguefish (*Symphurus atricauda*) (Haaker and Lane 1973, Mearns and Sherwood 1977). In 1994, this anomaly was found in California halibut, California tonguefish, spotted turbot, Dover sole, hornyhead turbot, rex sole, and fantail sole (Table 8). Diffuse pigmentation (noted in Dover sole in the 1970s; Mearns and Sherwood 1977) was found in Dover sole, rex sole, and California tonguefish in 1994 (Table 8).

The most common external parasite on demersal fish collected from 1969 to 1976 was the eye copepod (Mearns and Sherwood 1977). As in 1994, this parasite primarily infested Pacific sanddab and was widespread throughout the SCB. Although Mearns and Sherwood (1977) found a lower parasite prevalence on the Palos Verdes Shelf in the early 1970s (when that area was highly contaminated), its incidence was relatively high in fish collected from 1979 to 1994 (Perkins and Gartman 1997).

Oral papillomas and exophthalmos found in white croaker from 1969 to 1976 (Mearns and Sherwood 1977) were not found in 1994. However, lesions were found in seven fish, albinism in four fish, and a skeletal deformity in one fish. Regionwide, demersal fish populations were relatively healthy, with notable decreases in anomalies since the 1970s.

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