TECHNICAL REPORT

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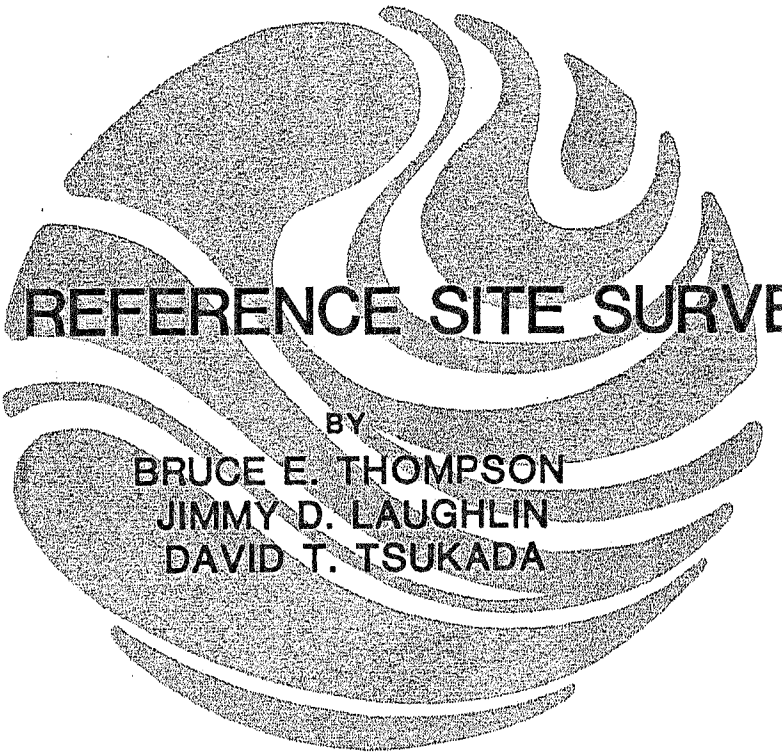

1985 REFERENCE SITE SURVEY

BY

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ERRATA

Please make the following corrections to the 1985 Reference Site Survey Report:

Page		
i	Paragraph 5	Change hepatopanreas to hepatopancreas.
ii	Paragraph 2	Change th to the.
iii	Change Acknowledgments to Acknowledgements.	
1	Paragraph 2	Change station to stations.
6	Paragraph 3	Change soluable to soluble.
9	Paragraph 2	Change Spio- phanes to Spio-phanes.
22	Paragraph 3	Change anlaysis to analysis.
49	Table 2	Units should be ng/wet g.
50	Table 3	Units should be ng/wet g; and change hexachlorodane to hexachlorobenzene.

SUMMARY

The purpose of the Reference Site Survey is to provide information on environmental conditions from the least contaminated areas on the southern California mainland shelf, and to evaluate changes in conditions at these sites from those reported in the 60-Meter Control Survey in 1977 (Word and Mearns, 1979). Thirteen of the 60-Meter Survey Sites were resampled, and additional reference sites were established at 30 and 150 m in each area, for a total of 38 sites. Grab samples were collected for sediment grain-size, organic material, trace metals, chlorinated and petroleum hydrocarbons, and infaunal analysis. Trawl samples were collected for characterization of megafaunal invertebrate and fish assemblages, and for analyses of tissue contamination and histopathology.

In the 1985 Reference Site Survey sediment types changed with depth from sandy-silt to silty-sand, and organic content increased with shelf depth. Silver (Ag) and Cd were measured in tens and hundreds of ppb (dry wt.) respectively and the other metals (Cr, Cu, Ni, Pb, and Zn) were measured in the tens of ppm range. Trace organic contaminants (total PAHs, total DDTs, and total PCBs) were measured in the tens of ppb (dry wt.) in sediments. In general, trace contaminants increased in concentration with shelf depth and in areas closer to Los Angeles.

Species composition and structure of infaunal assemblages of the mainland shelf were influenced mostly by depth and sediment type (grain-size and organic content). Mainland shelf assemblages at 30 and 60 m sites were dominated by the ophiuroid Amphiodia urtica and polychaete Spiophanes missionensis except in sandy areas where a much different fauna existed. Infaunal assemblages at the 150 m sites were dominated by the polychaete Spiophanes berkeleyorum and A. urtica. Differences in species composition and structure from the shallower sites reflected a transition to normal slope assemblages.

Trawl-caught megafaunal invertebrates were heterogeneously distributed on the mainland shelf. The asteroid Astropecten verrilli, the urchin Lytechinus pictus, and the prawn Sicyonia ingentis were the most common and abundant species collected. Similarly, trawl-caught epibenthic and demersal fish were heterogeneously distributed on the shelf. Speckled and Pacific sanddabs, bigmouth sole, and plainfin midshipman were the most common and abundant species collected. At 150 m, both megafaunal invertebrate and fish association showed differences in composition and structure compared with the shallower sites reflecting transitions to the slope fauna. The large amount of variation in the trawl data precluded showing significant trends.

Animal tissues in reference areas were contaminated with lower concentration of chlorinated hydrocarbons than animals collected near sewage outfalls. (For sewage outfall comparison, see Brown, et al., 1986). Livers of four species of flatfish averaged around 4.3 ppm (wet wt.) and hepatopanreas from Sicyonia averaged around 0.61 ppm (wet wt.) in chlorinated hydrocarbon contaminants.

Environmental conditions in the Reference Site Survey are similar to those observed in the 60-Meter Survey. Compared with other studies on the mainland shelf of the region, the Reference Site Survey showed similar trends in sediments an biological assemblages with depth. The reference sites sampled represent "normal" mainland shelf conditions, and may be the least contaminated coastal sites in the region.

ACKNOWLEDGEMENTS

This survey was a cooperative one from the beginning. The sampling design and parameters sampled were agreed upon by a committee of: Dr. John Dorsey, City of Los Angeles Hyperion Treatment Plant; Janet Stull, Los Angeles County Sanitation District; Susan Hamilton, City of San Diego, Pt. Loma Treatment Plant; Drs. Robert Smith and Brock Bernstein of EcoAnalysis, Inc., Ojai, CA; and Drs. David Brown and Jeff Cross of SCCWRP.

Field collection was coordinated and directed by Mr. Harold Stubbs of SCCWRP. Shiptime was provided by the City of Los Angeles (Marine Surveyor), and the City of San Diego (Monitor III), for which we are grateful. Thanks also to the skippers and crew of th R/V Westwind and R/V VanTuna. Providing shipboard assistance were: Dr. John Dorsey and Jim Roney, City of Los Angeles; Mike Moore, County Sanitation District of Orange County; and G. Patrick Hershelman, Dario Diehl, Jimmy Laughlin, and Karen Rosenthal of SCCWRP.

Analyses of the samples at SCCWRP were done by G. Patrick Hershelman, trace metals: Richard Gossett, Skip Westcott, and Chuck Ward, trace organics; Jimmy Laughlin, TVS; David Tsukada and G. Patrick Hershelman, sediment grain-size. Total organic carbon analyses were conducted by Global Geochemistry, Canoga Park, CA, and sediment grain-size values were verified by Susan Reynolds, Sedimentation Lab, USC. The taxonomists who identified the organisms collected during this survey are listed in Appendix 3.

The report has been reviewed and improved by Drs. John Dorsey, Robert Spies, Donald Reish, Jack Anderson, David Brown, Jeff Cross, Irwin Haydock, and Janet Stull, to whom we are grateful.

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INTRODUCTION

Changes in the marine coastal environment caused by wastewater discharge are evaluated best by comparisons to normal or reference conditions and natural fluctuations. These differences may be factored into assessments of discharge related changes (e.g. Bernstein and Zalinski, 1983). Additionally, far field dispersion and accumulation of contaminants in the southern California coastal region should be measured periodically to appraise general environmental quality.

SCCWRP provided control or reference data in 1977 when the 60-Meter Control Survey, with station from Pt. Conception to San Diego, was conducted by Word and Mearns (1979). Information from that survey has been widely used in evaluating effects of discharges into the region, (e.g., Tetra-Tech, 1980; Smith and Bernstein, 1985; Swartz et al., 1986).

The purpose of the Reference Site Survey is to update the 60-M Survey by resampling some of the 60 m sites and to provide reference values for additional parameters and depths not sampled in that earlier survey. This report lists and summarizes the data from the Reference Site Survey and evaluates changes in some of these parameters since the 60-M Survey in 1977.

Summary tables and figures are included in the text of the report and raw data is included in Appendix 5.

METHODS

Thirteen of the 60-M Survey sites were selected for this study. Sites were selected based on the designation of "control" sites by Word and Mearns (1979) and on separate analysis of the infauna of the 60-M Survey data (Smith and Bernstein, 1985). In addition to the 60 m sites, sites at 30 and 150 m were sampled creating cross-shelf transects in each area (Fig. 1). A total of 38 sites were sampled; Station R61-30 off La Jolla was abandoned since it was located in a kelp bed. Sampling was conducted Aug.-Oct., 1985 using 4 different ships (station location, sampling dates, and ships used are listed in Appendix 1).

Water column temperature and dissolved oxygen (D.O.) were measured at each site. Temperature was measured using a bathythermograph and was corrected to surface water temperatures measured with a thermometer. D.O. samples were collected at 3 depths: surface, thermocline (if present), and near bottom (1-14 m) using a Niskin-type sampler, and analyzed by Winkler titration.

A sampling design using single samples at each site was chosen to maximize areal coverage and to survey as many sites as possible (Cuff and Coleman, 1979). Two grab samples were collected at each site; one for infauna and one for sediment analyses.

The grabs were taken with a 0.10 m^2 chain-rigged Van Veen grab. For sediment analyses, subsamples were taken from the grab sample: one for trace metals, grain-size, and organic material, and the second for chlorinated and petroleum hydrocarbons. To collect the subsamples, 5 small subcores were taken from the top 2 cm of the sample using an open barreled syringe (26 mm dia.), composited, and immediately frozen (see Appendix 2A-C for details of analysis).

Seven trace metals (Ag, Cd, Cr, Cu, Ni, Pb, Zn) were measured in each sample using atomic absorption spectrophotometry (see Appendix 2D, for methods of analysis). Concentrations of 38 organic contaminants (Table 1) were also measured (see Appendix 2E for methods of analysis). Many of the components measured are included on the EPA list of priority pollutants.

Macrobenthic infauna were collected from the Van Veen grab sample by sieving through on a 1.0 mm screen. The animals and debris were fixed in 10% borax buffered formalin in sea water. Upon return to the laboratory, the samples were transferred to 70% ethanol for preservation, sorted to major taxa and identified to the lowest taxon practical (see Appendix 3 for listing of taxonomists).

Megafaunal invertebrates and fishes were collected at each site using a 25 ft. otter trawl; trawl dimensions and configuration are as described by Word and Mearns (1979). Trawls were made along the depth contours for 10 min. (estimated time on bottom) and at a speed of 2 kts using a scope of between 2.5:1 and 4.5:1, covering an estimated 0.5 km along the bottom. All organisms collected in the trawls were identified and counted. Total biomass (wet weight) and biomass of the most abundant species were measured. Size-frequency measurements were made of the species used for tissue chemistry and histopathology analysis.

Samples for tissue contaminant analysis and histopathology were collected from live, healthy specimens of ridgeback prawns, (Sicyonia), and from 1 of 4 flatfish species--Pacific sanddab (Citharichthys soridus), longfin sanddab (Citharichthys xanthostigma), gulf sanddab (Citharichthys fragilis), or Dover sole (Microstomus pacificus)--depending on availability at each site. These samples were collected from the 60 and 150 m sites only. They were dissected in a "clean area" set up in the lounge or galley of the vessel to

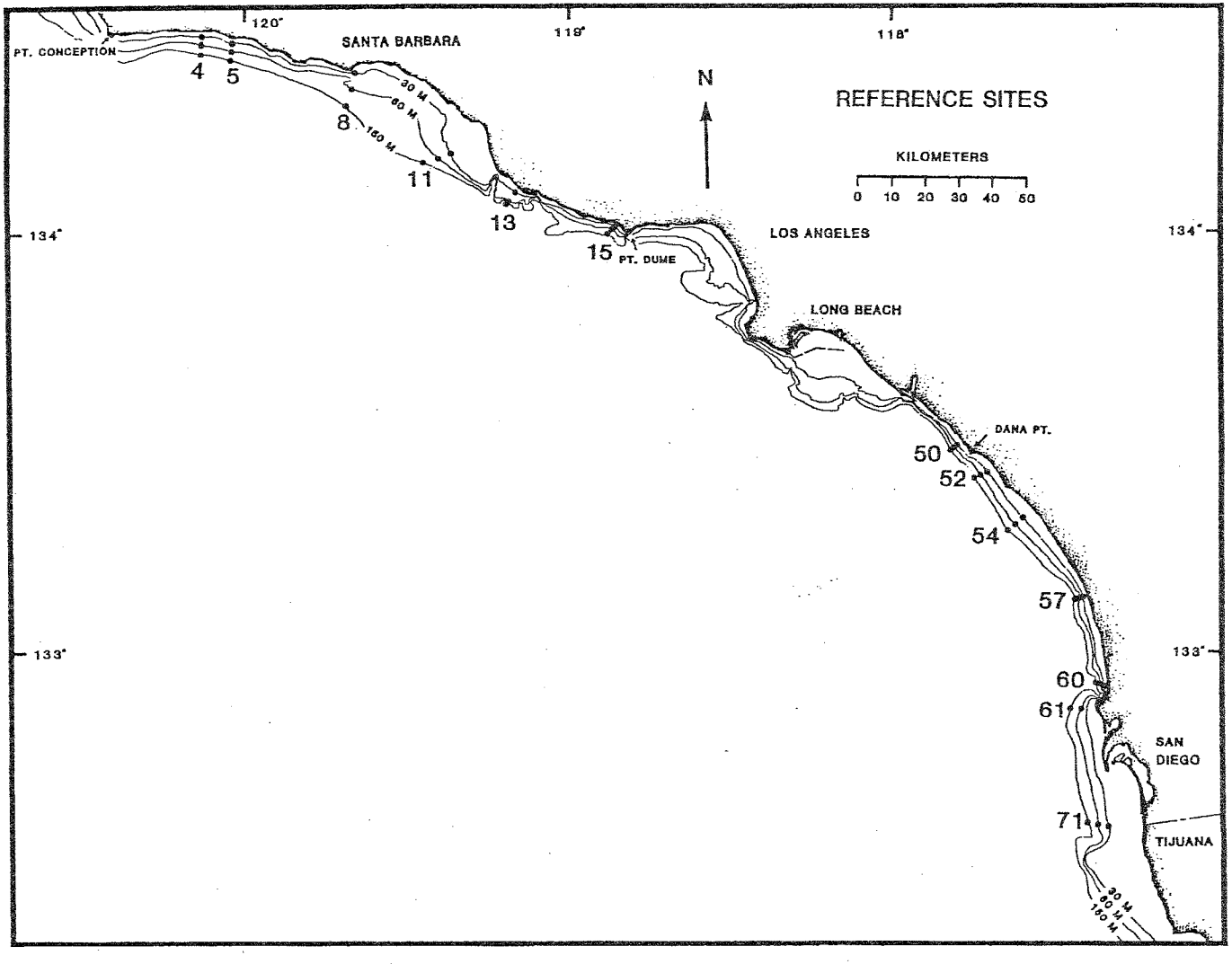

Fig. 1 Chart of the southern California coastal shelf showing Reference site sampling locations. Station numbers are those used in the 60-M survey (Word and Mearns, 1979).

Table 1. Organic compounds measured in sediments and tissues, and their detection limits for sediment samples.

Organic Compound	Detection Limit Range for Sediments (ng/dry g [ppb])
1. Chlorinated hydrocarbons	
p,p'-DDE	<1
o,p'-DDE	1-18
p,p'-DDD	1-4
o,p'-DDD*	1-2
p,p'-DDT	1-6
o,p'-DDT	1-3
Aroclor 1242	3-40
Aroclor 1254	4-47
Lindane*	1-2
Hexachlorobenzene	1-2
2. Polynuclear aromatic hydrocarbons (PAH's)	
Naphthalene*	3-34
1-methylnaphthalene*	3-36
2-methylnaphthalene*	3-28
2,6-dimethylnaphthalene*	5-49
1,3-dimethylnaphthalene*	4-30
1,6-dimethylnaphthalene*	8-72
2,3-dimethylnaphthalene*	3-17
1,4-dimethylnaphthalene*	12-93
1,2-dimethylnaphthalene*	12-57
2,3,6-trimethylnaphthalene*	5-49
2,3,5-trimethylnaphthalene*	9-74
Biphenyl*	3-6
Acenaphthylene*	3-36
Acenaphthene*	6-28
Fluorene*	4-57
Dibenzothiophene*	13-40
Phenanthrene*	3-30
Anthracene*	1-15
Fluoranthene	1-17
Pyrene	1-17
2,3-benzofluornene*	4-40
Benz(a)anthracene	2-19
Chrysene/Triphenylene	1-17
Benzofluoranthenes	<3
Benzo(a)pyrene	1-15
Perylene	1-15
9,10-diphenylanthracene*	1-13
Dibenz (a,h)anthracene*	3-19

*below given detection limits in all reference site sediment samples.

minimize contamination from diesel exhaust and other sources. Tissues from 2-30 specimens at each site were composited for tissue chemistry analysis (Appendix 4). The composites were split into 2 subsamples: one for trace metals and one for chlorinated and petroleum hydrocarbons (same compounds as in sediment analysis, Table 1). These subsamples were then frozen until analyzed.

Detection limits for the organic contaminants in the sediment samples (Table 1) were dependent on the contaminant measured, the sample size extracted, and equipment sensitivity. For sediment samples with values below detection limits, a value equal to one-half the detection limit value was used in statistical analysis. Detection limits for trace metals in sediments are listed in Appendix 2D.

Analysis has not been completed for trace metals or PAHs in tissues, or histopathology. These data will be reported in an Addendum to this report when analyses are complete.

Species abundance data from grabs and trawls were analyzed using several multivariate methods. Classification analysis was used to determine which sites had similar species and abundances, and weighted discriminant analysis was used to evaluate the relationships between sediment parameters and infaunal assemblages (see Appendix 2F for summary of analytical method).

Three indices of community structure, species diversity H' (Shannon and Weaver, 1949), evenness J (Pielou, 1966), and dominance C (Simpson, 1949), were calculated for grab infauna, trawl-caught megafaunal invertebrates, and fish. The latter 2 indices are scaled between 0 and 1.0 where values of 1 indicate perfect evenness (all species equally abundant) and complete dominance respectively.

The Reference Site Survey and the 60-M Survey used similar methods of sampling and collecting; Van Veen grabs and 25 ft. otter trawls were used. However, some methods of analysis (TVS, sand, PCBs, DDTs, and taxonomy) have changed and are detailed in the appropriate sections of Appendices 2 and 3.

An additional sediment chemistry sample and infaunal grab sample were collected and archived from each site. These archived samples as well as the specimens and computerized forms of the data reported herein are stored at SCCWRP.

RESULTS

1. Bottom Temperature and Dissolved Oxygen

Water temperatures and dissolved oxygen concentrations were taken for several water column depths at each site; however, only near-bottom (taken at 1-14 m above the bottom) values are reported here.

Near bottom temperatures in the August to October sampling period ranged from 9°C at two 150 m sites, to 17°C at Station R4-30, nearest Point Conception. Temperatures decreased with depth; mean temperature was 13.5°C for 30 m sites and 10.6°C for 150 m sites (Table 2). Near bottom dissolved oxygen concentrations also decreased with depth, with a mean of 8.1 mg/l at the 30 m sites and 4.7 mg/l at the 150 m sites (Table 2). Near bottom temperatures and D.O. concentrations at each reference site are plotted on Appendix 5, Figs. 1 and 2.

Table 2. a. Means (std. dev.) for sediment parameters measured in the Reference Site Survey, on a dry wt. basis.
b. Means (std. dev.) for sediment trace organics expressed on a TOC wt. basis.

2a.		30m (n=12)		60m (n=13)		150m (n=13)	
I.	Sediment Quality (percent dry wt.)						
	Sand	63.1	(27.3)	37.0	(28.0)*	37.2	(25.1)
	Silt	32.5	(26.0)	53.4	(25.7)	49.8	(18.8)
	Clay	4.4	(2.1)	9.6	(3.3)*	13.0	(7.7)
	Dry/Wet	69.3	(2.9)	64.4	(5.8)	61.5	(7.7)
	TVS	2.4	(1.0)	3.9	(1.0)*	4.5	(1.6)
	TOC	0.52	(0.38)	0.72	(0.22)*	0.85	(0.33)
	Lipid	0.34	(0.26)	0.19	(0.26)	0.26	(0.36)
II.	Trace Metals (µg/dry g [ppm])						
	Ag	0.01	(0.01)	0.03	(0.04)	0.04	(0.05)
	Cd	0.13	(0.11)	0.14	(0.09)	0.23	(0.11)
	Cr	18.5	(5.6)	25.4	(9.3)	31.1	(11.9)
	Cu	5.7	(2.5)	10.4	(5.7)	13.1	(7.9)
	Ni	9.0	(5.0)	12.9	(6.5)	13.6	(6.3)
	Pb	2.9	(1.3)	4.8	(2.6)	5.5	(3.0)
	Zn	31.1	(12.0)	48.0	(19.5)	52.3	(23.8)
III.	Trace Organics (ng/dry g [ppb])						
	PAHs	38.7	(55.1)	20.3	(33.9)	36.9	(48.3)
	DDTs	9.1	(8.0)	18.9	(19.8)	30.1	(26.7)
	PCBs	10.8	(17.0)	19.2	(10.4)	22.5	(18.3)

2b.	Trace Organics (ng/dry g C [ppb])						
	PAHs	8365	(12630)	3861	(5846)	3885	(4446)
	DDTs	1762	(1589)	2773	(2385)	3861	(3543)
	PCBs	1857	(1228)	3597	(3056)	3114	(3008)

*excluding Stas. R71-60 & R60-60, due to high sand content.

2. Sediment Grain-size and Chemistry

A. Grain-size and organic material. The distributions of sand (>62µm), silt (4-62µm), and clay (<4µm) fractions of the sediment at each reference site are shown in Appendix 5, Figs. 3-5; mean values for each depth are reported on Table 2. Sediment texture became finer, percent sand decreased and percent clay increased, with depth. Several of the southern reference sites, Stations R60-60, R71-30, R71-60 had much sandier sediment (>90% sand) than the other sites at similar depths and represent localized sandy intrusions into deeper water.

Two measures of organic material, total volatile solids (TVS) and total organic carbon (TOC) decreased with depth, but a third measure of organic material, lipid content, showed no obvious trend with depth (Table 2). Values of these parameters at each reference site are plotted on Appendix 5, Figs. 7-9.

All grain-size and organic material parameters except percent silt and percent lipid were significantly correlated with depth (Table 3). TVS was more highly correlated to the sediment grain-size measures than was TOC, but both measures of organic material were significantly correlated with grain-size, and with each other (Figs 2, 3). TOC accounts for about 20% of the organic material in sediments. Lipids contributed from 26 to 65% of the TOC, but these parameters were not significantly correlated. The correlation between percent lipid and TOC was not improved using log-transformed values of either or both variables.

B. Trace Metals. Concentrations of Ag, Cd, Cr, Cu, Ni, Pb, Zn in the sediment increased with depth (Table 2). The values of each trace metal at each reference site are listed in Appendix 5, Figs. 10-16. Concentrations of Ag and Cd were one to two orders of magnitude lower

Table 3. Pearson product-moment correlation matrix for Reference Site Survey sediments. Correlation coefficients for A. sediment type, and B. contaminant concentrations.

A.	Depth	% Sand	% Silt	% Clay	Dry/Wet	% TVS	% TOC	% Lipid	bottom Temp.	bottom D.O.
Depth	-	-.32*	.24	.55*	-.44*	.52*	.39*	-.05	-.58*	-.83*
% Sand		-	-.99*	-.75*	.81*	-.78*	-.64*	-.11	.39*	.32*
% Silt			-	.64*	-.72*	.69*	.56*	.08	-.37*	-.23
% Clay				-	-.95*	.93*	.81*	.21	-.36*	-.58*
% Dry/wet					-	-.94*	-.84*	-.18	-.30	-.50*
% TVS						-	.89*	.16	-.37*	-.53*
% TOC							-	.23	-.15	-.42*
% Lipid								-	.16	.05
bottom Temp.									-	.61*
bottom D.O.										-

	Trace Metals							Organic Hydrocarbons		
B.	Ag	Cd	Cr	Cu	Ni	Pb	Zn	PAHs	DDTs	PCBs
Depth	.33*	.41*	.46*	.42*	.13	.35*	.36*	.04	0.40*	0.27
% Sand	-.15	-.24	-.59*	-.81*	-.49*	-.63*	-.79*	-.22	-.21	-.15
% Silt	.11	.17	.50*	.73*	.42*	.55*	.70*	.22	.17	.12
% Clay	.26	.45*	.79*	.91*	.64*	.76*	.89*	.13	.29	.26
%Dry/Wet	-.18	-.38*	-.80*	-.93*	-.62*	-.72*	-.90*	-.14	-.26	-.18
% TVS	.24	.51*	.78*	.85*	.66*	.71*	.87*	.19	.30	.25
% TOC	.18	.56*	.77*	.72*	.69*	.63*	.75*	.24	.36*	.40*
% Lipid	-.16	-.03	.06	.16	-.02	-.05	.10	-.22	-.17	-.09
Temp.	-.19	-.20	-.30	-.37*	-.27	-.32*	-.37*	-.21	-.21	-.01
D.O.	-.32*	-.43*	-.59*	-.46*	-.42*	-.50*	-.48*	-.10	-.47*	-.28

* > 0.312 is significant, α=0.05, n=38.

than the other metals. Silver concentrations were particularly low; they were below detection limits at 76% of the sites.

All metals except for Ni were significantly, positively correlated with depth (Table 3). All metals were more highly correlated, usually significantly, with percent clay than with percent silt or percent sand. All metals except Ag were significantly, positively correlated with TVS and TOC, but none were significantly correlated with percent lipid.

C. Chlorinated and petroleum hydrocarbons. Concentrations of 23 of the 38 organic contaminants measured in the sediment samples were below detection limits at all reference sites (Table 1). Of the compounds detected, p,p' DDE contributed most to total DDTs at most sites (Appendix 5, Table 1). Total PCBs (Aroclor 1242 and 1254) were below detection limits at 39% of the sites. Total PAHs were below detection limits at 61% of the sites, but the lower molecular weight alkyl naphthalenes were below detection limits at all sites; because they are more soluable than the higher molecular weight compounds they were not expected to be measured in sediments.

The types of PAHs measured were generally different at each site; perylene was detected at 9 sites and flouranthene, pyrene, chrysene/triphenylene, benzo-flouranthenes, and benzo(a)pyrene were detected at 6-7 sites each. Benzo-flouranthenes were measured in the highest concentrations, 30-70 ppb, at sites R8, R15 and R50. Reference sites farthest from the metropolitan Los Angeles area generally contained only 1 or 2 PAH compounds (except Station R8-150), but reference sites closest to Los Angeles contained much more complex mixtures (4-6 compounds) of PAH's, especially at Stations R15-30, R60, and R150. At the northernmost sites (R4 and R5), the only PAH detected was perylene. The distribution of total DDTs, PCBs and PAHs at the reference sites are shown in Appendix 5, Figs. 17-19.

Total DDTs and PCBs were highest to the north of the greater Los Angeles area (R13-150, R15-60, and R-150) and lowest at the southern-most 30 m sites. Total PAHs

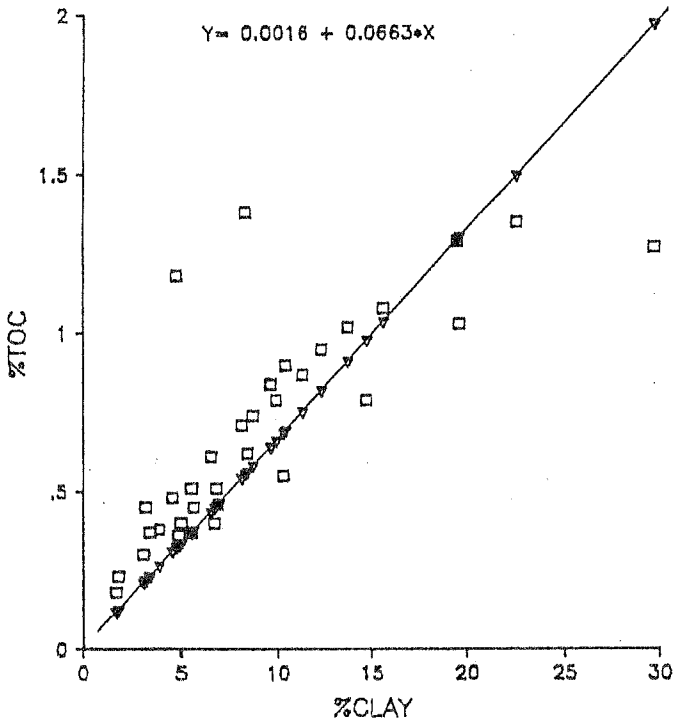

Fig. 2 Relationship between % clay and % total organic carbon (TOC) in sediments at all 38 sites. These two parameters were highly significantly correlated ($r=0.81$, $\alpha=0.05$). The regression equation for predicting % TOC given a % clay value is shown. □ = 30 m sites; ▽ = 60 m sites; ▼ = 150 m sites.

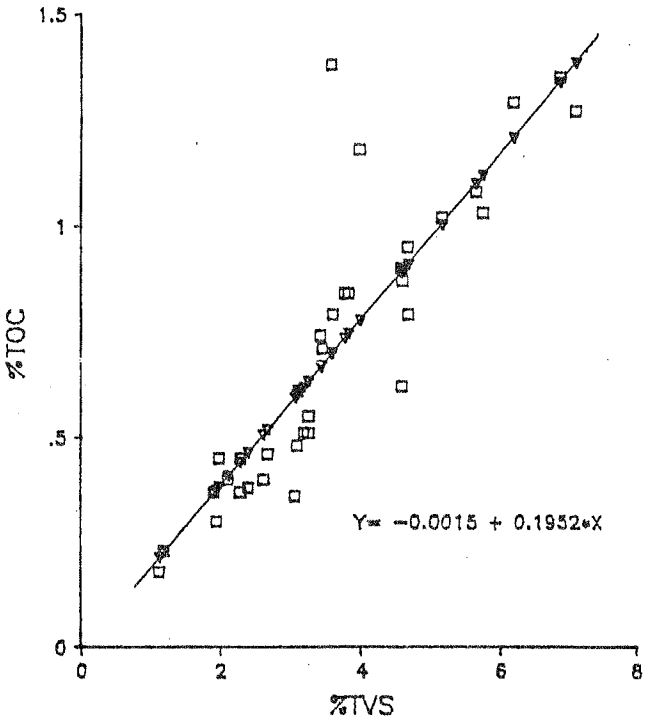

Fig. 3 Relationship between % total volatile solids (TVS) and % total organic carbon (TOC) in sediments at all 38 sites. These two measures of organic material were highly significantly correlated ($r=0.89$, $\alpha=0.05$). The regression equation for predicting TOC given a TVS value is shown. Symbols same as for Fig. 2.

were highest at the sites nearest to Los Angeles, but several sites to the north and south also contained concentrations greater than 100 ppb. Both total DDTs and total PCBs concentrations increased over depth, but total PAHs showed no trend over depth (Table 2). Standardization of trace organic compounds to organic carbon weights (mg/g C) produced values two orders-of-magnitude higher than those expressed on a dry basis (Table 2b). Additionally, the trends over depth shown when expressed as dry wt. were changed. When standardized, PAHs were about 1/2 as high at the 60 and 150 m sites as at the 30 m sites, and PCBs became similar at the deepest sites. Of the organic contaminants measured only DDTs were significantly positively correlated with depth (Table 3). DDTs and PCBs were significantly positively correlated with TOC but not with lipids, and PAHs did not correlate significantly with any parameter.

3. Biological Communities

A. Infaunal invertebrates.

Species composition. Classification analysis produced 3 major site groupings based on species composition and abundances (Fig. 4). The lower main branch of the dendrogram includes the 150 m sites and the upper main branch includes the 30 and 60 m sites. Within the upper main branch, the 30 and 60 m sites are generally separated into secondary branches. These main depth divisions are arbitrarily termed site groups 1, 2, and 3. Within these site groups the northern and southern sites are generally grouped together and are given subgroup designations (i.e., 1a, 1b, etc.).

Groups 1a and 1b represent mainland shelf 30 m assemblages, however, two small subgroups of group 1 (groups 1c, 1d) are different. Group 1c includes 2 sites, R60-60 and R71-30, and group 1d is a single site, R71-60. These three sites had much coarser sediment than the other sites which is reflected in their species composition.

The distributions of the infaunal site groups (assemblages) are shown on Fig. 5. In each of the 30 m site groups (1a, 1b, 1c), different species were most abundant (Table 4). The distribution of Spiophanes missionensis, the most abundant species in group 1b, is shown in Appendix 5, Fig. 24. This species was significantly more abundant, on the average, at the 30 and 60 m sites than at the deeper stations (Fig. 6). The ophiuroid Amphiodia urtica was the most abundant species in group 1a, but none were collected in the group 1c or 1d sites. Group 1c sites were inhabited by many species not collected at the group 1a or 1b sites. The most abundant species collected at (R71-30) was the pelecypod Parvilucina tenuisculpta.

At the 60 m sites (groups 2a, 2b) the most abundant species was A. urtica (Table 4). The distribution of this species at the reference sites is shown in Appendix 5, Fig. 23. It was significantly more abundant at the 60 m sites than at the 30 or 150 m sites (Fig. 6). S. missionensis was also among the most abundant species at the 60 m sites. Stations R60-60 (group 1c) and R71-60 (group 1d) were both located in areas of the southern mainland shelf that contained considerably more sand (>90%) than the other 60 m sites. The most abundant species from each of these sites were different from those at the other 60 m sites; the most abundant species in group

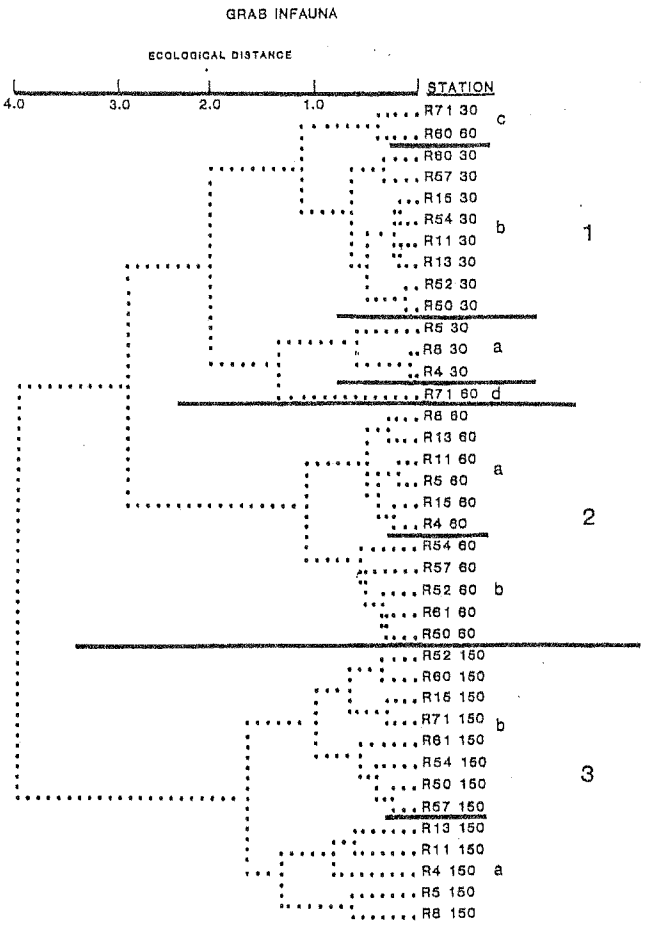

Fig. 4 Dendrogram from classification analysis of infaunal grab samples. See Appendix 2.F.a for details of analysis.

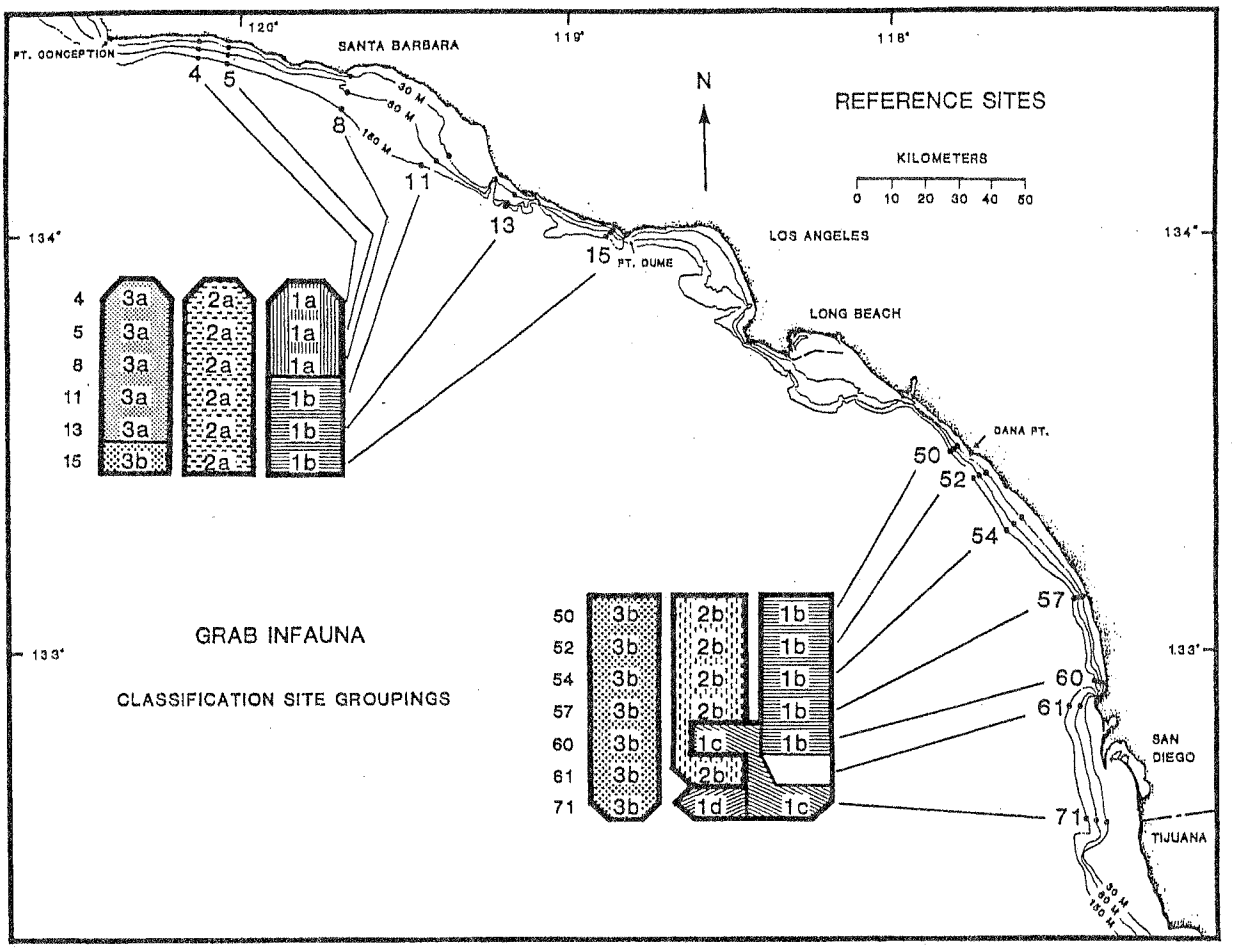

Fig. 5 Distribution of infaunal site groups from classification analysis.

1c, the pelecypod Tellina modesta, was only collected at the Station R60-60. At Station R71-60 the most abundant species was the molluscan Caecum crebricinctum, collected only at this site.

At the 150 m sites (group 3a, 3b) the most abundant species was the polychaete Spiophanes berkeleyorum (Table 4); the distribution of this species at the reference sites is shown on Appendix 5, Fig. 25. It was significantly more abundant at the 150 m sites than at the shallower sites (Fig. 6). A. urtica was also an important member of the 150 m assemblage.

Trends in infaunal assemblage structure over shelf depth.

The number of species, individuals, and biomass per grab at each of the reference sites decreased significantly over depth (Fig. 7). There was a large amount of variation in the biomass measurements, due to chance collection of large, widely dispersed species such as echinoids, holothuroids and echiurans. The values of these parameters at each reference site are shown on Appendix 5, Figs. 20-22. Comparing the classification site groups, generally, the 150 m site groups had significantly fewer species and individuals than the 30 m site groups. There were significantly more (about 2x) species per grab in the northern 60 m site group (2a) than in the southern 60 m site group (2b), but there was no significant difference in biomass among the site groups.

Species diversity (H') decreased over shelf depth, ranging from 1.6-4.2 (Appendix 5, Fig. 26). The highest diversity occurred at Station R4-30, an area of natural oil seeps. However, a previous study of the seep areas has shown that species diversity is not affected by the seeps (Spies and

Table 4. Two-way table of mean infaunal abundances per grab in each classification site group. The species used in this table include at least the 3 most abundant species in each site group (superscript) and the 10 most commonly collected species (frequency of occurrence, F.O.) in all 38 samples. The order of the species in this table was produced by inverse classification analysis of the species. The horizontal lines show the major "breaks" in the dendrogram produced in that analysis. The vertical lines show the major groups from the classification analysis of the sites (see Fig. 4). Shown along the bottom are mean numbers of species, individuals, and biomass for each site group. Means underscored by the same line are not significantly different (SNK multiple comparisons test, α=0.05, Sokal & Rohlf, 1969) P=polychaete, M=mollusk, E=echinoderm, B=brachiopod, CR=crustacean.

MEAN INFAUNAL ABUNDANCE PER GRAB IN EACH SITE GROUP

SPECIES	Ranking by F.O.	1a	1b	1c	1d	2a	2b	3a	3b
Tellina modesta (M)	126	0	3.6	30.0[1]	0	0	0	0	0
Pista disjuncta (P)	61	0	3.0[2]	8.5[2]	0	0.2	0	0.4	1.4
Glottidia albida (B)	30	9.7	15.0[2]	5.0	0	1.5	0.2	0	0
Euphilomedes carcharodonta(CR)	41	0.3[2]	8.9	4.0	0	15.8	0	0	0
Amphideutopus oculatus (CR)	34	12.3[2]	4.4	3.0	0	6.0	0	0	0
Caecum crebricinctum (M)	338	0	0	0	51.0[1]	0	0	0	0
Protodorvillea gracilis (P)	340	0	0	0	9.0[2]	0	0	0	0
Oligochaetes	340	0	0	0	8.0[3]	0	0	0	0
Parvilucina tenuisculpta (M)	7	12.0[3]	8.8	8.0[3]	0	6.5	3.4	0.6	1.5
Spiochaetopterus costarum (P)	10	5.3	3.6[3]	3.0	3.0	3.7	1.2	0.6	0.8
Paraprionospio pinnata (P)	5	7.7	11.0[3]	0.5	0	1.5	0.4	2.2	3.4
Praxillella pacifica (P)	11	1.7	12.6[1]	3.0	0	2.2[2]	0	1.2	5.5
Spiophanes missionensis (P)	1	3.3	36.0[1]	5.5	7.0	28.7[2]	17.8[3]	3.2	2.4
Tellina carpenteri (M)	8	3.7	8.4	1.5	0	5.3	6.4	0.8	1.6
Prionospio sp. A (P)	9	3.0	4.6	0	2.0	3.2	4.4[2]	0	2.4
Myriochele sp. M (P)	40	0	4.9	5.5	0	1.7	60.6[2]	0	0.1
Sternaspis fossor (P)	4	1.7	4.9	0	0	6.3	8.0	2.6	5.5
Amage scutata (P)	32	0.3[1]	0.5	0	0	26.0[3]	13.6[1]	0	0.1[2]
Amphiodia urtica (E)	2	14.7[1]	7.0	0	0	109.0[1]	135.2[1]	14.2[2]	14.9[2]
Chloeia pinnata (P)	67	0.3	0.1	1.0	1.0	3.8	0	5.2[3]	0
Sarsonuphis parva (P)	26	0	0.5	0	0	0.8	0.4	4.4[1]	6.1[3]
Spiophanes berkeleyorum (P)	6	2.0	0.4	0	0	4.3	4.2	43.2[1]	52.5[1]
# Sites in group		3	8	2	1	6	5	5	8
Mean # spp/grab		91.3	91.1	62.5	71.0	86.2	46.8	36.4	45.4
Mean abundance/grab		268.3	358.3	213.0	220.0	393.8	346.8	128.0	171.6
Mean biomass/grab		17.2	14.5	17.5	1.4	15.2	8.2	10.6	6.5

Davis, 1979). Species diversity at the group 1c and 1d sites was similar to the other group 1 and 2 sites. Evenness (J) index values were highest (more even abundances) at the 30 m sites, but were similar at the 60 and 150 m sites (Appendix 5, Fig. 27). Evenness values were moderate to high ranging from 0.91 to 0.45. Dominance index (C) values generally increased (more dominance) with shelf depth but were always moderate to low ranging 0.49 to 0.02 (Appendix 5, Fig. 28). They were very low at 30 m and became more variable at the 150 m sites.

Relationship between infaunal assemblage distribution and sediment conditions.

Nineteen abiotic variables were considered for use in weighted discriminant analysis; however because many abiotic variables are redundant (ie. TVS and TOC) or co-vary (i.e., percent sand, silt, clay) they may confound multivariate methods. To reduce these problems, principal components analysis (PCA) of several subsets of abiotic variables were conducted to determine which variables contributed most to among site variations and to derive better numerical abiotic "factors" for analysis. (For method, see Appendix 2F.b)

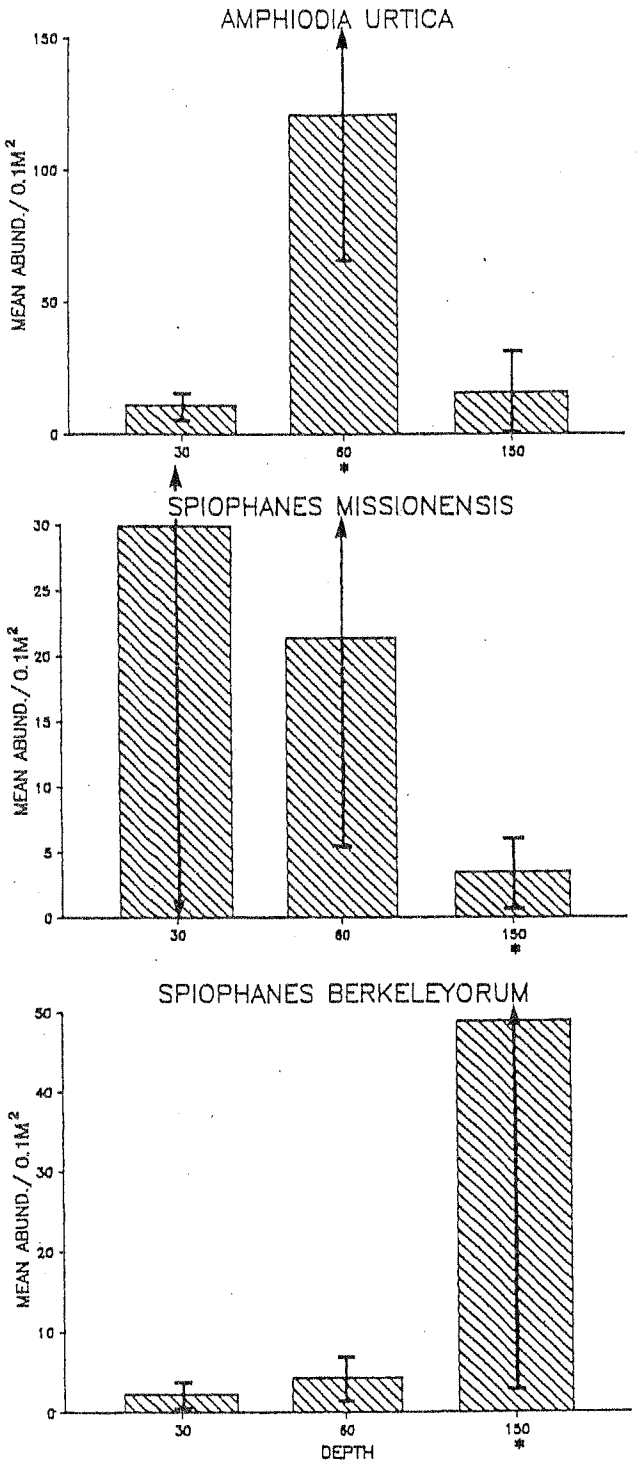

Fig. 6 Trends over depth in mean (std. dev.) abundances of Spiophanes missionensis, Amphiodia urtica, and Spiophanes berkeleyorum. Arrows indicate std. dev. is off scale. * indicates mean value is significantly different from means at other depths (Student-Newman-Keuls multiple comparisons, $\alpha = 0.05$).

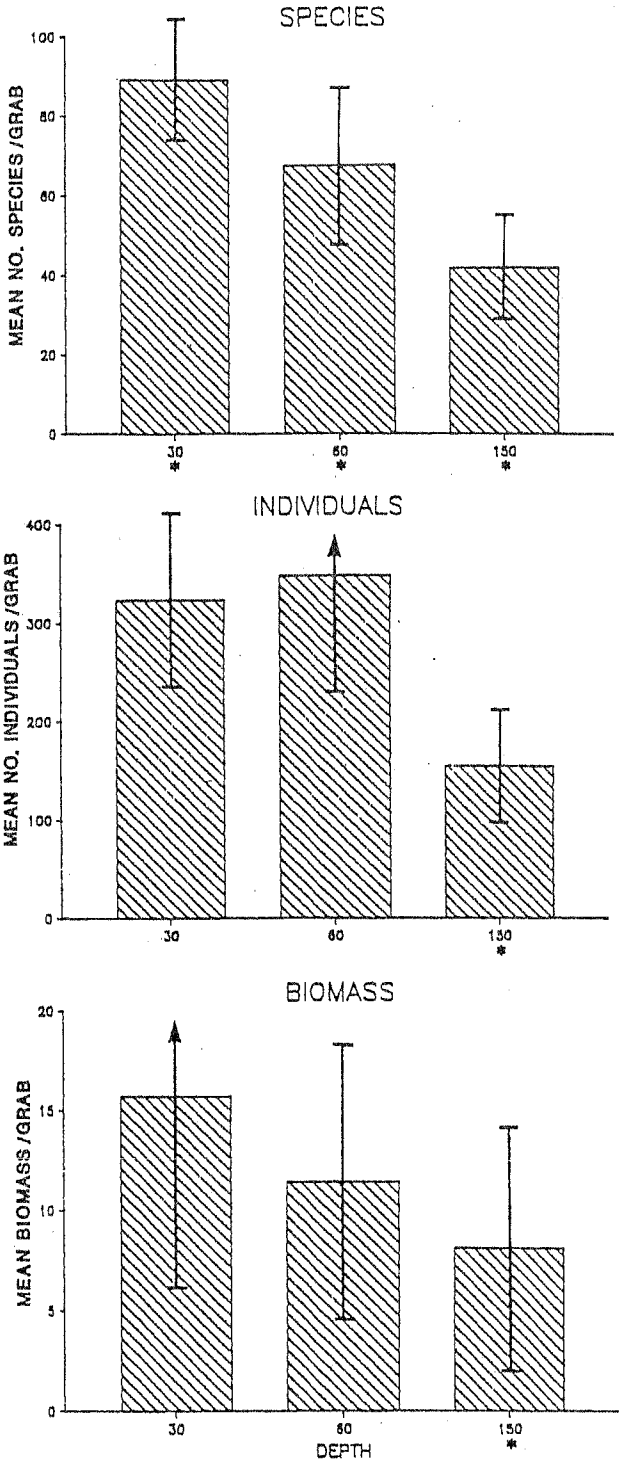

Fig. 7 Trends over depth in mean (std. dev.) number of infaunal species, individuals, and biomass (g wet). For symbol meanings, see Fig. 6.

Table 5. Coefficients of separate determination from weighted discriminant analysis. The coefficients indicate the realtive importance of the variables in separating the sites along the respective axes.

Variable	Discriminant axes AXIS 1	AXIS 2	AXIS 3
1. Depth	24.5	36.2	0.6
2. Organic factor	20.2	4.7	7.1
3. Bottom D.O.	12.0	4.4	0.9
4. Bottom temperature	5.2	0	3.4
5. Sediment size factor	17.6	26.9	63.7
6. Clay factor	2.0	9.0	5.5
7. General metals factor	11.6	10.7	1.0
8. Ag-Cd factor	0	3.4	3.1
9. Total alkyl naphalenes	0.5	0.2	6.3
10. Total other PAHs	0.8	2.0	2.1
11. DDTs	2.0	1.9	0
12. PCBs	3.4	0.4	1.5
13. Lipids	0.1	0	4.8

PCA of the 7 trace metals produced a general metals factor that included 5 metals (axis 1) and an Ag-Cd factor (axis 2). Similarly, organic material measurements (TVS, TOC) and sediment grain-size measurements (percent sand, silt, clay) produced an "organic factor" and a "sediment-size factor". Consequently, these 4 factors and 9 other abiotic measurements (Table 5) were used in the weighted discriminant analysis.

Coefficients of separate determination for the first 3 discriminant axes are listed in Table 5. On axis 1, depth, organic material, and sediment grain-size were most important in differentiating the reference sites. Depth and sediment grain-size were also most important on axis 2.

Each reference site is plotted in the discrimitant space (Fig. 8), which shows the separation of the reference sites due to difference in depth, organic material and grain-size (vectors shown on plot). Sites closest together reflect most similar sediment characteristics. The sites show very similar groupings to those determined by classification analysis of the infauna (shading). This plot helps to understand the differences in the infauna at the group 1d site (Station R71-60) and the group 1c sites (Stations R60-60, R71-30) from the other 30 and 60 m sites. These results demonstrate the well known relationships between sediment quality (grain-size and organic material) and infaunal species compositon (Jones, 1969; Fauchald and Jones, 1979).

In summary, species composition and abundances of the infaunal assembleges off southern California varied with depth and sediment type. As depth and organic material increased and sediment grain-size decreased, the number of species, individuals, and biomass decreased. The most abundant species in each assemblage was different. The mainland shelf or A. urtica assemblege (Barnard and Ziesenhenne, 1961; Jones, 1969) exists in muddy areas at 30 and 60 m depths. Where localized sandy intrusions exist, the infauna are quite different.

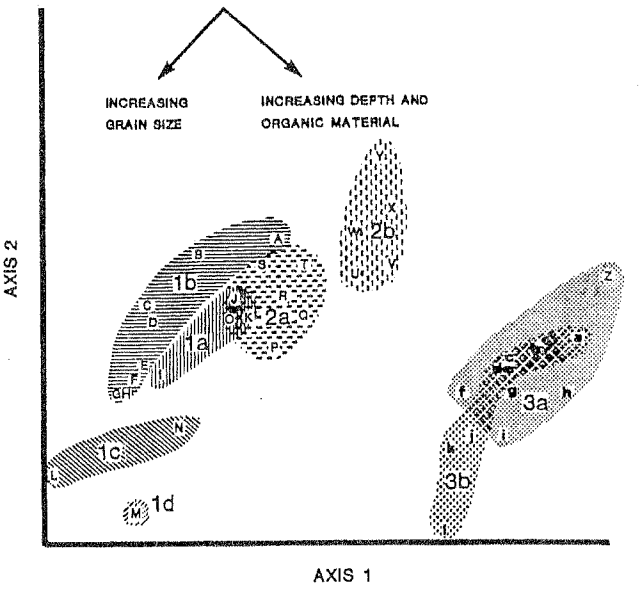

Fig. 8 Plot of infaunal sites in discriminant space showing first 2 discriminant axes. Vectors show direction of maximum separation along each axis. Shading for 30, 60, and 150 m sites is the same as that used on distribution plots (Fig. 5). See Appendix 2.F.b for details of analysis.

KEY TO SYMBOLS

	Sta.#		Sta.#		Sta.#
A	50-30	N	60-60	a	57-150
B	52-30	O	13-60	b	52-150
C	54-30	P	8-60	c	15-150
D	13-30	Q	5-60	d	50-150
E	15-30	R	4-60	e	61-150
F	57-30	S	11-60	f	13-150
G	11-30	T	15-60	g	11-150
H	60-30	U	61-60	h	5-150
I	8-30	V	54-60	i	4-150
J	5-30	W	52-60	j	60-150
K	4-30	X	57-60	k	54-150
L	71-30	Y	50-60	l	71-150
M	71-60	Z	8-150		

The 150 m sites (group 3) were inhabited by many different species than the shallower shelf sites, and by fewer species and individuals. This outer shelf assemblage represents a transition from the mainland shelf assemblage to the deeper slope assembleges described by Thompson and Jones (1987).

Among sites of similar depth, a subtle change in species composition sometimes occurred from north-to-south. This appears to have resulted from a few species that were present in one sub-group but not the other, e.g. the polychaetes Chloeia pinnata and Myriochele sp. M*, in group 2, and from species that occurred in low frequency and abundance.

B. Megafaunal invertebrates.

Species composition. Classification analysis of the trawl-caught invertebrates resulted in 3 site groupings (Fig. 9). The lower main branch of the dendrogram is composed only of 150 m sites (group 3). The upper main branch is composed mostly of 30 and 60 m sites, and is further divided into secondary branches (groups 1 and 2), each of which contains 30, 60, and 150 m sites.

Unlike the infaunal assemblages with fairly clear depth related groupings, the shallower megafaunal assemblages (groups 1 and 2) were more heterogeneous in distribution over depth and at the north-south sites (Fig. 10). Groups 3a and 3b were restricted to the 150 m stations and show slight north-south differences in species composition.

The asteroid Luidia foliolata was the most commonly collected megafaunal species (74% of the sites; for distribution see Appendix 5, Fig. 33).

The most abundant species in group 1 were the asteroid Astropecten verrilli, and echinoid Lytechinus pictus (Table 6). The distribution of these species at the reference sites is shown on Appendix 5, Figs. 32 and 34. A. verrilli was significantly more abundant at the 30 m sites than at the deeper sites, but L. pictus showed no significant differences in abundance over depth (Fig. 11).

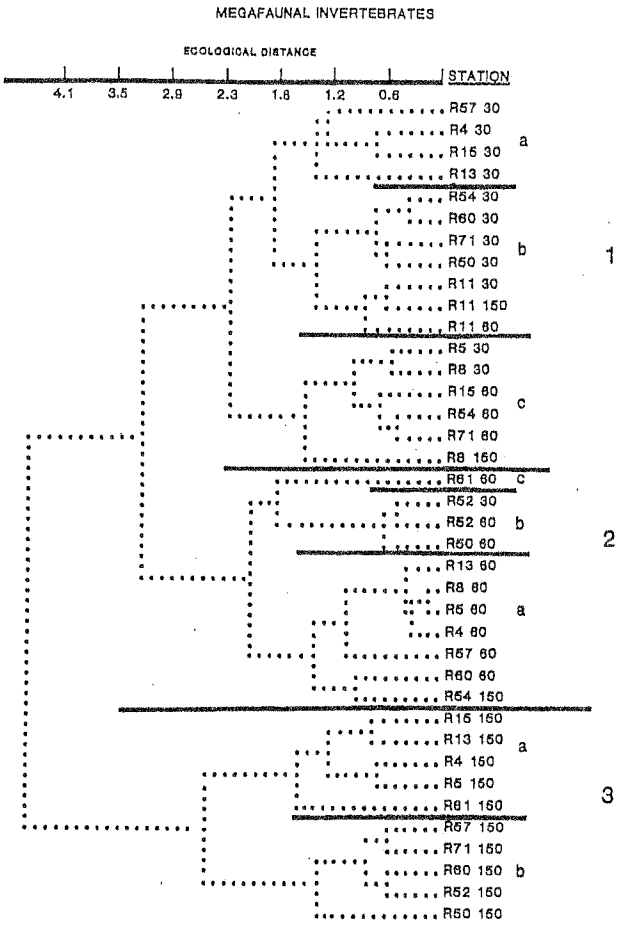

Fig. 9 Dendrogram for classification analysis of trawl-caught megafaunal invertebrates. See Appendix 2.F.a for details of analysis.

*Provisional name as desginated by Southern California Association of Marine Invertebrate Taxonomists.

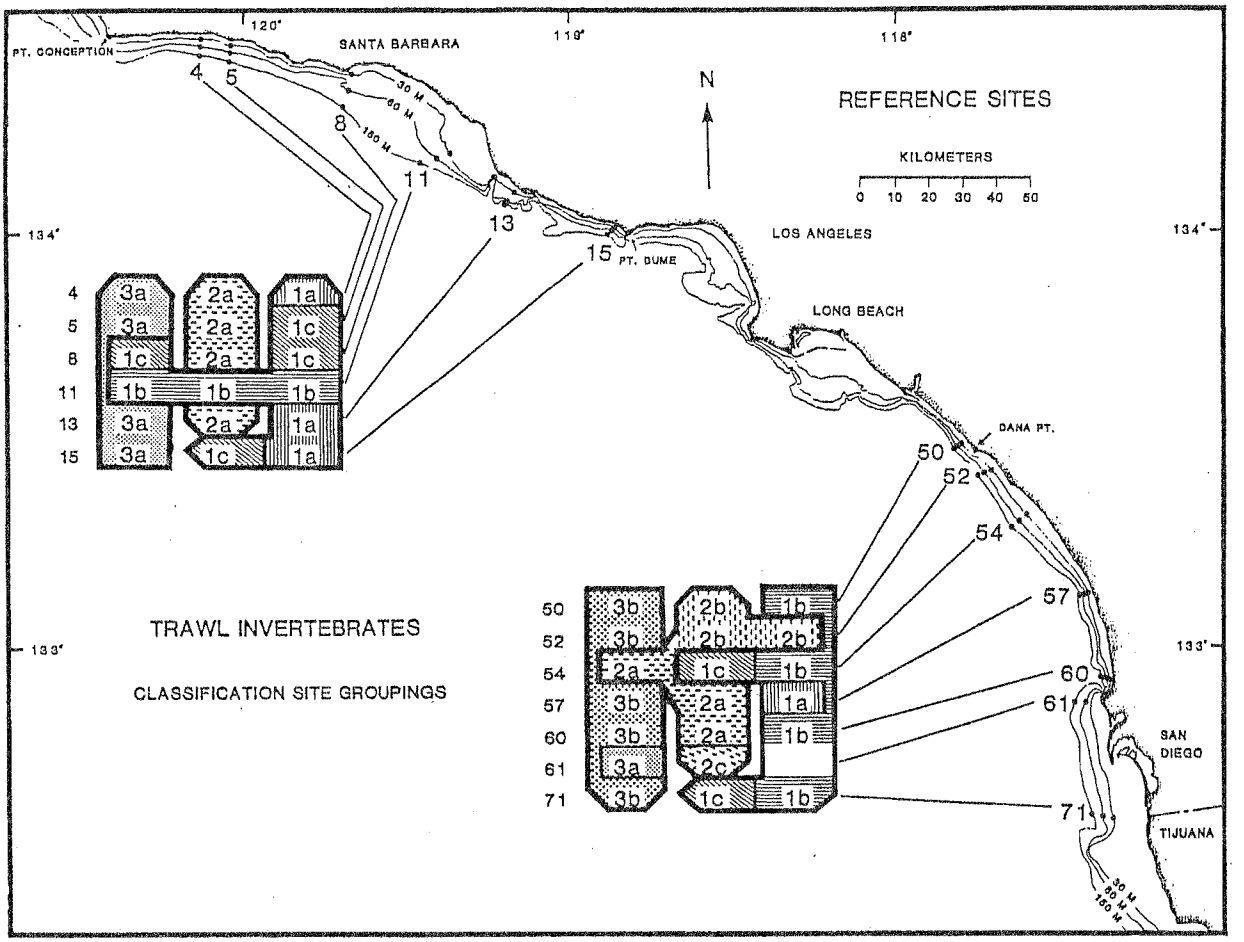

Fig. 10 Distribution of megafaunal site groups from classification analysis.

The ridgeback prawn, Sicyonia ingentis, was the most abundant species collected from the 60 m (group 2) sites (Table 6). The distribution of this species is shown on Appendix 5, Fig. 35). Station R61-60 (group 2c) was inhabited by different megafaunal species than the other 60 m sites. The most abundant species, the pelecypod Hyatella arctica, is a nestling species that was collected from pieces of rock that were in the trawl.

Sicyonia, also dominated the 150 m sites (groups 3a and 3b), and was significantly more abundant there than at the shallower sites (Fig. 11). They were especially numerous at the southern sites (group 3b) where they contributed up to 99% of trawl catch abundance and trawl biomass. At the northern 150 m sites, 3 species of slope echinoids were among the most abundant species, but to the south their abundances decreased and the prawn Pandalus platyceros was more abundant (Table 6).

Trends in megabenthic assemblage structure over shelf depth.

Mean numbers of individuals and biomass per trawl were significantly higher at the 150 m sites than at the shallower sites (Fig. 12) mainly due to large catches of Sicyonia. This trend is opposite that shown by the infauna. There was no significant difference in the number of species per trawl among the 3 depths.

Megafaunal species diversity (H') per trawl was moderate to low, ranging between 2.4 and 0.01, and generally decreased over shelf depth (Appendix 5, Fig. 36). Evenness index (J) values had a wide range, 0.92 to 0.01, and generally decreased over shelf depth (Appendix 5, Fig. 37).

Table 6. Two-way table of mean megafaunal abundances per trawl in each classification site group. The species used in this table include at least the 4 most abundant species in each site group (superscript) and the 10 most commonly collected species (frequency of occurrence, F.O.) in all 38 samples. The order of the species in this table was produced by inverse classification analysis of the species. The horizontal lines show the major "breaks" in the dendrogram produced in that analysis. The vertical lines show the major groups from the classification analysis of the sites (see Fig. 10). Shown along the bottom are mean numbers of species, individuals, and biomass for each site group. Means underscored by the same line are not significantly different (SNK multiple comparisons test, α=0.05). AS=ascidian, C=cnidarian, CR=crustacean, E=echinoderm, M=mollusk

MEAN MEGAFAUNAL ABUNDANCE PER TRAWL IN EACH SITE GROUP

SPECIES	Ranking by F.O.	1a	1b	1c	2a	2b	2c	3a	3b
Stylatula elongata (C)	15	0	0	0.3	0	7.0^{2}	0	0	0
Strongylocentrotus purpuratus (E)	32	11.8^{2}	0	0.7	0	0	0	0.4	0
Astropecten verrilli (E)	2	66.5^{1}	7.7^{2}	30.3^{2}	10.9^{4}	2.7^{3}	0	0.4	7.4
Lytechinus pictus (E)	6	3.8^{3}	5.4^{4}	144.6^{1}	12.4^{3}	0	0	1.4	0.2
Filigella mitsukurii (C)	7	0	0	1.0	0.1	0	0	0	0
Loligo opalescens (M)	-	0.3	10.9^{1}	1.0_{3}	4.0	0.3	0	0.2	0.8
Ophiura lutkeni (E)	10	0.3_{4}	1.0_{3}	11.2^{3}	5.9	1.3_{4}	0	0	0
Luidia foliolata (E)	1	3.0^{4}	6.1^{3}	5.7	9.0	2.0^{4}	0	1.8	1.2
Pleurobranchaea californica (M)	5	0.3	2.1	0.7	2.6	0.3	0	3.0	0
Octopus rubescens (M)	8	0.5	2.3	2.3	0.1_{2}	0	0	1.4	0.4_{4}
Parastichopus californicus (E)	4	0	1.6	1.7	32.3^{2}	0.3	1.0	11.0	12.4^{4}
Hyatella arctica (M)	-	0	0	0	0	0	6.0^{1}_{3}	0	0
Styela gibbsii (AS)	27	0	0	0	0.7	0.3	4.0^{3}	0	0
Allocentrotus fragilis (E)	13	0	0	0.2	0.3	0	0	134.8^{2}_{4}	0.4
Spatangus californicus (E)	17	0	0	0.3	0	0	0	39.8^{3}	0.2
Brisaster latifrons (E)	16	0	0	2.0_{4}	0	0	0	46.6^{3}	0.2_{1}
Sicyonia ingentis (CR)	3	0	0.4	10.3^{4}	109.0^{1}	44.7^{1}	4.0^{2}	280.4^{1}	1865.6^{1}_{2}
Pandalus platyceros (CR)	9	0	0	1.2	0.1	0	0	4.2	60.4^{2}_{3}
Pleuroncodes planipes (CR)	22	0	0.1	0	0	0	0	0.2	20.2^{3}
# Sites in group		4	7	6	7	3	1	5	5
Mean # spp./trawl		14.3	9.9	18.0	19.6	7.3	12.0	19.4	9.0
Mean abundance/trawl		98.3	44.3	213.3	213.3	61.7	20.0	561.4	1979.6
Mean biomass/trawl		0.5	0.9	1.4	13.3	0.5	0.8	26.4	40.2

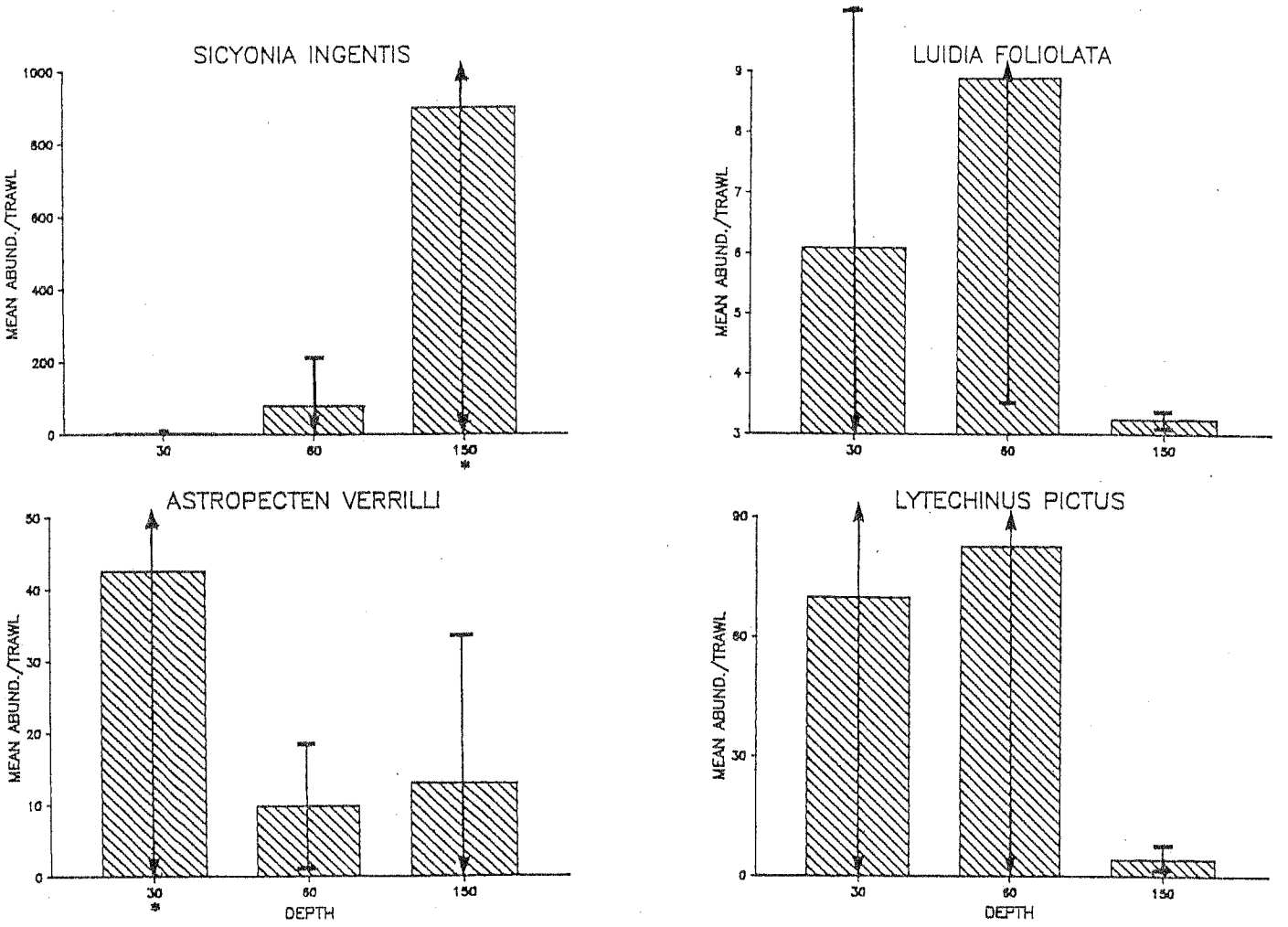

Fig. 11 Trends over depth in mean (std. dev.) abundances of Astropecten verrilli, Lytechinus pictus, Luidia folioata, and Sicyonia ingentis. See Fig. 6 for symbol meanings.

Dominance index (C) values also showed a wide range, 0.997 to 0.13, but increased over shelf depth (Appendix 5, Fig. 38), Station R52-150 had the lowest megafaunal species diversity, lowest evenness, and highest dominance values measured. This is due to the large number of Sicyonia collected at that site.

In summary, the megafaunal invertebrates showed heterogeneous assemblages that were widely distributed along the entire southern California coastal shelf. Distinct assembleges did not occur. Instead, the megabenthos was characterized by a few dominant species that changed over depth and from north to south. Astropecten and Lytechinus dominated shallower areas and Sicyonia dominated the outer shelf, but these large, motile species range into all shelf depths and areas, and are very patchy in distribution (e.g., Appendix 5, Figs. 32-35), resulting in the mosaic patterns shown in the classification analysis.

C. Epibenthic and demersal fishes.

Species composition. Classification analysis of trawl-caught fishes shows 3 main site groups (Fig. 13). The lower main branch of the dendrogram is composed of the 150 m sites and the upper main branch is divided into two secondary branches, each of which contains 30 and 60 m sites; group 2a contains one 150 m site.

Group 1 and 2 sites showed little depth zonation, but the group 3 sites were mostly

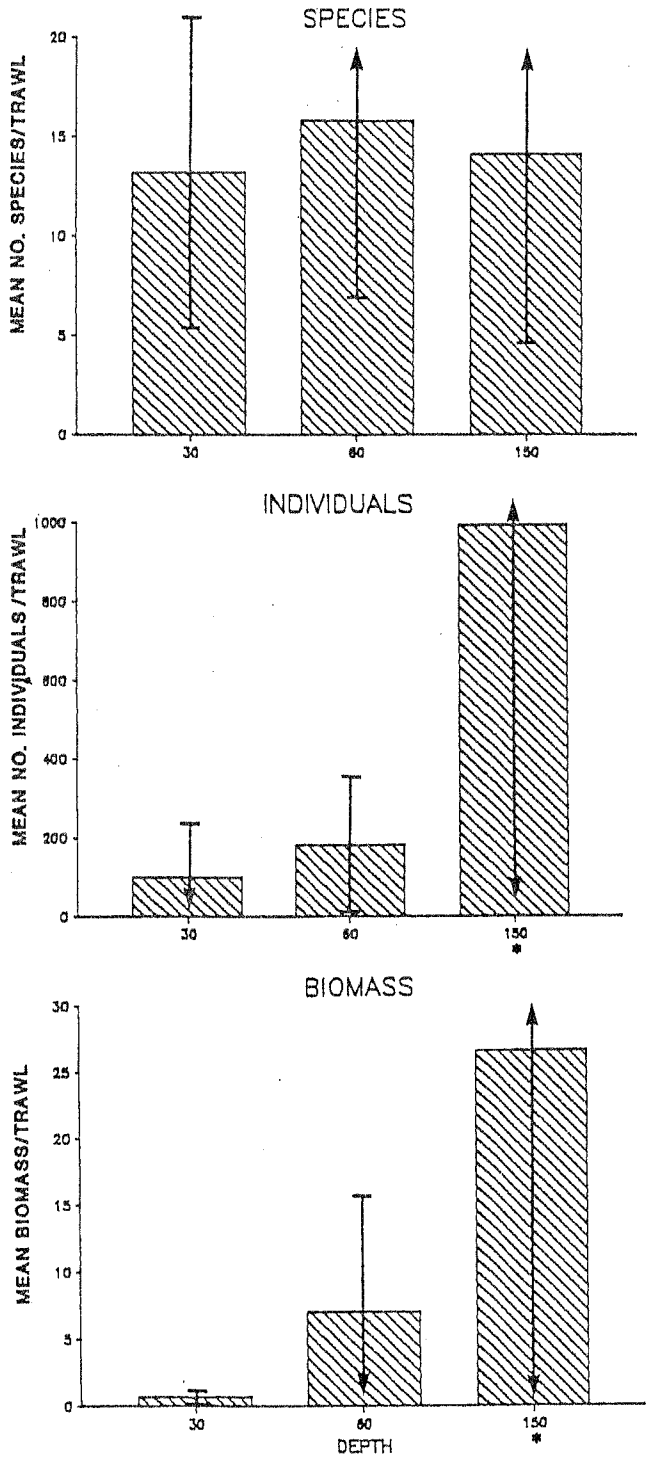

Fig. 12 Trends over depth in mean (std. dev.) number of megafaunal species, individuals, and biomass (kg wet) per trawl. See Fig. 6 for symbol meanings.

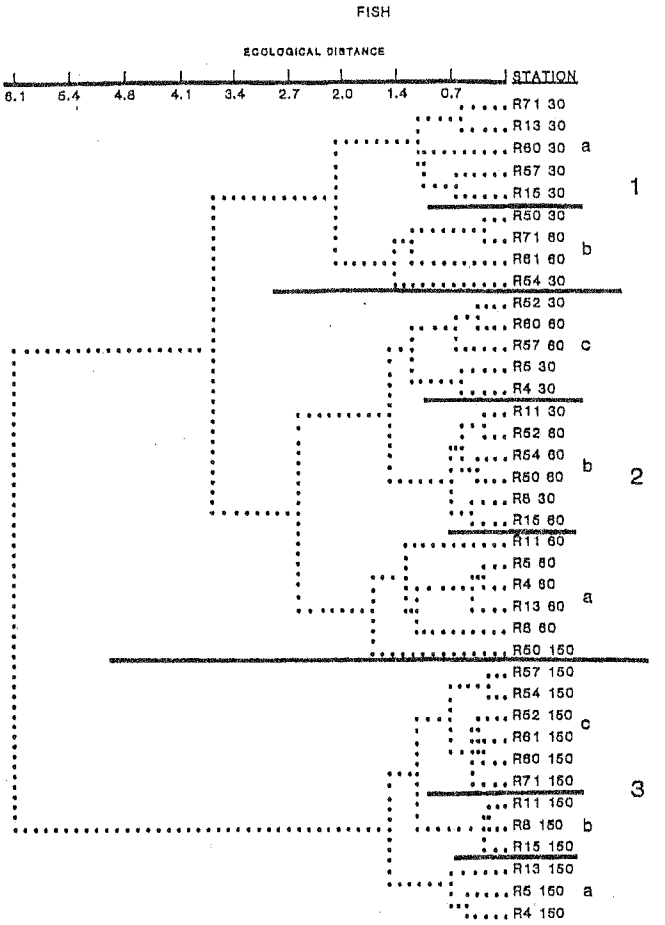

Fig. 13 Dendrogram for classification analysis of trawl-caught fish. See Appendix 2.F.a for details of analysis.

restricted to 150 m (Fig. 14). Group 2 included sites from 30 and 60 m at the northern end of the region, and group 1 included 30 and 60 m sites at the southern end of the region.

Only the bigmouth sole was collected from sites in all of the groups. The distribution of this species at the reference sites is shown on Appendix 5, Fig. 42; there was no significant difference in abundances among the 3 depths sampled (Fig. 15).

Group 1 sites had many fish species in common, but the most abundant species in each subgroup was different (Table 7). At the group 1a sites, speckled sanddabs were most abundant and at the group 1b sites, Pacific sanddabs were most abundant. Stripetail rockfish, Pacific sanddabs, and yellowchin sculpin were the most abundant

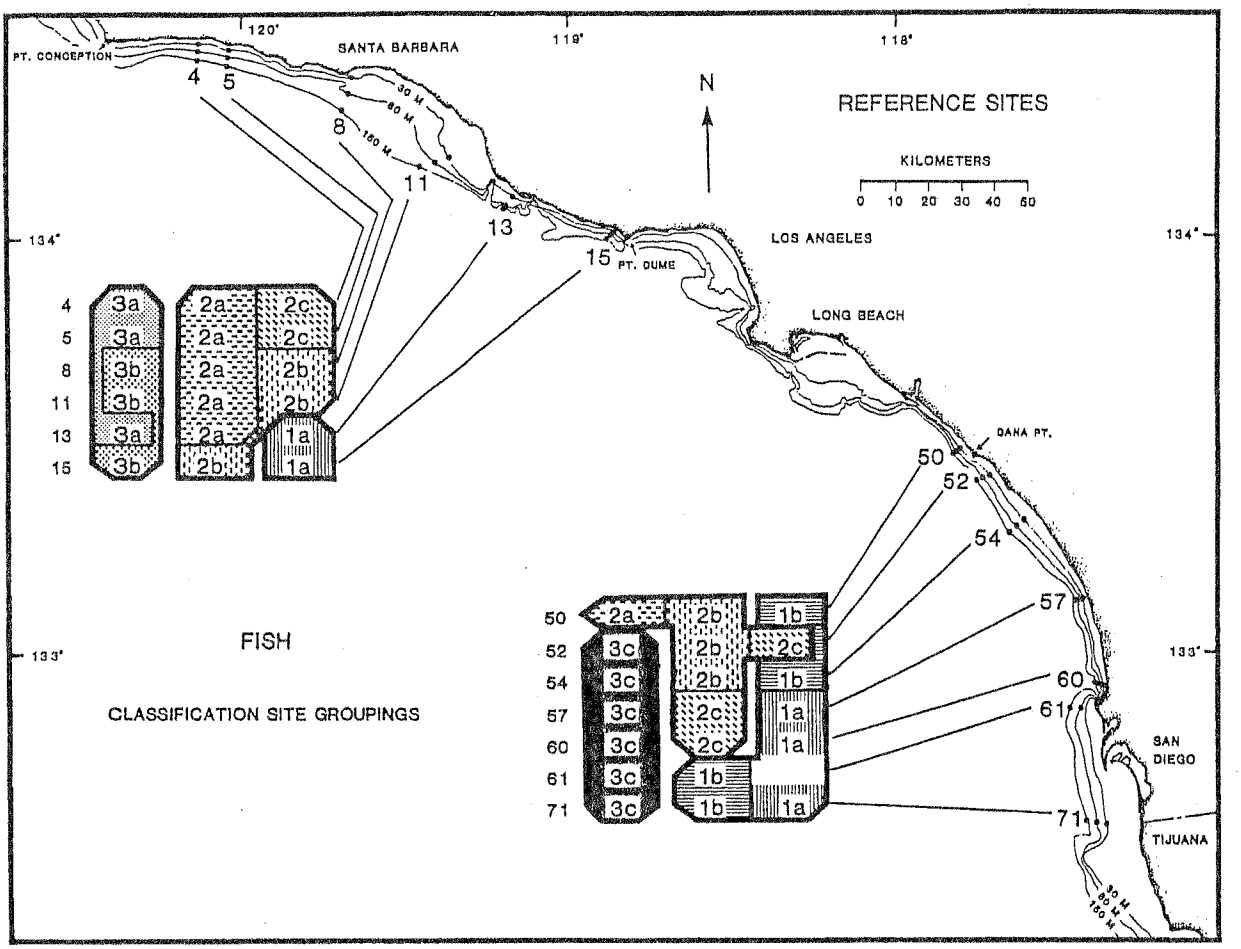

Fig. 14 Distribution of fish site groups from classification analysis.

fish collected at the group 2 sites. Species composition and abundances of the fish collected at the group 2a, 2b, and 2c sites were similar, and what separated these subgroups in the classification analysis is not clear.

The 150 m sites were inhabited by a somewhat different assemblage of fishes than at the 30 and 60 m sites. The most abundant species were plainfin midshipman and Pacific sanddabs. The distributions of these 2 species are shown on Appendix 5, Figs. 43 and 44. Plainfin midshipman were significantly more abundant at the 150 m sites than at the shallower sites, but Pacific sanddabs showed no significant differences among the depths sampled (Fig. 15). Gulf sanddabs and slender sole were also collected at the deepest sites, but generally were not collected from the shallower sites.

Trends in trawl-caught fish assemblage structure over shelf depth.

The number of fish species, individuals, and biomass per trawl were significantly higher at the 150 m sites than at the shallower sites (Fig. 16). The value of each of these parameters at each reference site are shown on Appendix 5, Figs. 39 and 41. Similar trends over depth shown were comparing means among the classification site groups (Table 7), except that there were no significant differences in fish biomass per trawl among the groups.

Fish species diversity (H') per trawl showed values similar to megafaunal diversity, but showed no trends over shelf depth; values ranged from 2.2 to 0.56 (Appendix 5, Fig. 45). Evenness (J) index values were moderate ranging from 0.86 to 0.31 and did not show any depth related

Table 7. Two-way table of mean fish abundances per trawl in each classification site group. The species used in this table include at least the 4 most abundant species in each site group (superscript) and the 10 most commonly collected species (frequency of occurrence, F.O.) in all 38 samples. The order of the species in this table was produced by inverse classification analysis of the species. The horizontal lines show the major groups in the dendrogram produced in that analysis. The vertical lines show the major groups from the classification analysis of the sites (see Fig. 13). Shown along the bottom are mean numbers of species, individuals, and biomass for each site group. Means underscored by the same line are not significantly different (SNK multiple comparisons test, α=0.05).

MEAN FISH ABUNDANCE PER TRAWL IN EACH SITE GROUP

Species	Rank by F.O.	1a	1b	2a	2b	2c	3a	3b	3c
speckled sanddab	18	31.4^{1}	0	0	2.5	3.0	0	0	0
fantail sole	24	5.6^{4}	0.5_{2}	0	0.2	0.2	0	0	0
white croaker	34	0	8.8^{2}	0	2.5	0	0	0	0.8
hornyhead turbot	5	6.4_{3}	2.0_{3}	1.7	4.8_{4}	1.2_{3}	0	0	0.5
longfin sanddab	7	8.6^{2}	8.5^{3}	0.5	10.7^{4}	20.4^{3}	0	0	9.7
calico rockfish	23	0	5.0^{4}	0.5	0.2	0.8	0	0	0.2
Calif. tonguefish	9	0.4	0.8	1.0_{2}	7.8_{1}	6.8_{4}	0	0	0.2
yellowchin sculpin	6	1.8	0.5	27.2^{2}	64.8^{1}	14.0^{4}	0	0	0.2
bigmouth sole	1	3.8	0.8	1.7	5.2_{3}	9.0	0.3	0.3	7.3
pink surfperch	10	0	0	2.7_{3}	12.0_{2}	13.2_{2}	0	0.3_{2}	0.7_{1}
Pacific sanddab	3	0	11.3^{1}	22.2_{3}	23.2^{2}	42.8^{1}	3.0_{3}	43.3^{2}	114.5^{1}
stripetail rockfish	4	0	0	157.0^{1}	4.0	69.0^{1}	48.7^{3}	28.0^{3}	63.0^{2}
plainfin midshipman	2	0	0	13.5^{4}	4.3	2.6	70.7^{1}	253.7^{1}	61.5^{3}
Dover sole	8	0	0	7.2	0.3	0.4	6.7_{4}	16.3	38.0
gulf sanddab	32	0	0	0	0	0	15.7^{2}	0	4.3
slender sole	14	0	0	1.3	0	0	53.3^{2}	17.7^{4}	25.5
# Sites in Group		5	4	6	6	5	3	3	6
Mean # spp/trawl		8.0	7.8	11.5	13.0	13.2	13.3	13.0	16.0
Mean abundance/trawl		67.0	42.3	252.0	163.2	201.8	243.3	376.7	401.7
Mean biomass/trawl		6.8	5.1	2.4	4.0	4.7	9.3	23.6	21.2

trends (Appendix 5, Fig. 46). Dominance index (C) values ranged between 0.76 and 0.16 and were generally similar over slope depths (Appendix 5, Fig. 47).

In summary, species composition and structure of the epibenthic and demersal fish assembleges of the mainland shelf were heterogeneous at the 30 and 60 m sites. Many species were collected at all sites, but abundances of the dominant species changed over depth and from the northern to the southern sites. Group 1 represented a southern facies and group 2 represented northern facies of a large mainland shelf fish association. At 150 m, species composition and structure changed reflecting the transition to slope fish assemblages (Thompson et al., 1984).

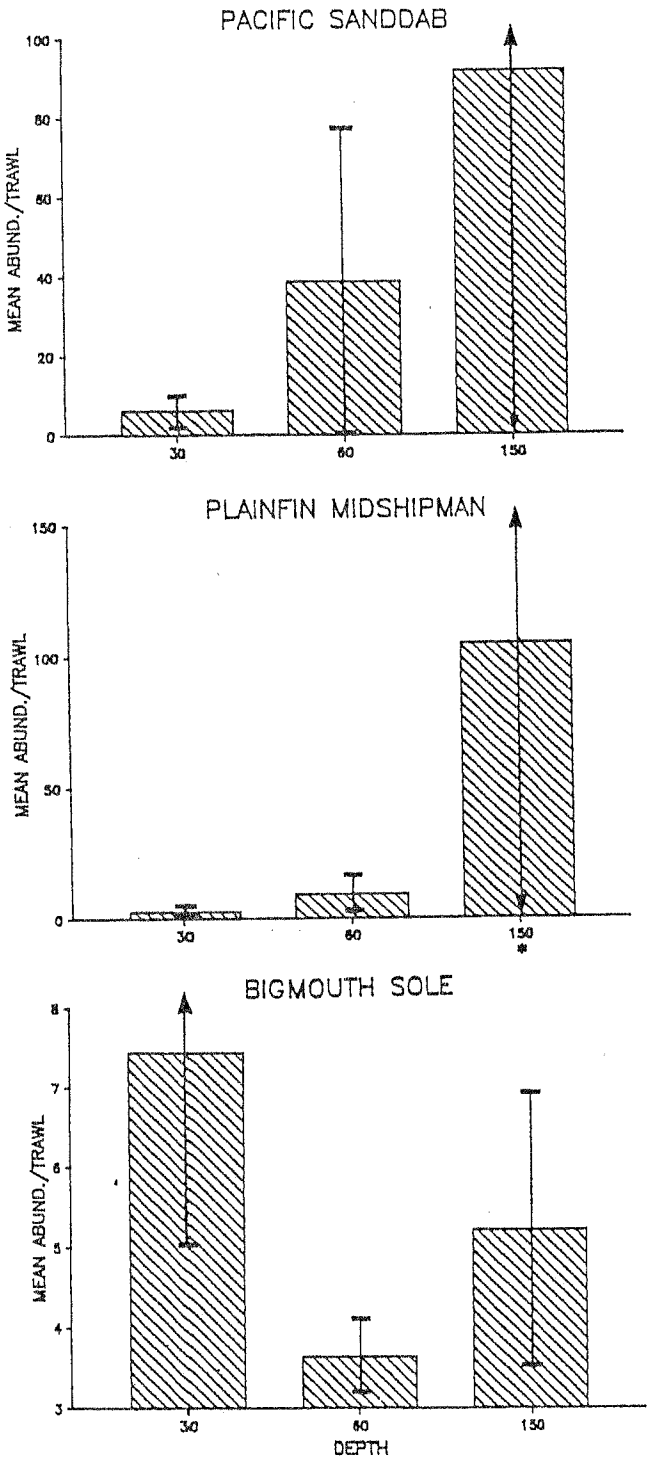

Fig. 15 Trends over depth in mean (std. dev.) abundances of bigmouth sole, plainfin midshipman and Pacific sanddabs. See Fig. 6 for symbol meanings.

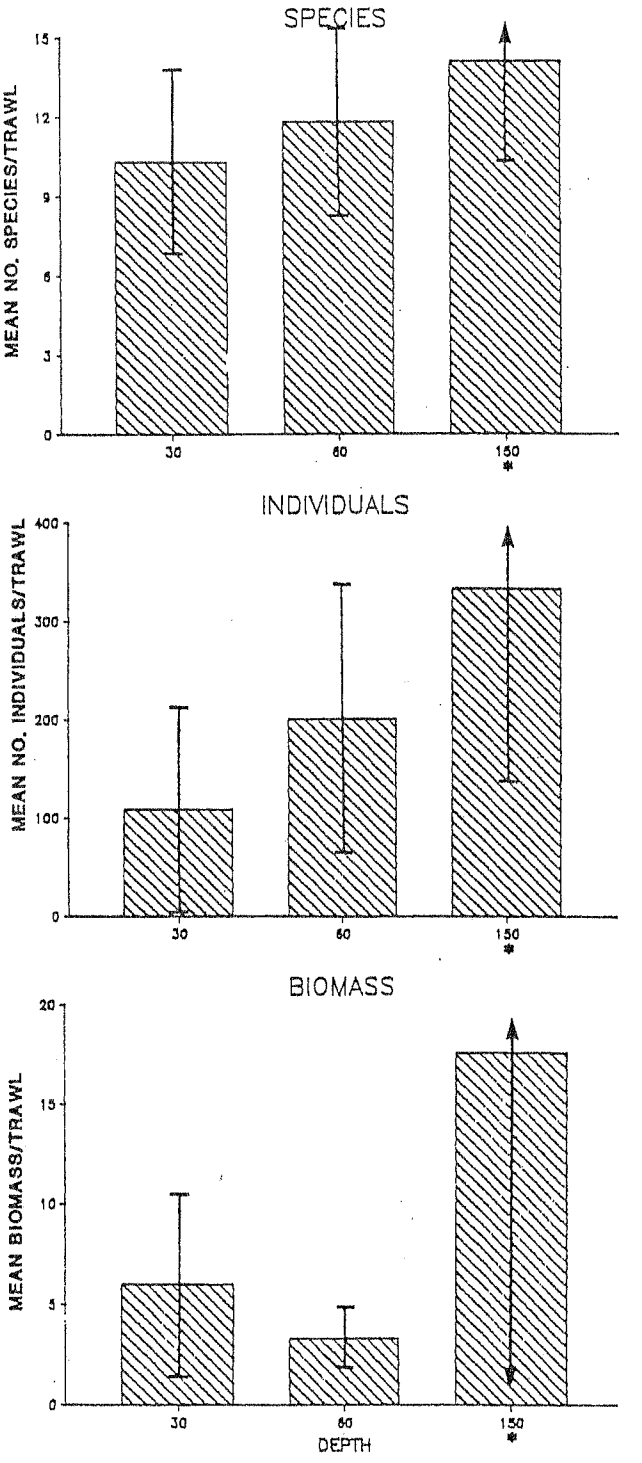

Fig. 16 Trends over depth in mean (std. dev.) number of fish species, individuals, and biomass (kg wet) per trawl. See Fig. 6 for symbol meanings.

Table 8. Mean (std. dev.) of chlorinated hydrocarbon concentrations and lipid content in Sicyonia hepatopancreas and livers of 4 species of flatfish. Means are expresses on a wet wt. and lipid wt. basis.

CHLORINATED HYDROCARBONS IN ANIMAL TISSUES
(Mean (± std. dev.)

Depth	No. of Stations	DDTs (ng/wet g [ppb])		DDTs (ng/g lipid [ppb])		PCBs (ng/wet g [ppb])		PCBs (ng/g lipid [ppb])		Lipids (%, wet wt.)	
Sicyonia ingentis											
60m	10	591.4	(253.6)	6658	(2779.3)	533.2	(262.6)	6509	(4418.8)	9.5	(3.4)
150m	12	708.1	(507.5)	6374	(4326.3)	598.3	(323.5)	6241	(4233.9)	11.4	(5.8)
Pacific Sanddab											
60	2	4329.5	(140.7)	9382	(3995.6)	5822.0	(5990.6)	9981	(7933.6)	50.4	(20.0)
150	8	5567.1	(3038.0)	10049	(5997.6)	5501.1	(3418.3)	9826	(6242.7)	59.2	(14.1)
Longfin Sanddab											
60	6	6209.7	(3974.5)	11710	(7019.6)	7810.3	(2831.6)	15402	(6822.0)	52.9	(9.3)
150	1	2330.0	-	5973	-	3023.0	-	6380	-	47.4	-
Dover Sole											
60	2	415.0	(28.3)	1903	(869.4)	346.0	(73.5)	1500	(285.5)	24.0	(9.5)
150	2	465.0	(12.7)	4361	(2283.5)	390.5	(46.0)	3809	(2453.0)	12.4	(6.8)
Gulf Sanddab											
60		----------		----------		none sampled----------					
150	2	7394.5	(2926.7)	15040	(8699.4)	2656.5	(2991.8)	5794	(6917.0)	52.3	10.8

4. Contaminants in Animal Tissues.

Samples of Sicyonia hepatopancreas and flatfish livers were collected from the 60 and 150 m site for analysis of the same contaminants that were measured in the sediments (see Table 1). In this summary we report only the chlorinated hydrocarbon concentrations; the trace metals and petroleum hydrocarbon concentrations in these tissues will be reported in an Addendum when analyses are complete.

Concentrations of contaminants in tissues may vary due to age, reproductive status, lipid content, and other factors. Information on size, sex, and number of specimens composited is contained in Appendix 4; lipid concentrations in the tissue samples are listed in Table 8.

Concentrations of 10 different chlorinated hydrocarbons were measured in each sample (Appendix 5, Tables 2 and 3). On a wet weight basis, total DDTs in Sicyonia hepatopancreas ranged up to 1600 ppb, and PCBs ranged up to 1200 ppb. (see Appendix 5, Figs. 48 to 49). Mean concentrations were slightly higher at the 150 m stations than at the 60 m stations (Table 8). The concentrations of total DDTs and total PCBs in flatfish livers at each reference site are shown in Appendix 5, Figs. 50-51. Except for Dover sole, flatfish livers generally contained an order of magnitude higher chlorinated hydrocarbon concentrations (wet weight basis) than Sicyonia. In the fish livers, DDTs ranged up to 13.2 ppm and PCBs ranged up to 12.2 ppm. Dover sole were generally smaller, younger fish and contained lower contaminant concentrations. There was no obvious trend with depth in the concentration of DDTs and PCBs in the flatfish livers.

Lipids were 2 to 6 times higher in fish livers than in Sicyonia hepatopancreas. When expressed on a lipid weight basis, fish liver concentrations are comparable to Sicyonia hepatopancreas levels (Table 8).

DISCUSSION & CONCLUSIONS

Environmental conditions in reference areas on the mainland shelf off southern California have been described in many previous reports (e.g. for infauna: Jones, 1969; Fauchald and Jones, 1979, 1983; for fish: Allen and Voglin, 1976; for sediments: Anderholt and Reed, 1978; multidisciplinary: AHF/USC, 1959; Word and Mearns, 1979). Sediment and biological conditions reported in these studies are generally similar to the results reported herein from the reference sites, suggesting a relatively stable mainland shelf habitat.

This report contains information on PAHs, megafaunal distributions, and tissue chemistry that has not been reported previously from reference areas of the region.

Very little is known about long-term (more than 2 years) changes in conditions at reference areas off southern California. Many of the parameters measured during the Reference Site Survey were also measured during the 60-M Survey which provides an opportunity to evaluate long-term changes (8 years). However, there are many problems with comparing the data from these 2 surveys, particularly statistical comparisons. The methods of analysis for TVS, percent sand, and chlorinated hydrocarbons were different in the 2 surveys (see the appropriate section of Methods of Analysis, Appendix 2 for explanation of differences), but the methods of anlaysis for trace metals was the same in both surveys. Neither survey used within-site replication and there have been no studies of statistical power and precision for sediment and tissue contaminants within composite samples, among sites, or in analytical procedures. Finally, contaminants generally exist in very low concentrations in reference site sediments, often near the limits of detection, and differences in the means between surveys may reflect the high variability associated with measuring very low concentrations, rather than any real trends.

Keeping the above limitations in mind, the means and standard deviations of the parameters measured in both surveys are shown on Table 9. There were no consistent trends in the changes of contaminant concentrations between the 2 surveys; Ag, Cd, Pb, and DDTs decreased and Cr, Cu, Ni, and PCBs increased in concentration. Except for order-of-magnitude decreases in Ag, and significant changes in Cd, Cr, and Cu, values from the 2 surveys are similar. Although PCBs increased by a factor of about 2.7, both values are quite small and the variation (standard deviation) estimates from each survey overlap.

Except for infaunal biomass and number of megafaunal species, all of the biological parameters decreased between the 2 surveys. Due to large amounts of variation in these parameters, particularly the trawl parameters, none of the changes tested were significant. Numbers of species per sample were not compared because the taxonomists that identified the animals collected in each survey were different and we have not attempted to standardize species names in the 2 surveys.

Differences in methods of analysis, lack of within site replication, etc. notwithstanding, there does not appear to have been any large or obvious changes (except for silver) in the sediments or biology of the mainland shelf habitats off southern California over the past 8 years.

The reference sites sampled probably represent the least contaminated areas that exist along the coastal shelf of the region, but they all have measurable contamination in the sediments and animals that inhabit them. While such contamination may complicate the use of sediment or animals from these areas as experimental controls, the data will be useful in waste discharge monitoring programs.

How to use this information in a monitoring context must be decided. Some of the

Table 9. Comparisons of means (std. dev.) from the Reference Site Survey and 60-m Survey. Wilcoxon's matched-pairs signed-ranks test (Siegel, 1959) was used. A T value of 0 indicates that all sites changed. Data from 13 sites were compared for all parameters exept DDTs and PCBs where 5 sites were compared.

COMPARISONS TO 60-M SURVEY

	60-M Survey, 1977		Ref. Survey, 1985		
	mean	std. dev.	mean	std. dev.	Wilcoxon's T
Sediment Measurements					
+ % TVS	2.8	(.6)	3.5	(1.42)	Not Tested
+ % Sand	45.9	(26.9)	45.8	(33.46)	NT
Ag (ppm)	0.2	(.2)	0.03	(.04)	0*
Cd (ppm)	0.3	(.2)	0.14	(.09)	2*
Cr (ppm)	21.7	(7.5)	25.4	(9.3)	9.5*
Cu (ppm)	6.8	(3.8)	10.4	(5.7)	3*
Ni (ppm)	12.1	(7.6)	12.9	(6.5)	0*
Pb (ppm)	5.8	(2.2)	4.8	(2.6)	0*
Zn (ppm)	40.3	(12.6)	48.0	(19.5)	18
+ DDTs (ppb)	20.2	(22.8)	18.9	(19.8)	NT
+ PCBs (ppb)	7.2	(5.5)	19.1	(10.4)	NT
Biological Measurements (per sample)					
+ Infaunal species	74.7	(19.9)	67.7	(19.9)	NT
Infaunal indiv.	407.5	(96.0)	348.4	(120.3)	21
Infaunal biom.	6.9	(2.6)	11.4	(7.0)	21
+ Megafaunal species	10.8	(4.6)	15.8	(8.7)	NT
Megafaunal indiv.	638.8	(1153.8)	181.9	(175.7)	32
Megafaunal biom.	8.4	(8.0)	7.0	(8.7)	29
+ Fish species	14.4	(3.8)	11.8	(3.6)	NT
Fish indiv.	386.6	(353.4)	201.3	(141.0)	16
Fish biom.	5.6	(5.1)	3.2	(1.7)	23.5

*indicates significant difference, α=0.01
+indicates differences in methods of measurements between the two surveys; see Appendix 2 for details of differences.

reference sites (Station R60-30, -60, R71-30, -60) have very sandy sediment, therefore different infaunal assemblages, than the other sites. While these are normal conditions at those sites, they should not be used as reference sites for outfall areas in silty-clay sediments. Should the means for each parameter from all sites be used for comparison to outfall parameters or should only the reference site(s) nearest to an outfall be used? The data included in this report will be useful in evaluation of these, and many other questions about monitoring.

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APPENDICES

APPENDIX 1

TABLE OF STATION LOCATIONS, SAMPLING DATES, AND VESSELS USED

STATION	Loran C LI	Loran C L2	DATE	VESSEL
R4-30	27910.0	41708.3	7 AUG 85	MARINE SURVEYOR
R4-60	27910.2	41704.3	"	"
R4-150	27909.8	41695.3	"	"
R5-30	27928.0	41682.1	"	"
R5-60	27928.0	41678.2	"	"
R5-150	27928.2	41665.2	"	"
R8-30	27994.5	41566.5	8 AUG 85	"
R8-60	27993.3	41556.8	"	"
R8-150	27991.0	41540.2	"	"
R11-30	28043.0	41422.0	9 OCT 85	SEAWATCH
R11-60	28038.3	41427.8	"	"
R11-150	28032.0	41433.4	"	"
R13-30	28073.2	41345.0	6 AUG 85	MARINE SURVEYOR
R13-60	28069.0	41344.0	"	"
R13-150	28068.4	41344.0	"	"
R15-30	28118.0	41246.2	9 OCT 85	SEAWATCH
R15-60	28117.0	41246.2	"	"
R15-150	28113.5	41245.8	"	"
R50-30	28246.5	40835.0	17 SEPT 85	WESTWIND
R50-60	28244.7	40835.5	"	"
R50-150	28243.5	40836.0	"	"
R52-30	28254.8	40788.2	18 JULY 85	"
R52-60	28252.8	40790.0	17 SEPT 85	"
R52-150	28250.4	40794.7	"	"
R54-30	28262.7	40744.8	19 SEPT 85	"
R54-60	28260.2	40747.3	17 SEPT 85	"
R54-150	28256.1	40750.2	18 SEPT 85	WESTWIND
R57-30	28276.1	40671.1	"	"
R57-60	28275.2	40675.2	"	"
R57-150	28272.8	40681.3	"	"
R60-30	28272.3	40631.7	26 SEPT 85	MONITOR III
R60-60	28170.9	40633.5	"	"
R60-150	28271.5	40636.9	"	"
R61-60	28262.0	40639.0	"	"
R71-30	28261.8	40588.0	27 SEPT 85	"
R71-60	28253.8	40606.0	"	"
R71-150	28248.0	40621.2	"	"

APPENDIX 2

METHODS OF ANALYSIS

A. TVS

B. TOC

C. Sediment Grain-Size

D. Trace Metals

E. Trace organics and lipids

F. Numerical analyses of biological data
   a. Classification analysis
   b. Weighted discriminant analysis

A. Total Volatile Solids

Total Volatile Solids (TVS) or total organic material, was measured using the methods of Byers et al., (1978). Approximately 4 grams of the top 2 cm of surface sediment is dried at 60°C, weighed, then ashed at 500°C for 5 hours and placed in a dessicator until cool. The ash weight is measured and % TVS calculated using the following formula:

$$\% \text{ TVS} = \frac{\text{Dry Wt.} - \text{Ash Wt.}}{\text{Dry Wt.}} \times 100$$

B. Total Organic Carbon

Sediment samples for analysis of total organic carbon were oven dried at 60°C for 24 hours. Analysis was conducted by Global Geochemistry (6919 Eton Ave., Canoga Park, CA 91303) using a LECO model WR12 Carbon Analyzer.

C. Sand, Silt, Clay Analysis

The sample was thoroughly homogenized by stirring or shaking. Approximately 20-40 g was subsampled and placed in a 1000 ml beaker or flask. For sandy sediments, more was used (~40 g); for finer sediments less was used (~20 g). Twenty-five ml 10% hydrogen peroxide was added to digest organic material. When frothing ceased, an additional 10 ml hydrogen peroxide was added and the sample was boiled to remove any excess hydrogen peroxide. Care was taken to avoid boiling over the sample.

The sample was separated into sand and silt/clay fractions by wet sieving through a 63 µm stainless steel sieve. The silt/clay fraction that passed through the sieve was collected and the sand fraction was retained on the sieve. The bottom of the sieve was wrapped with foil, to prevent loss of sample, and the sample was dried at 40-50°C.

The silt/clay fraction was transferred to a 1000 ml graduated cylinder and allowed to stand until most of the particles had settled (over night). The water was decanted into 500 ml polypropylene bottles and centrifuged for 20 minutes at 1000 RPM. The clear water from the centrifuged bottles was siphoned off and the remaining fine residue was washed back into the graduated cylinder. Twenty-five ml of 1% Calgon solution was added to the silt/clay fraction to prevent flocculation of the sediment particles.

The sample was then adjusted to 1000 ml with distilled H_2O and observed for flocculation. The sample was vigorously mixed and a 25 ml sample was withdrawn from a depth of 20 cm, 20 seconds after the stirring was stopped (silt fraction). The sample and pipet were rinsed with distilled water into the aluminum dish and dried in a pre-weighed aluminum weighing dish. A 25 ml sample was taken from a depth of 5 cm at the times tabulated by Plumb (1981) and transfered to a pre-weighed aluminum dish (clay fraction). Twenty-five mls of 1% Calgon solution was also dried in a pre-weighed dish to act as a correction factor in the pipette analysis calculations.

After the sand fraction was dried, a sieve was placed over a smooth sheet of paper. A 1-inch soft bristle paint brush was used to brush the particles across the screen until no fine particles continued to pass through the sieve. The fine particles that passed through the 63 µm sieve were dried in a pre-weighed aluminum dish and the dried weight added to the silt fraction. The sieve was inverted and the screen brushed to remove additional sand particles caught in the sieve and added to the sand dish. In the 60-M Survey, % Sand was measured in a similar manner, but the dry sieving step was omitted.

Aluminum dishes containing the samples were dried at 50°C and weighed to the nearest 0.0001 g. Calculations were as follows:

Silt weight = ([Net weight sample - Calgon correction factor] X 40) + Additional silt

Clay Weight = (net weight sample - Calgon correction factor) X 40

Calgon correction factor = (net weight of 25ml Calgon) X .025 (ml of Calgon in sample)

D. Trace Metals in Sediments. Sediment samples were analyzed for silver, cadmium, chromium, copper, nickel, lead, zinc. A wet-ashing technique was used to digest the samples. This moderate digestion procedure extracts most of the metals usually considered to be biologically available, such as those associated with organic matter, sulfides, oxides and those adsorbed on the surface of solids. Metals associated with the silicate minerals (part of the lithogenous fraction) essentially are not biologically available and are not extracted by this procedure.

To prepare samples, approximately 0.5 to 2.0 g of well-mixed sediment are weighed into a glass-covered, 150-ml beaker and dried to constant weight at 75°C. A nitric acid solution (20 ml of 1:1) is added to the dried samples, which are then heated to incipient boiling until about 3 ml of liquid remains; this procedure is then repeated. Then 15 ml of distilled deionized water and 5 ml of concentrated hydrochloric acid are added and the mixture boiled for 20 minutes. After cooling to room temperature, the digestate is then filtered through an acid-washed Whatman No. 40 filter paper (8-micron pore size), and the resulting filtrate is diluted with distilled, deionized water to 50 ml. Analytical blanks are prepared along with the sediment samples, using the same procedures and reagents.

Samples are analyzed on a Varian-Techtron atomic absorption spectrophotometer (Model AA-6) equipped with a simultaneous background corrector (Model BC-6), a premix type of burner, and a carbon-rod atomizer (Model 63). When a sample has a relatively high metals content, the diluted filtrate is aspirated into an air/acetylene flame. The concentrations of trace metals are then determined by comparing the results against known standards. A previous study of matrix interferences in flame atomic absorption revealed no significant interferences in detection of the seven elements in question, given a sample size of up to 2 grams. The approximate detection limits for the metals using this method are as follows:

Metal	Limit (µg/kg)	Metal	Limit (µg/kg)
Silver	0.8	Nickel	1.8
Cadmium	0.4	Lead	3.0
Chromium	1.5	Zinc	0.3
Copper	1.4		

If a metal is present in concentrations below the flame detection limit, a flameless method is used in the analysis; with the flameless procedure, 5 µl of treated solution are injected into a graphite furnace. The silver and cadmium concentrations in some samples from this survey were determined using this method. Matrix interferences are checked, and compensations are made by running seperate spiked samples. The detection limits for silver and cadmium, with the flameless method are approximately 20 and 10 ng/gram, respectively.

All reagents are analytical regeant grade, the water is deionized and distilled, and all standards are prepared by the dilution of 1,000 ppm stock solutions. The glassware and plastic containers are cleaned by soaking in 6 percent nitric acid solution for more than 24 hours and then rinsed in distilled water.

E. Measurement of Trace Organics and Lipids. All glassware was cleaned by washing with soap and water, rinsing with tap water, rinsing with deionized water, and heated to 540°C for 4 hours. All utensils were either stainless steel or Teflon coated and were rinsed with solvent before each use. All solvents were of pesticide quality.

The sediment and tissue samples were extracted by weighing out 1-10 g of sample, adding 8 ml distilled water, 20 ml methanol, 10 ml chloroform and homogenizing for 1 minute with a high speed homogenizer (polytron) equipped with a Titanium blade. Then 10 ml chloroform was added and the sample blended for 30 seconds, followed by adding 10 ml of distilled water and 30 seconds of homogenizing. The sample was then centrifuged at approximately 1000 X to separate the layers. The chloroform layer was removed and the remaining aqueous layer was extracted two more times with 10 ml of chloroform. The combined chloroform extracts were split into 3 fractions; one for archive, one for polynuclear aromatic hydrocarbon (PAH) analysis and one for chlorinated hydrocarbon (CHC) analysis/lipid determination.

Percent lipids were determined by removing the chloroform from that fraction and weighing the residue.

Chlorinated hydrocarbons were determined by re-dissolving the lipid in hexane and eluting the sample through activated Florisil (heated to 700°C for 4 hours) with 45 ml 6% diethyl ether in hexane. The samples were then chromatographed on a Varian Vista 44 system equipped with a split injector at 250°C, a 30 m X 0.25 mm I.D. DB-5 fused silica capillary column (J & W Scientific) which was temperature programmed from 150°C to 274°C at 4°C/min. with a helium carrier velocity of 25 cm/sec, and an electron capture detector heated to 325°C. The internal standard used was Mirex and all calculations were based on response factors for the standards of p,p'-DDE; p,p'-DDD; p,p'-DDT; o,p'-DDE; o,p'-DDD, o,p'-DDT; Aroclor 1242; Aroclor 1254; hexachlorobenzene and lindane.

Polynuclear aromatic hydrocarbons were determined by replacing the chloroform with hexane and reducing the volume to 0.5 ml. The sample was then placed on a column containing activated silica gel (heated to 260°C for 16 hours). The column was then eluted with 20 ml of hexane, the first 5 ml were discarded and the next 15 collected as the aliphatic fraction (F1). Next the column was eluted with 32 ml of 60:40 (hexane:benzene), the first 7 ml were collected in F1 and the remaining 25 ml were collected as the aromatic fraction (F2). Stable isotope labelled standards of naphthalene, acenapthene, phenanthrene, chrysene, and perylene wer added just prior to placing each sample onto the silica gel column. The F2 samples were reduced to 100 ml and anthracene-d10

was assessed as an internal standard. The samples were then analyzed by splitless injection on a Hewlett Packard 5970B GCMS equipped with a 30 x 0.25 mm I.D. DB5 fused silica capillary column (J & W Scientific) with a helium carrier velocity of 25 cm/sec. Each sample was scanned by selected ion monitoring for the major fragment of each compound reported with an ionizing voltage of 1400 volts. Relative response factors were determined for each individual compound using actual standards.

The extraction technique used for this study varies from the 60-M Survey as follows. For the sediments, the samples were oven-dried at 60° C overnight for the 1977 survey. This technique has been shown to cause an unpredictable loss of up to 50% for the DDTs and PCBs (Roger Baird, L.A. County Sanitation District, personal Communication). Therefore, for the 1985 survey, we switched to a wet extraction technique. For the tissues, we used acetonitrite as the extraction solvent and for the 1985 survey, we used chloroform and methanol. This change in our tissue extraction technique has been shown to produce comparable results. The final difference between the 1977 and 1985 surveys was the change from packed column to capillary column, which did not significantly affect the results.

F. Numercial analyses of biological data.

An agglomerative, hierarchical clustering method, called flexible sorting strategy (Clifford and Stephenson, 1975), was used to create a dendrogram showing the biological relationships between the sites and groups of sites. The flexible coefficient associated with this method was set at the usual value of -0.25. The dissimilarities used in the computations were euclidean distances between the respective sites in a nonmetric multidimensional scaling (NMS) ordination space (Smith and Bernstein, 1985; Smith et al., in press). The Bray-Curtis dissimilarity index (Clifford and Stephenson, 1975), with all dissimilarities greater than .8 reestimated with the step-across procedure (Williamson, 1978; Smith, 1984), was used in the NMS computations.

The species were also classified into groups using flexible sorting. The inter-species dissimilarities utilized were the Euclidean distances between the weighted mean positions of the species in the NMS ordination space. The weights in the weighted mean were the square-root transformed species abundance values. When the dissimilarities are defined in this manner, species which are relatively abundant in similar habitats will be associated with low dissimilarity values (Smith et al., in press).

The dendrograms from the site and species classifications were used to create two-way coincidence tables (Clifford and Stephenson, 1975), which show the patterns of species among the sites.

b) Discriminant Analysis

The relationships between the groups defined in the classification analyses and the environment can be studied with discriminant analysis (Bernstein et al., 1978; Green and Vascotto, 1978; Shin, 1982). With this technique, a theoretical multidimensional space with the dimensions or axes corresponding to the environmental variables is set up. The axes are then rotated so that projections onto the axes will maximally separate the groups of stations defined in the cluster analysis (Campbell and Atchley, 1981). The scores on the different axes will be uncorrelated. Coefficients of separate determination (Hope, 1969) were used to indicate which environmental variables are important in determining the position of a sample on the respective axes. Such variables may be related to features in the environment which caused the biological differences displayed in the cluster analysis. The first axis will account for the most group separation, and the last axis the least.

A modified version of discriminant analysis called weighted discriminant analysis (Smith, 1976, 1979; Helvey and Smith, 1985; Mahon et al., 1984; Thompson and Jones, 1987) was used. Here, the usual calculations are modified to utilize within- and between-group biological information. This makes the analysis more sensitive to the biological patterns in the data. Regular discriminant analysis only considers which stations are in which group; no further within- and between-group biological information is utilized.

The biological information utilized in the computations is contained in a set of weights which indicate how well each site "fits" into each site group. The weights are used to compute weighted means and weighted cross-products in the calculation of the usual sums of cross-products matrices (which are unweighted in the usual computations). All other computations are identical to unwieghted analyses. The weights are the average similarity between the site and group in question. The similarities are derived from the same dissimilarity values used in the cluster analysis.

APPENDIX 3

LIST OF TAXONOMISTS

SORTERS
Andrea Huvard
Debbie Brown

TAXONOMISTS

Polychaetes
Leslie Harris, Marine Biological Consultants, Costa Mesa, CA
Jim Laughlin, SCCWRP
Dr. John Dorsey, Hyperion Treatment Plant

Crustaceans
Jim Laughlin, SCCWRP
Jim Roney, Hyperion Treatment Plant
Ann Martin, Hyperion Treatment Plant

Molluscans
David Tsukada, SCCWRP

Echinoderms
Jim Laughlin, SCCWRP
David Tsukada, SCCWRP
Dr. Mary Bergen, Allan Hancock Foundation, U.S.C.

Sipuncula, Echiura, Ascidians
Dr. Bruce Thompson, SCCWRP

Cnidaria
John Ljubenkov, La Mer Taxonomics, San Pedro, CA

Nemertea
David Tsukada, SCCWRP
Dr. Bruce Thompson, SCCWRP

Fish
Dario Diehl, SCCWRP
Dr. John Dorsey, Hyperion Treatment Plant
Pat Hershelman, SCCWRP
Mike Moore, County Sanitation Districts of Orange County
Jim Roney, Hyperion Treatment Plant

APPENDIX 4
TISSUE CHEMISTRY COMPOSITE INFORMATION

STATION	SPECIES	NUMBER COMPOSITED	SIZE RANGE (mm TOTAL OR CARAPACE LENGTH)	SEX
R4-60	Dover sole	8	127-206	M or J
	Sicyonia ingentis	20	30-41	F
R4-150	Dover sole	4	166-273	M & ?
	S. ingentis	18	32-48	M & F
R5-60	Dover sole	7	102-186	J or M
	S. ingentis	20	32-42	M & F
R5-150	Pacific sanddab	5	183-246	F
	S. ingentis	20	40-48	F
R8-30	white croaker	10	192-255	M & F
R8-60	S. ingentis	30	20-39	M & F
R8-150	Pacific sanddab	7	206-251	M & F
	S. ingentis	21	33-47	M & F
R11-150	Pacific sanddab	5	223-245	F
	S. ingentis	2	33-40	M
R13-60	Pacific sanddab	8	157-242	M & F
	S. ingentis	21	20-30	M & F
R13-150	gulf sanddab	5	163-297	M & F
	S. ingentis	17	29-51	M & F
R15-60	S. ingentis	13	22-47	M & F
R15-150	Pacific sanddab	8	146-212	F
	S. ingentis	25	28-39	M & F
R50-60	longfin sanddab	4	170-188	M & F
	S. ingentis	30	25-43	M & F
R50-150	Dover sole	15	80-192	M & J
	S. ingentis	21	35-50	M & F
R52-60	longfin sanddab	8	159-179	M & F
	S. ingentis	20	27-44	M & F
R52-150	Pacific sanddab	8	168-240	M & F
	S. ingentis	20	36-48	M & F
R54-60	longfin sanddab	10	162-202	M & F
	S. ingentis	22	22-31	M & F
R54-150	Pacific sanddab	6	250-306	M & F
	S. ingentis	15	38-52	F
R57-60	longfin sanddab	8	179-245	M & F
	S. ingentis	20	25-40	M & F
R60-60	longfin sanddab	8	122-256	M & F
R60-150	gulf sanddab	8	130-180	M & F
	S. ingentis	20	35-46	M & F
R61-60	longfin sanddab	7	145-189	M & F
	S. ingentis	5	19-25	M & F
R61-150	Pacific sanddab	5	183-303	F
R71-150	Pacific sanddab	5	228-288	M & F
	S. ingentis	15	41-53	M & F

APPENDIX 5

DISTRIBUTION OF PARAMETERS MEASURED AT THE REFERENCE SITES

LIST OF FIGURES AND TABLES

APPENDIX 5, LIST OF FIGURES AND TABLES
(continued)

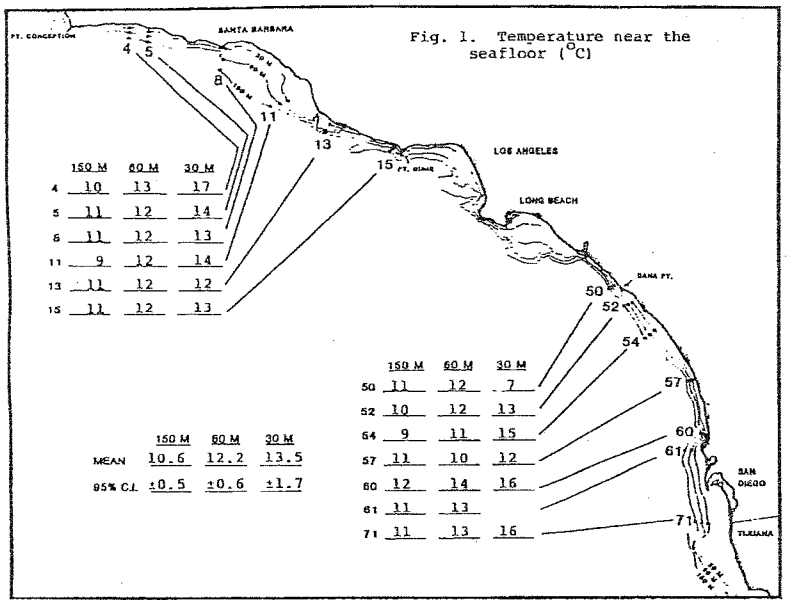


Fig. 1. Temperature near the seafloor (°C)

	150 M	60 M	30 M
4	10	13	17
5	11	12	14
8	11	12	13
11	9	12	14
13	11	12	12
15	11	12	13
50	11	12	7
52	10	12	13
54	9	11	15
57	11	10	12
60	12	14	16
61	11	13	
71	11	13	16
MEAN	10.6	12.2	13.5
95% C.I.	±0.5	±0.6	±1.7

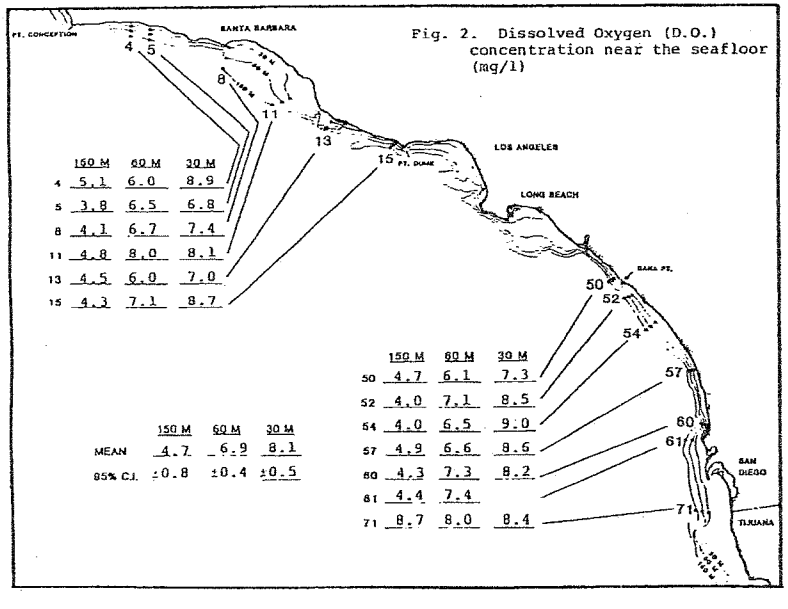


Fig. 2. Dissolved Oxygen (D.O.) concentration near the seafloor (mg/l)

	150 M	60 M	30 M
4	5.1	6.0	8.9
5	3.8	6.5	6.8
8	4.1	6.7	7.4
11	4.8	8.0	8.1
13	4.5	6.0	7.0
15	4.3	7.1	8.7
50	4.7	6.1	7.3
52	4.0	7.1	8.5
54	4.0	6.5	9.0
57	4.9	6.6	8.6
60	4.3	7.3	8.2
61	4.4	7.4	
71	8.7	8.0	8.4
MEAN	4.7	6.9	8.1
95% C.I.	±0.8	±0.4	±0.5

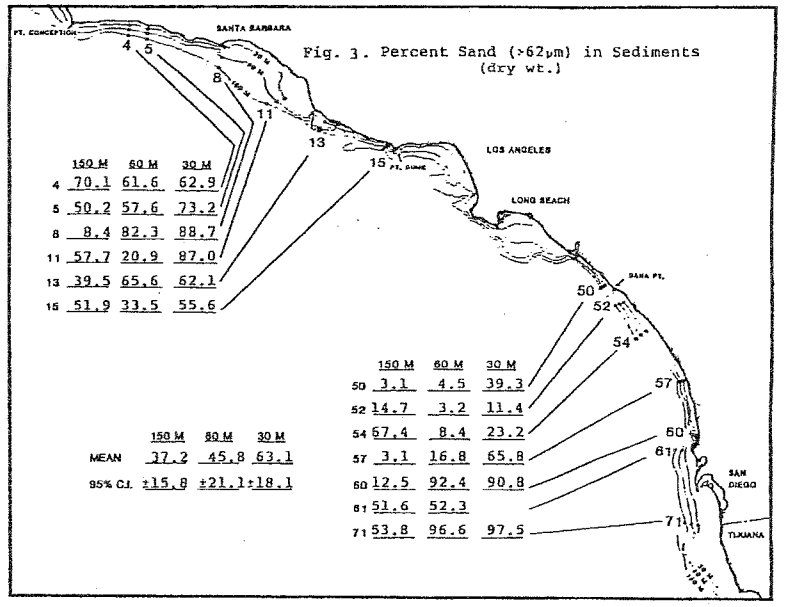


Fig. 3. Percent Sand (>62μm) in Sediments (dry wt.)

	150 M	60 M	30 M
4	70.1	61.6	62.9
5	50.2	57.6	73.2
8	8.4	82.3	88.7
11	57.7	20.9	87.0
13	39.5	65.6	62.1
15	51.9	33.5	55.6
50	3.1	4.5	39.3
52	14.7	3.2	11.4
54	67.4	8.4	23.2
57	3.1	16.8	65.8
60	12.5	92.4	90.8
61	51.6	52.3	
71	53.8	96.6	97.5
MEAN	37.2	45.8	63.1
95% C.I.	±15.8	±21.1	±18.1

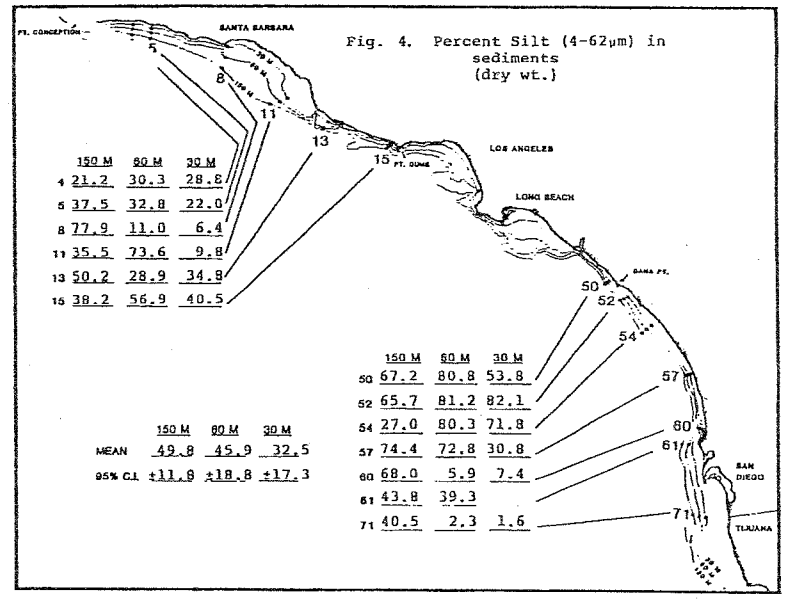


Fig. 4. Percent Silt (4-62μm) in sediments (dry wt.)

	150 M	60 M	30 M
4	21.2	30.3	28.8
5	37.5	32.8	22.0
8	77.9	11.0	6.4
11	35.5	73.6	9.8
13	50.2	28.9	34.8
15	38.2	56.9	40.5
50	67.2	80.8	53.8
52	65.7	81.2	82.1
54	27.0	80.3	71.8
57	74.4	72.8	30.8
60	68.0	5.9	7.4
61	43.8	39.3	
71	40.5	2.3	1.6
MEAN	49.8	45.9	32.5
95% C.I.	±11.9	±18.8	±17.3

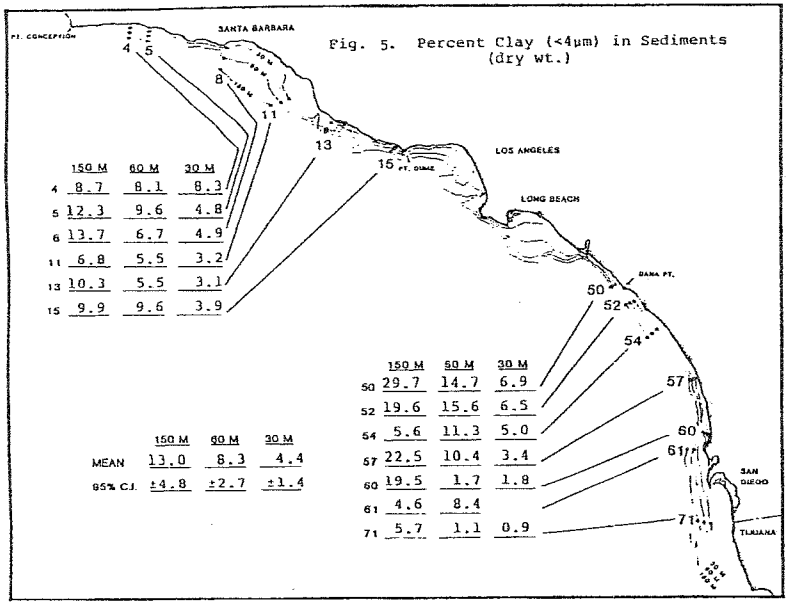


Fig. 5. Percent Clay (<4μm) in Sediments (dry wt.)

	150 M	60 M	30 M
4	8.7	8.1	8.3
5	12.3	9.6	4.8
6	13.7	6.7	4.9
11	6.8	5.5	3.2
13	10.3	5.5	3.1
15	9.9	9.6	3.9

	150 M	60 M	30 M
50	29.7	14.7	6.9
52	19.6	15.6	6.5
54	5.6	11.3	5.0
57	22.5	10.4	3.4
60	19.5	1.7	1.8
61	4.6	8.4	
71	5.7	1.1	0.9

	150 M	60 M	30 M
MEAN	13.0	8.3	4.4
95% C.I.	±4.8	±2.7	±1.4

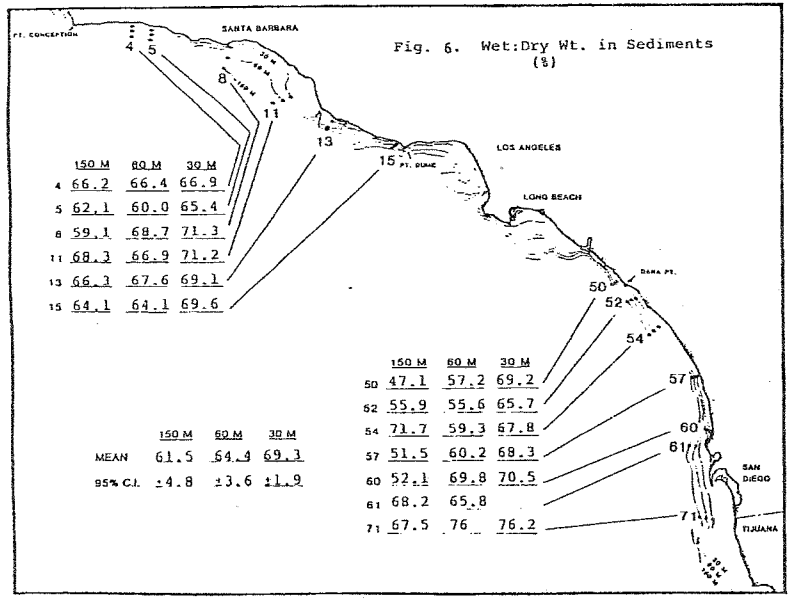


Fig. 6. Wet:Dry Wt. in Sediments (%)

	150 M	60 M	30 M
4	66.2	66.4	66.9
5	62.1	60.0	65.4
8	59.1	68.7	71.3
11	68.3	66.9	71.2
13	66.3	67.6	69.1
15	64.1	64.1	69.6

	150 M	60 M	30 M
50	47.1	57.2	69.2
52	55.9	55.6	65.7
54	71.7	59.3	67.8
57	51.5	60.2	68.3
60	52.1	69.8	70.5
61	68.2	65.8	
71	67.5	76	76.2

	150 M	60 M	30 M
MEAN	61.5	64.4	69.3
95% C.I.	±4.8	±3.6	±1.9

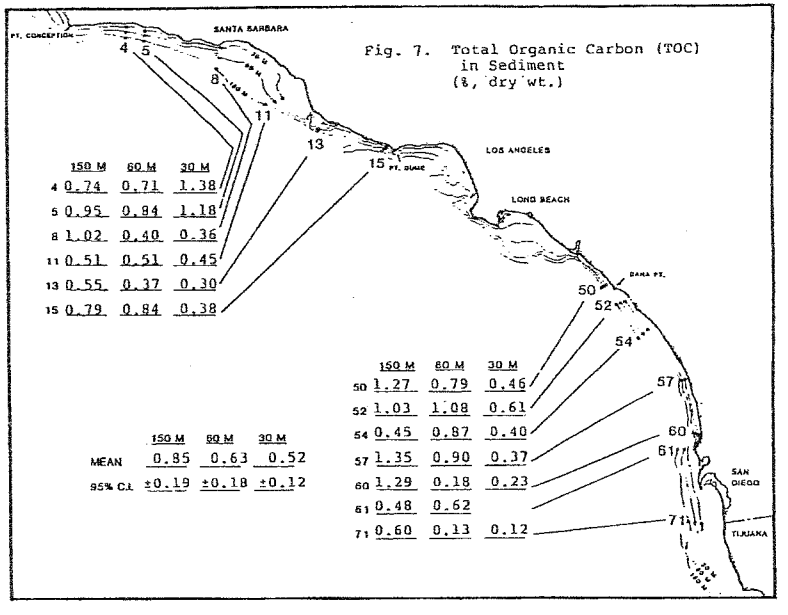


Fig. 7. Total Organic Carbon (TOC) in Sediment (%, dry wt.)

	150 M	60 M	30 M
4	0.74	0.71	1.38
5	0.95	0.84	1.18
8	1.02	0.40	0.36
11	0.51	0.51	0.45
13	0.55	0.37	0.30
15	0.79	0.84	0.38

	150 M	60 M	30 M
50	1.27	0.79	0.46
52	1.03	1.08	0.61
54	0.45	0.87	0.40
57	1.35	0.90	0.37
60	1.29	0.18	0.23
61	0.48	0.62	
71	0.60	0.13	0.12

	150 M	60 M	30 M
MEAN	0.85	0.63	0.52
95% C.I.	±0.19	±0.18	±0.12

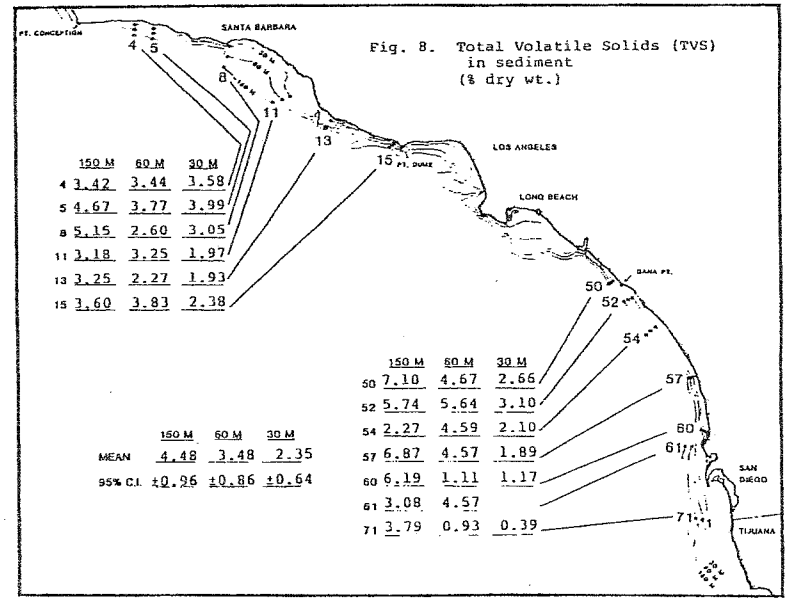
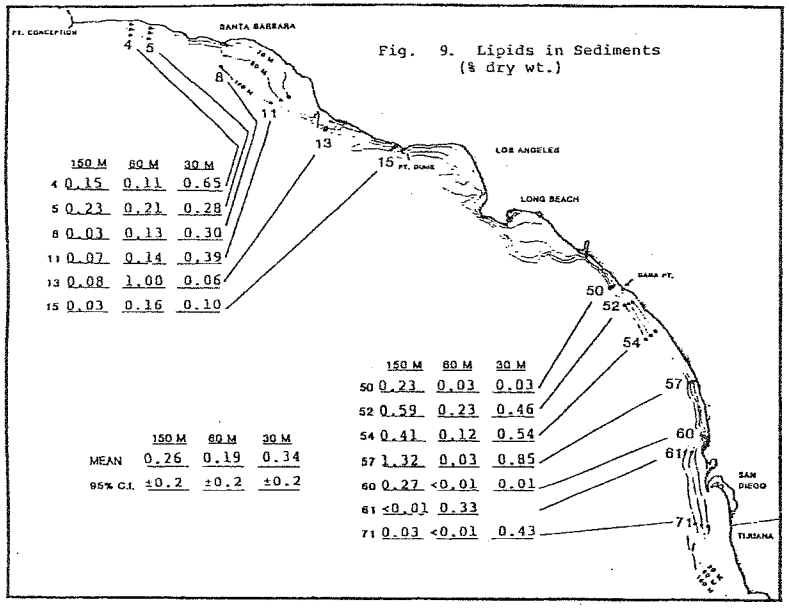


Fig. 8. Total Volatile Solids (TVS) in sediment (% dry wt.)

	150 M	60 M	30 M
4	3.42	3.44	3.58
5	4.67	3.77	3.99
8	5.15	2.60	3.05
11	3.18	3.25	1.97
13	3.25	2.27	1.93
15	3.60	3.83	2.38

	150 M	60 M	30 M
50	7.10	4.67	2.66
52	5.74	5.64	3.10
54	2.27	4.59	2.10
57	6.87	4.57	1.89
60	6.19	1.11	1.17
61	3.08	4.57	
71	3.79	0.93	0.39

	150 M	60 M	30 M
MEAN	4.48	3.48	2.35
95% C.I.	±0.96	±0.86	±0.64

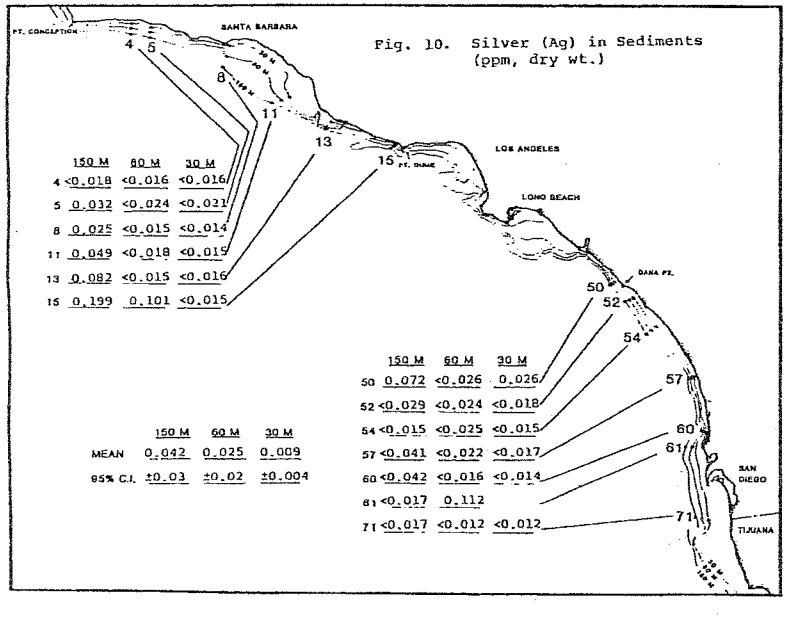


	150 M	60 M	30 M
4	0.15	0.11	0.65
5	0.23	0.21	0.28
8	0.03	0.13	0.30
11	0.07	0.14	0.39
13	0.08	1.00	0.06
15	0.03	0.16	0.10

	150 M	60 M	30 M
50	0.23	0.03	0.03
52	0.59	0.23	0.46
54	0.41	0.12	0.54
57	1.32	0.03	0.85
60	0.27	<0.01	0.01
61	<0.01	0.33	
71	0.03	<0.01	0.43

	150 M	60 M	30 M
MEAN	0.26	0.19	0.34
95% C.I.	±0.2	±0.2	±0.2

Fig. 9. Lipids in Sediments
(% dry wt.)

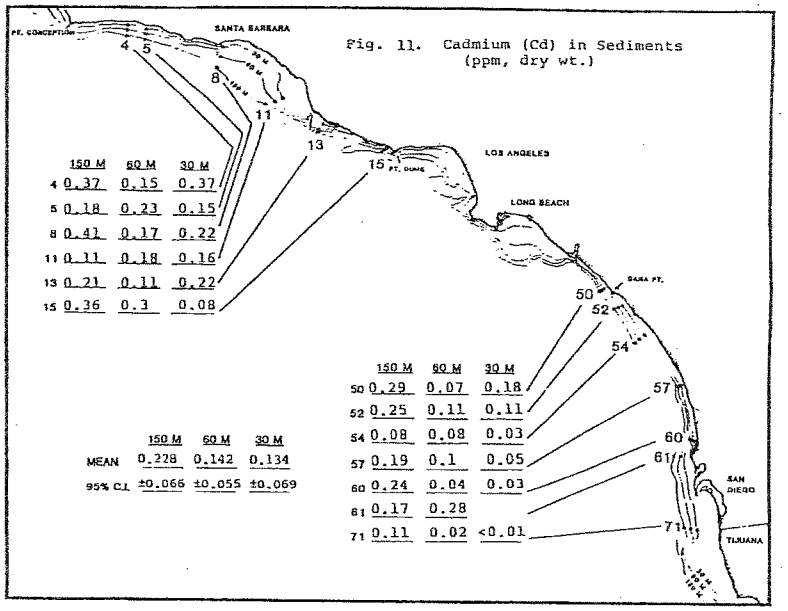


	150 M	60 M	30 M
4	<0.018	<0.016	<0.016
5	0.032	<0.024	<0.031
8	0.025	<0.015	<0.014
11	0.049	<0.018	<0.019
13	0.082	<0.015	<0.016
15	0.199	0.101	<0.015

	150 M	60 M	30 M
50	0.072	<0.026	0.026
52	<0.029	<0.024	<0.018
54	<0.015	<0.025	<0.015
57	<0.041	<0.022	<0.017
60	<0.042	<0.016	<0.014
61	<0.017	0.112	
71	<0.017	<0.012	<0.012

	150 M	60 M	30 M
MEAN	0.042	0.025	0.009
95% C.I.	±0.03	±0.02	±0.004

Fig. 10. Silver (Ag) in Sediments
(ppm, dry wt.)

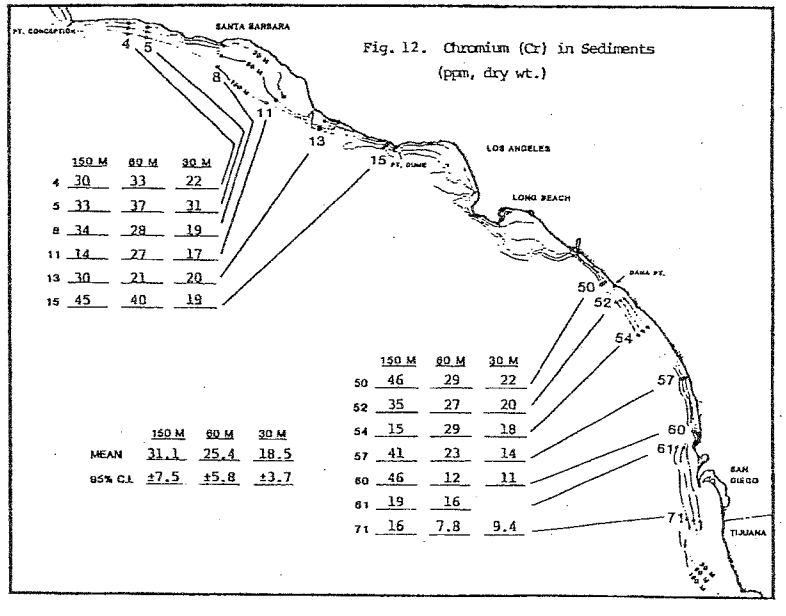


	150 M	60 M	30 M
4	0.37	0.15	0.37
5	0.18	0.23	0.15
8	0.41	0.17	0.22
11	0.11	0.18	0.16
13	0.21	0.11	0.22
15	0.36	0.3	0.08

	150 M	60 M	30 M
50	0.29	0.07	0.18
52	0.25	0.11	0.11
54	0.08	0.08	0.03
57	0.19	0.1	0.05
60	0.24	0.04	0.03
61	0.17	0.28	
71	0.11	0.02	<0.01

	150 M	60 M	30 M
MEAN	0.228	0.142	0.134
95% C.I.	±0.066	±0.055	±0.069

Fig. 11. Cadmium (Cd) in Sediments
(ppm, dry wt.)



	150 M	60 M	30 M
4	30	33	22
5	33	37	31
8	34	28	19
11	14	27	17
13	30	21	20
15	45	40	19

	150 M	60 M	30 M
50	46	29	22
52	35	27	20
54	15	29	18
57	41	23	14
60	46	12	11
61	19	16	
71	16	7.8	9.4

	150 M	60 M	30 M
MEAN	31.1	25.4	18.5
95% C.I.	±7.5	±5.8	±3.7

Fig. 12. Chromium (Cr) in Sediments
(ppm, dry wt.)

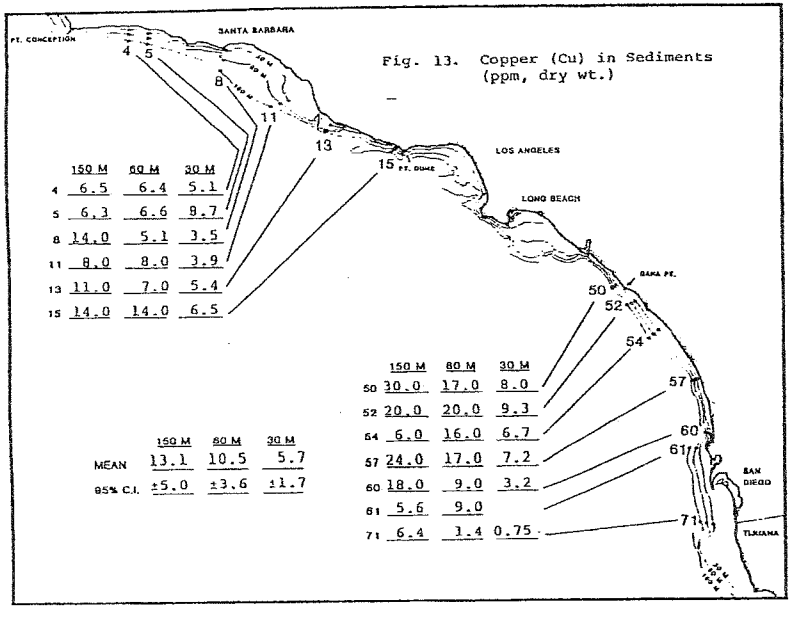


Fig. 13. Copper (Cu) in Sediments (ppm, dry wt.)

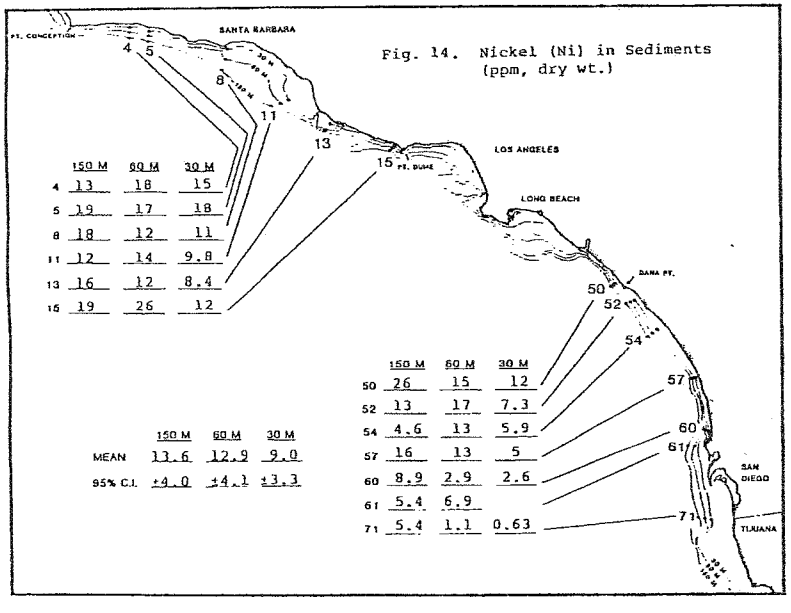


Fig. 14. Nickel (Ni) in Sediments (ppm, dry wt.)

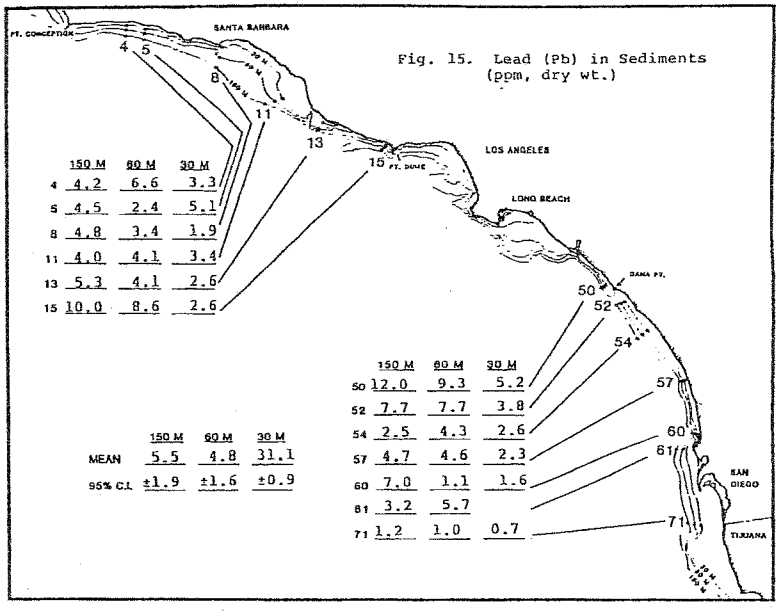


Fig. 15. Lead (Pb) in Sediments (ppm, dry wt.)

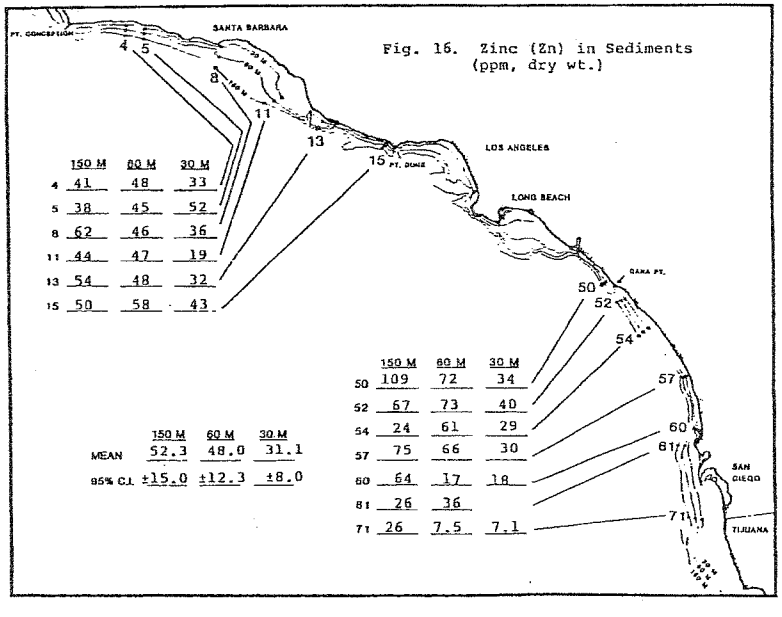


Fig. 16. Zinc (Zn) in Sediments (ppm, dry wt.)

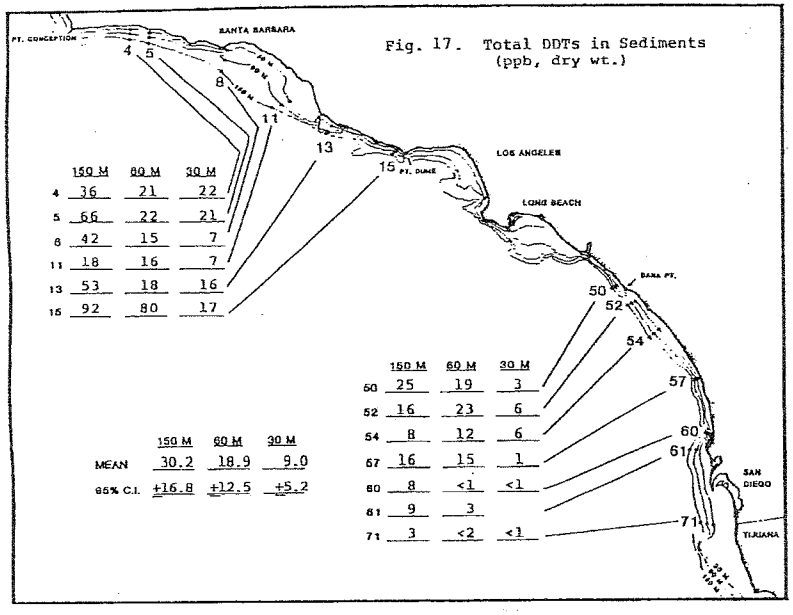


Fig. 17. Total DDTs in Sediments (ppb, dry wt.)

	150 M	60 M	30 M
4	36	21	22
5	66	22	21
8	42	15	7
11	18	16	7
13	53	18	16
15	92	80	17
50	25	19	3
52	16	23	6
54	8	12	6
57	16	15	1
60	8	<1	<1
61	9	3	
71	3	<2	<1
MEAN	30.2	18.9	9.0
95% C.I.	±16.8	±12.5	±5.2

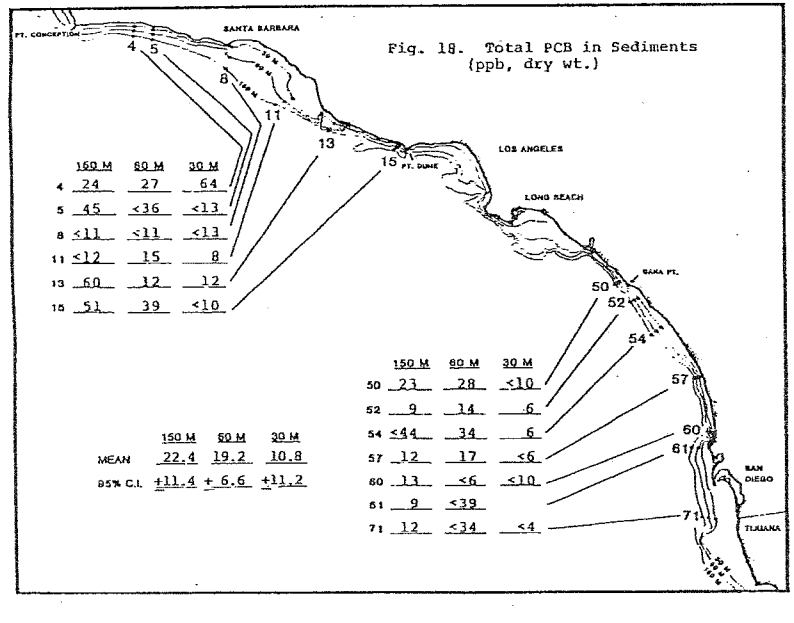


Fig. 18. Total PCB in Sediments (ppb, dry wt.)

	150 M	60 M	30 M
4	24	27	64
5	45	<36	<13
8	<11	<11	<13
11	<12	15	8
13	60	12	12
15	51	39	<10
50	23	28	<10
52	9	14	6
54	<44	34	6
57	12	17	<6
60	13	<6	<10
61	9	<39	
71	12	<34	<4
MEAN	22.4	19.2	10.8
95% C.I.	±11.4	± 6.6	±11.2

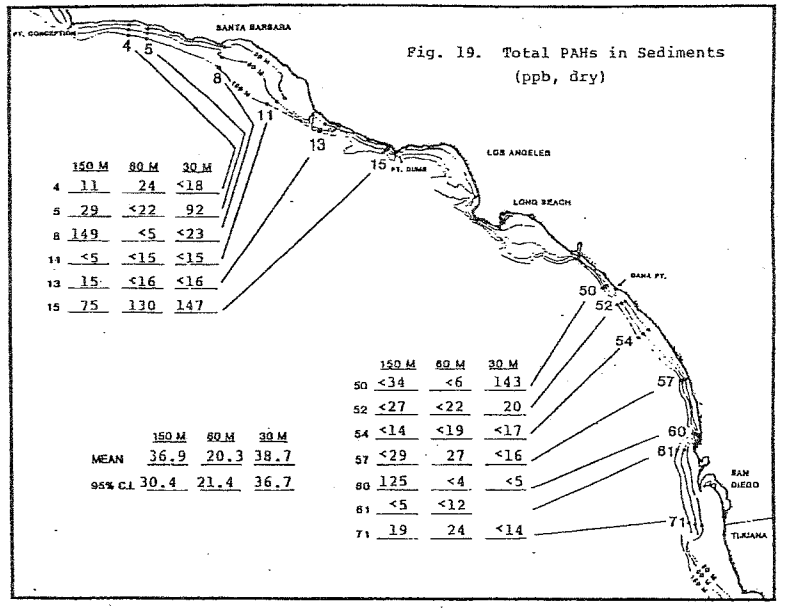


Fig. 19. Total PAHs in Sediments (ppb, dry)

	150 M	60 M	30 M
4	11	24	<18
5	29	<22	92
8	149	<5	<23
11	<5	<15	<15
13	15	<16	<16
15	75	130	147
50	<34	<6	143
52	<27	<22	20
54	<14	<19	<17
57	<29	27	<16
60	125	<4	<5
61	<5	<12	
71	19	24	<14
MEAN	36.9	20.3	38.7
95% C.I.	30.4	21.4	36.7

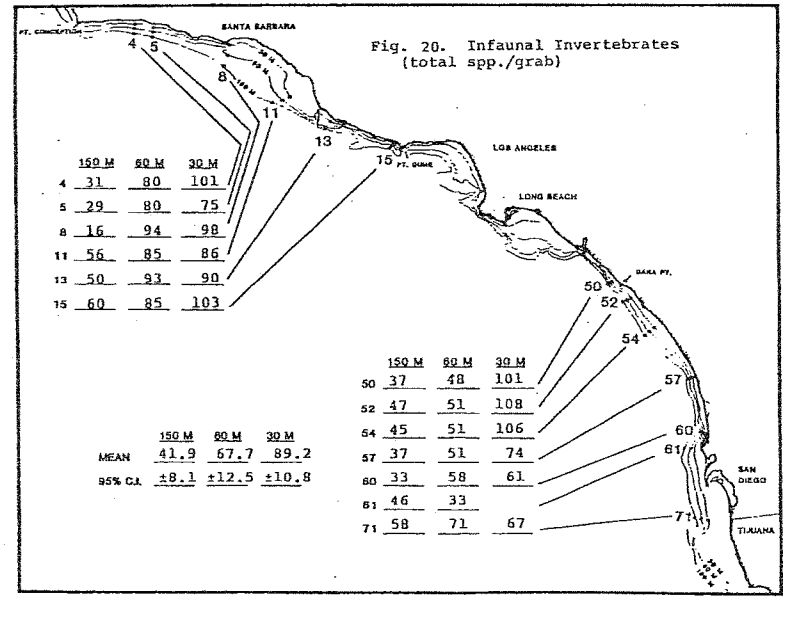


Fig. 20. Infaunal Invertebrates (total spp./grab)

	150 M	60 M	30 M
4	31	80	101
5	29	80	75
8	16	94	98
11	56	85	86
13	50	93	90
15	60	85	103
50	37	48	101
52	47	51	108
54	45	51	106
57	37	51	74
60	33	58	61
61	46	33	
71	58	71	67
MEAN	41.9	67.7	89.2
95% C.I.	±8.1	±12.5	±10.8

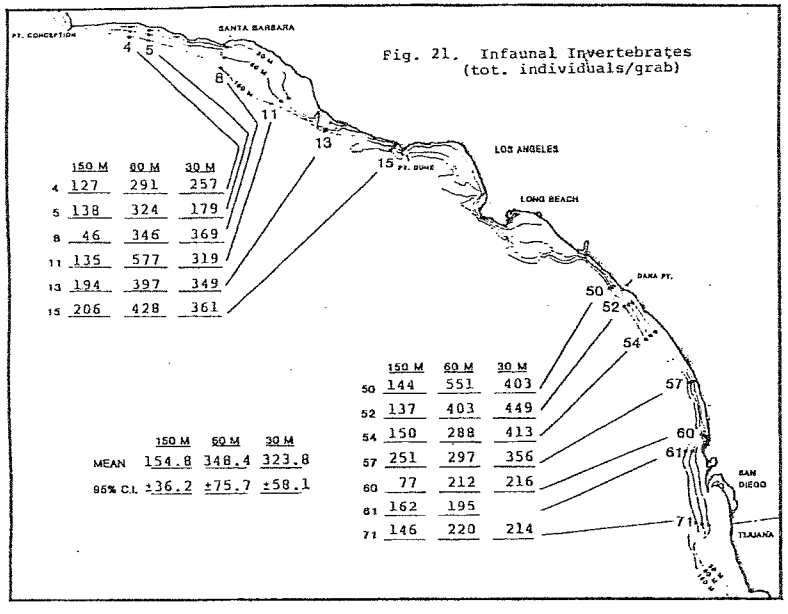


Fig. 21. Infaunal Invertebrates (tot. individuals/grab)

	150 M	60 M	30 M
4	127	291	257
5	138	324	179
8	46	346	369
11	135	577	319
13	194	397	349
15	206	428	361
50	144	551	403
52	137	403	449
54	150	288	413
57	251	297	356
60	77	212	216
61	162	195	
71	146	220	214
MEAN	154.8	348.4	323.8
95% C.I.	±36.2	±75.7	±58.1

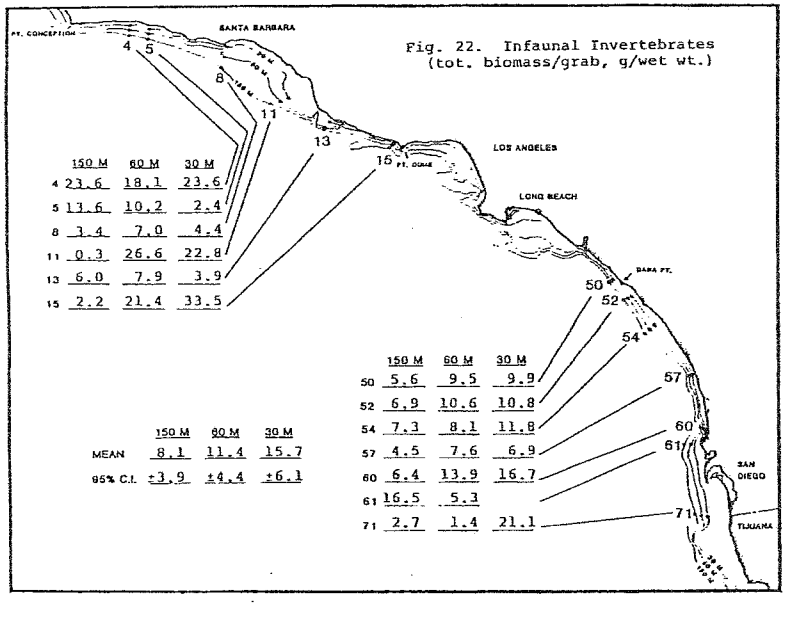


Fig. 22. Infaunal Invertebrates (tot. biomass/grab, g/wet wt.)

	150 M	60 M	30 M
4	23.6	18.1	23.6
5	13.6	10.2	2.4
8	1.4	7.0	4.4
11	0.3	26.6	22.8
13	6.0	7.9	3.9
15	2.2	21.4	33.5
50	5.6	9.5	9.9
52	6.9	10.6	10.8
54	7.3	8.1	11.8
57	4.5	7.6	6.9
60	6.4	13.9	16.7
61	16.5	5.3	
71	2.7	1.4	21.1
MEAN	8.1	11.4	15.7
95% C.I.	±3.9	±4.4	±6.1

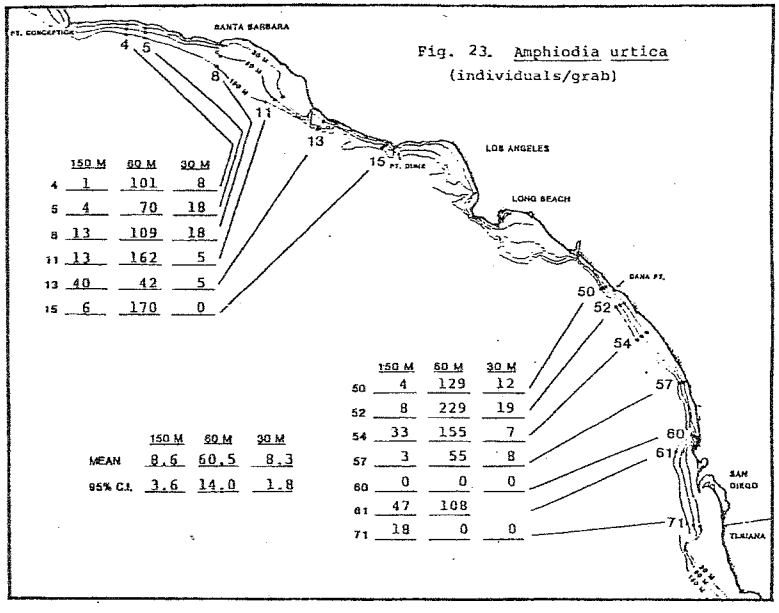


Fig. 23. Amphiodia urtica (individuals/grab)

	150 M	60 M	30 M
4	1	101	8
5	4	70	18
8	13	109	18
11	13	162	5
13	40	42	5
15	6	170	0
50	4	129	12
52	8	229	19
54	33	155	7
57	3	55	8
60	0	0	0
61	47	108	
71	18	0	0
MEAN	8.6	60.5	8.3
95% C.I.	3.6	14.0	1.8

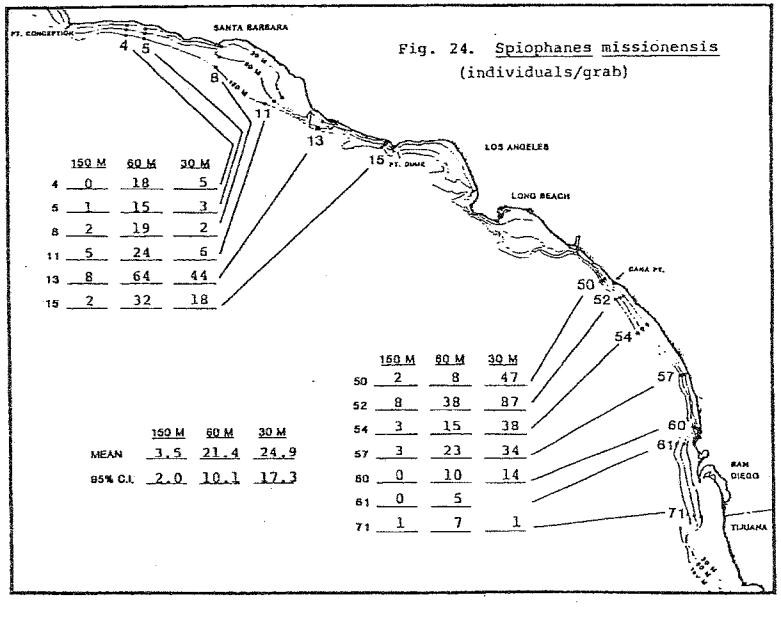


Fig. 24. Spiophanes missionensis (individuals/grab)

	150 M	60 M	30 M
4	0	18	5
5	1	15	3
8	2	19	2
11	5	24	6
13	8	64	44
15	2	32	18
50	2	8	47
52	8	38	87
54	3	15	38
57	3	23	34
60	0	10	14
61	0	5	
71	1	7	1
MEAN	3.5	21.4	24.9
95% C.I.	2.0	10.1	17.3

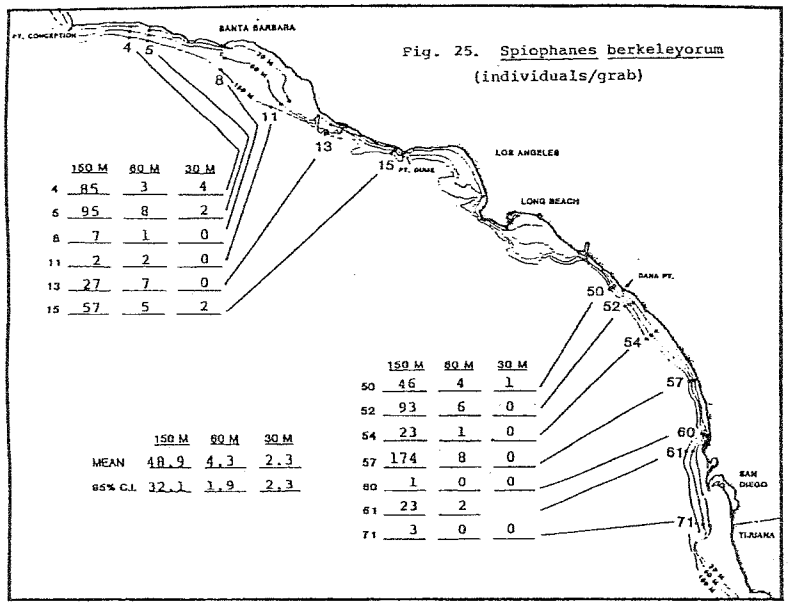


Fig. 25. Spiophanes berkeleyorum (individuals/grab)

	150 M	60 M	30 M
4	85	3	4
5	95	8	2
8	7	1	0
11	2	2	0
13	27	7	0
15	57	5	2
50	46	4	1
52	93	6	0
54	23	1	0
57	174	8	0
60	1	0	0
61	23	2	
71	3	0	0
MEAN	48.9	4.3	2.3
95% C.I.	32.1	1.9	2.3

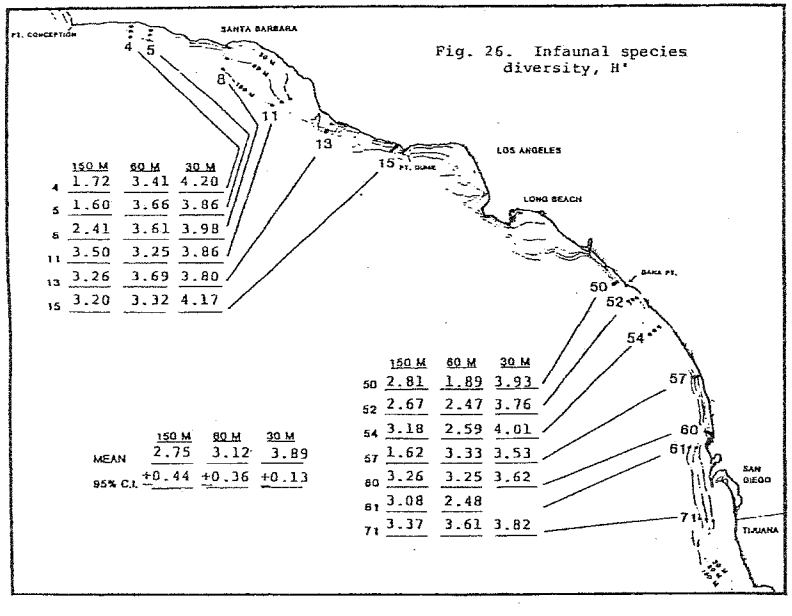


Fig. 26. Infaunal species diversity, H'

	150 M	60 M	30 M
4	1.72	3.41	4.20
5	1.60	3.66	3.86
8	2.41	3.61	3.98
11	3.50	3.25	3.86
13	3.26	3.69	3.80
15	3.20	3.32	4.17
50	2.81	1.89	3.93
52	2.67	2.47	3.76
54	3.18	2.59	4.01
57	1.62	3.33	3.53
60	3.26	3.25	3.62
61	3.08	2.48	
71	3.37	3.61	3.82
MEAN	2.75	3.12	3.89
95% C.I.	±0.44	±0.36	±0.13

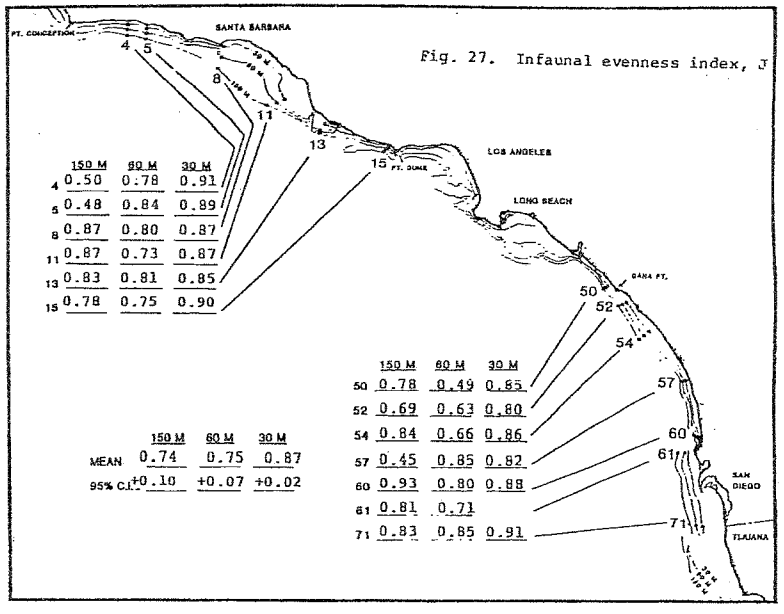


Fig. 27. Infaunal evenness index, J

	150 M	60 M	30 M
4	0.50	0.78	0.91
5	0.48	0.84	0.89
8	0.87	0.80	0.87
11	0.87	0.73	0.87
13	0.83	0.81	0.85
15	0.78	0.75	0.90
50	0.78	0.49	0.85
52	0.69	0.63	0.80
54	0.84	0.66	0.86
57	0.45	0.85	0.82
60	0.93	0.80	0.88
61	0.81	0.71	
71	0.83	0.85	0.91
MEAN	0.74	0.75	0.87
95% C.I.	±0.10	±0.07	±0.02

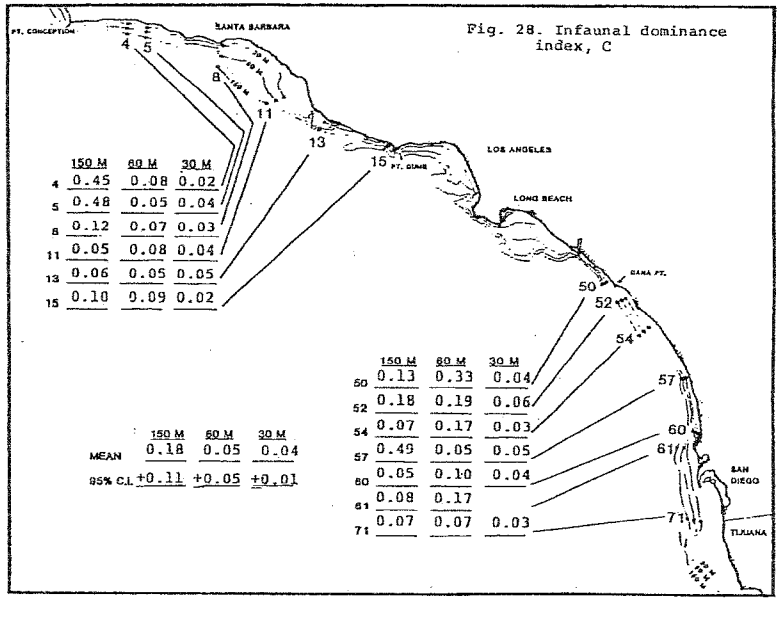


Fig. 28. Infaunal dominance index, C

	150 M	60 M	30 M
4	0.45	0.08	0.02
5	0.48	0.05	0.04
8	0.12	0.07	0.03
11	0.05	0.08	0.04
13	0.06	0.05	0.05
15	0.10	0.09	0.02
50	0.13	0.33	0.04
52	0.18	0.19	0.06
54	0.07	0.17	0.03
57	0.49	0.05	0.05
60	0.05	0.10	0.04
61	0.08	0.17	
71	0.07	0.07	0.03
MEAN	0.18	0.05	0.04
95% C.I.	±0.11	±0.05	±0.01

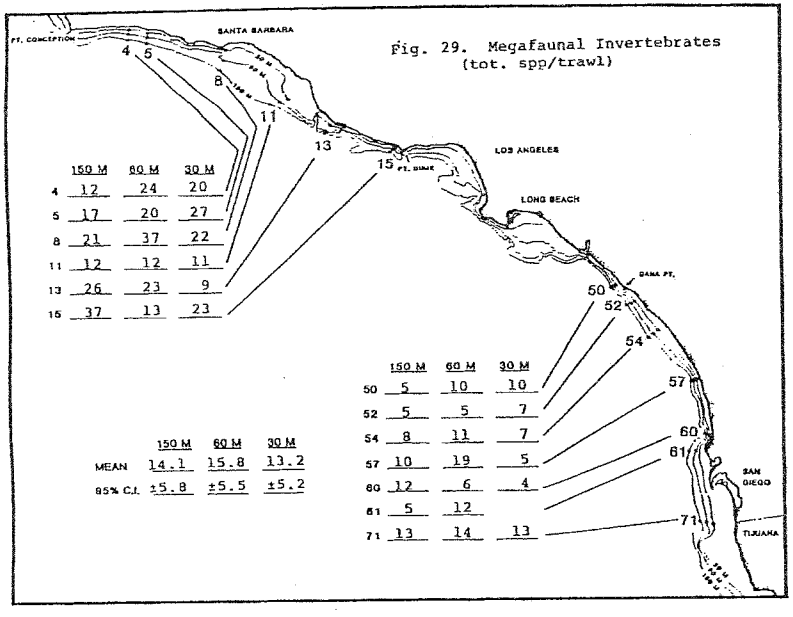


Fig. 29. Megafaunal Invertebrates (tot. spp/trawl)

	150 M	60 M	30 M
4	12	24	20
5	17	20	27
8	21	37	22
11	12	12	11
13	26	23	9
15	37	13	23

	150 M	60 M	30 M
50	5	10	10
52	5	5	7
54	8	11	7
57	10	19	5
60	12	6	4
61	5	12	
71	13	14	13

	150 M	60 M	30 M
MEAN	14.1	15.8	13.2
95% C.I.	±5.8	±5.5	±5.2

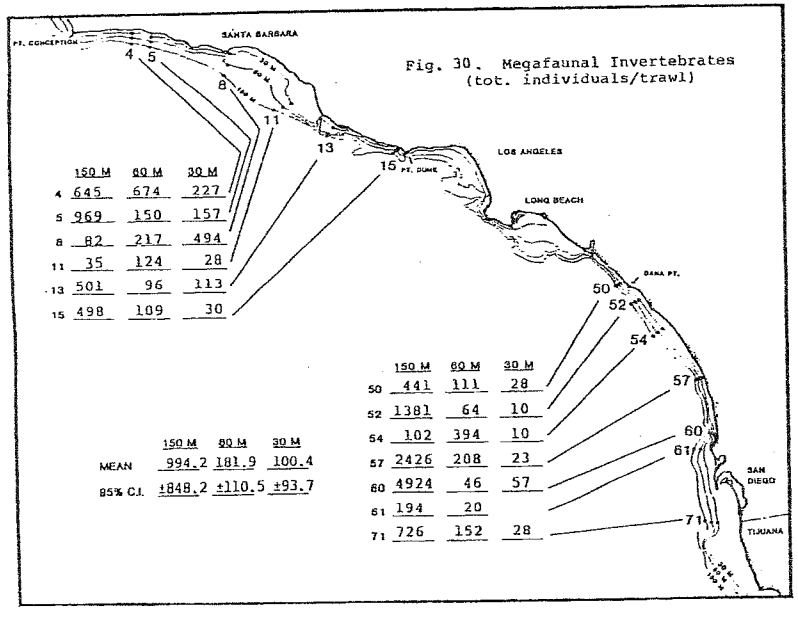


Fig. 30. Megafaunal Invertebrates (tot. individuals/trawl)

	150 M	60 M	30 M
4	645	674	227
5	969	150	157
8	82	217	494
11	35	124	28
13	501	96	113
15	498	109	30

	150 M	60 M	30 M
50	441	111	28
52	1381	64	10
54	102	394	10
57	2426	208	23
60	4924	46	57
61	194	20	
71	726	152	28

	150 M	60 M	30 M
MEAN	994.2	181.9	100.4
95% C.I.	±848.2	±110.5	±93.7

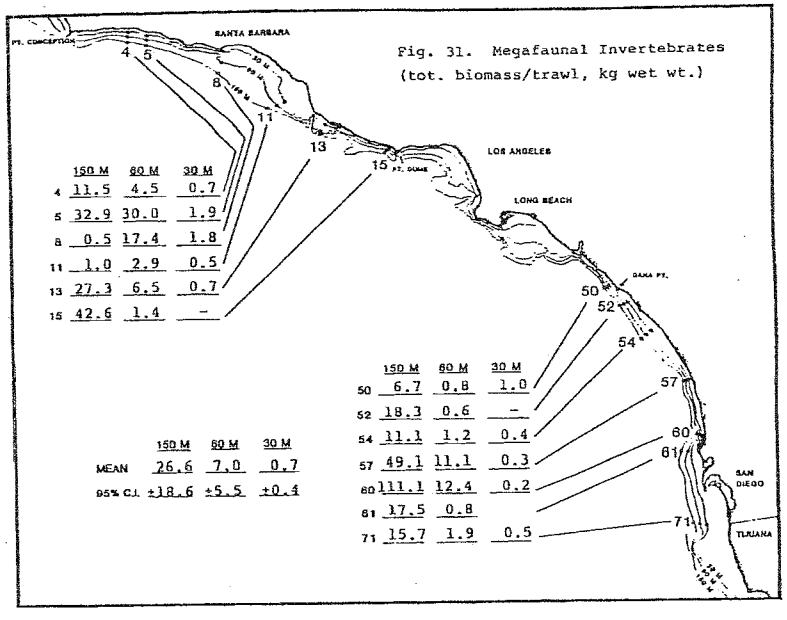


Fig. 31. Megafaunal Invertebrates (tot. biomass/trawl, kg wet wt.)

	150 M	60 M	30 M
4	11.5	4.5	0.7
5	32.9	30.0	1.9
8	0.5	17.4	1.8
11	1.0	2.9	0.5
13	27.3	6.5	0.7
15	42.6	1.4	–

	150 M	60 M	30 M
50	6.7	0.8	1.0
52	18.3	0.6	–
54	11.1	1.2	0.4
57	49.1	11.1	0.3
60	111.1	12.4	0.2
61	17.5	0.8	
71	15.7	1.9	0.5

	150 M	60 M	30 M
MEAN	26.6	7.0	0.7
95% C.I.	±18.6	±5.5	±0.4

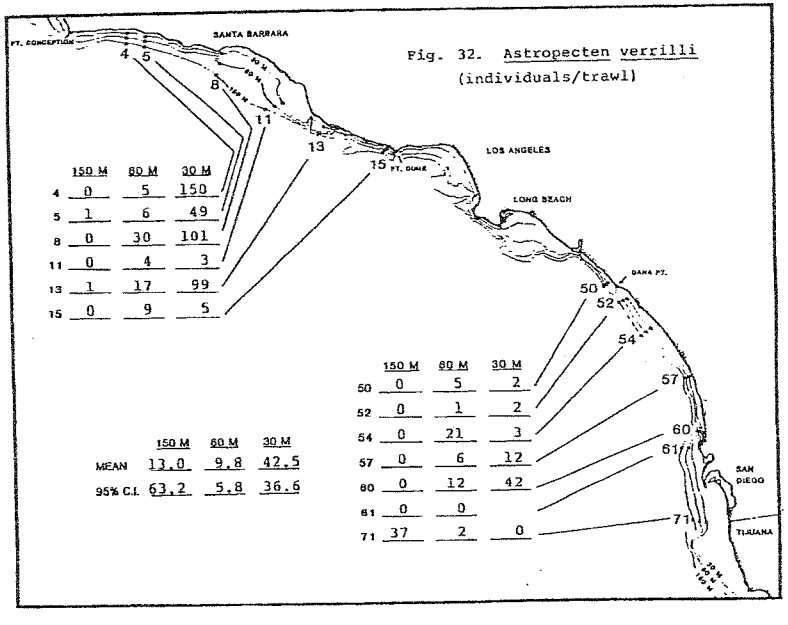


Fig. 32. Astropecten verrilli (individuals/trawl)

	150 M	60 M	30 M
4	0	5	150
5	1	6	49
8	0	30	101
11	0	4	3
13	1	17	99
15	0	9	5

	150 M	60 M	30 M
50	0	5	2
52	0	1	2
54	0	21	3
57	0	6	12
60	0	12	42
61	0	0	
71	37	2	0

	150 M	60 M	30 M
MEAN	13.0	9.8	42.5
95% C.I.	63.2	5.8	36.6

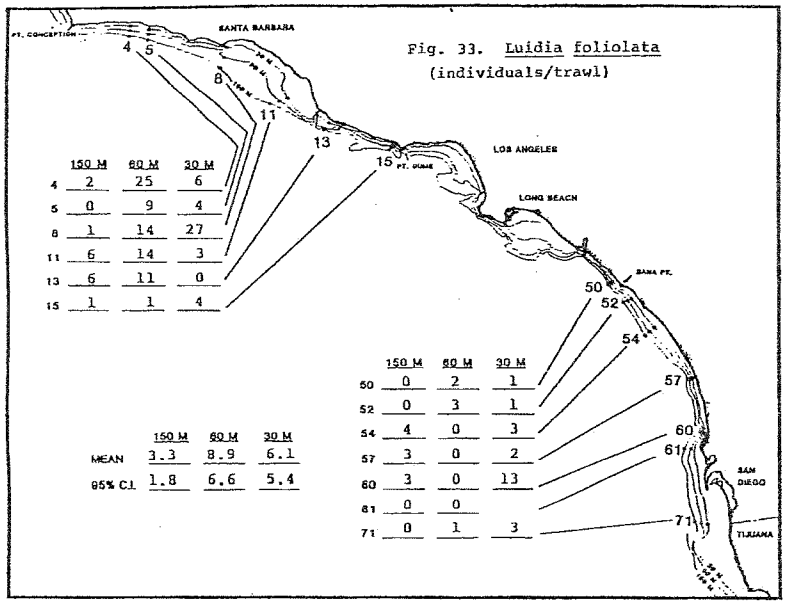


Fig. 33. Luidia foliolata
(individuals/trawl)

	150 M	60 M	30 M
4	2	25	6
5	0	9	4
8	1	14	27
11	6	14	3
13	6	11	0
15	1	1	4
50	0	2	1
52	0	3	1
54	4	0	3
57	3	0	2
60	3	0	13
61	0	0	
71	0	1	3
MEAN	3.3	8.9	6.1
95% C.I.	1.8	6.6	5.4

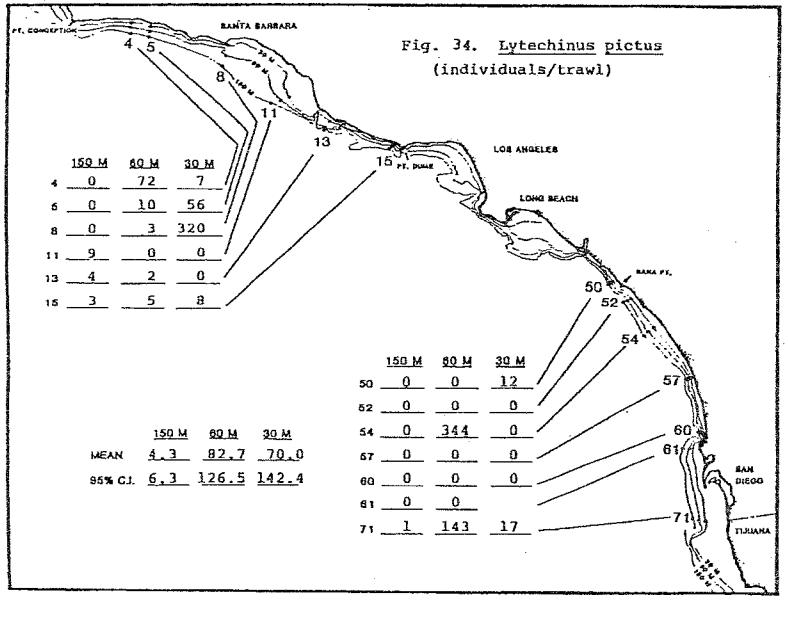


Fig. 34. Lytechinus pictus
(individuals/trawl)

	150 M	60 M	30 M
4	0	72	7
5	0	10	56
8	0	3	320
11	9	0	0
13	4	2	0
15	3	5	8
50	0	0	12
52	0	0	0
54	0	344	0
57	0	0	0
60	0	0	0
61	0	0	
71	1	143	17
MEAN	4.3	82.7	70.0
95% C.I.	6.3	126.5	142.4

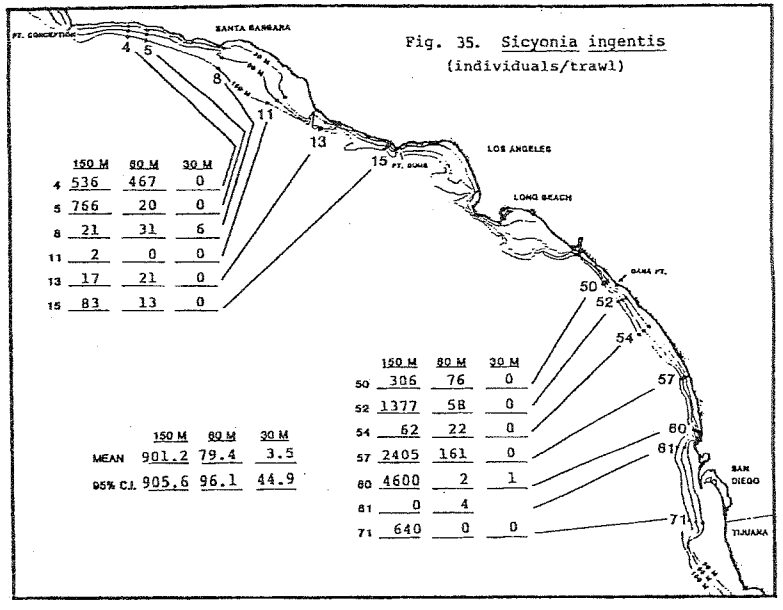


Fig. 35. Sicyonia ingentis
(individuals/trawl)

	150 M	60 M	30 M
4	536	467	0
5	766	20	0
8	21	31	6
11	2	0	0
13	17	21	0
15	83	13	0
50	306	76	0
52	1377	58	0
54	62	22	0
57	2405	161	0
60	4600	2	1
61	0	4	
71	640	0	0
MEAN	901.2	79.4	3.5
95% C.I.	905.6	96.1	44.9

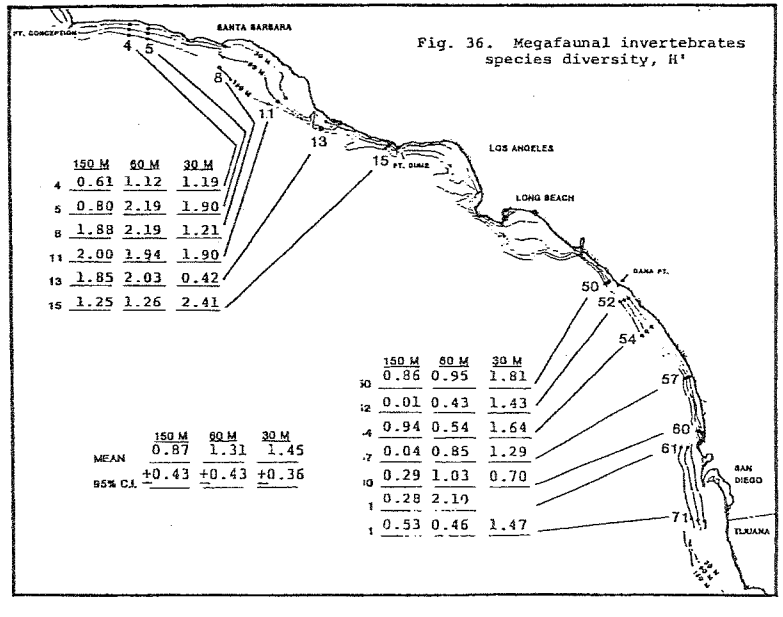


Fig. 36. Megafaunal invertebrates
species diversity, H'

	150 M	60 M	30 M
4	0.61	1.12	1.19
5	0.80	2.19	1.90
8	1.88	2.19	1.21
11	2.00	1.94	1.90
13	1.85	2.03	0.42
15	1.25	1.26	2.41
50	0.86	0.95	1.81
52	0.01	0.43	1.43
54	0.94	0.54	1.64
57	0.04	0.85	1.29
60	0.29	1.03	0.70
61	0.28	2.10	
71	0.53	0.46	1.47
MEAN	0.87	1.31	1.45
95% C.I.	±0.43	±0.43	±0.36

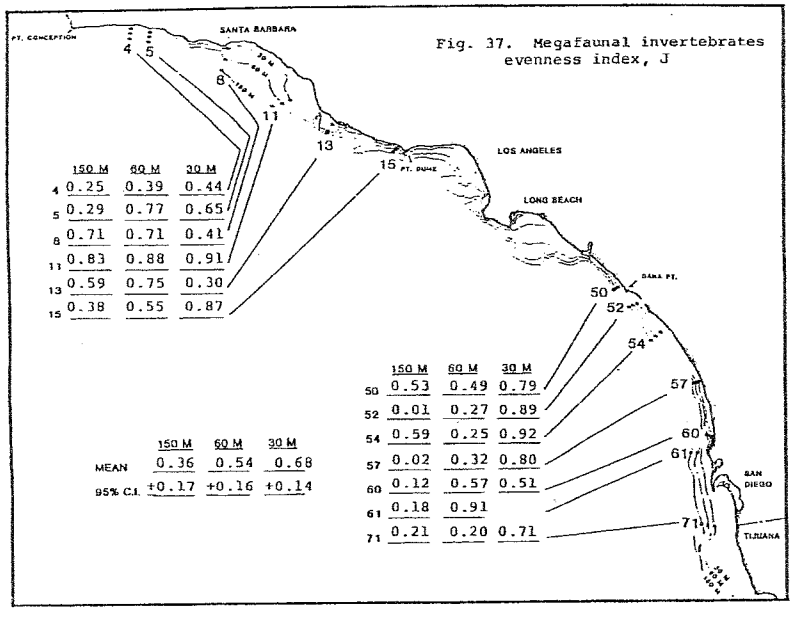


Fig. 37. Megafaunal invertebrates evenness index, J

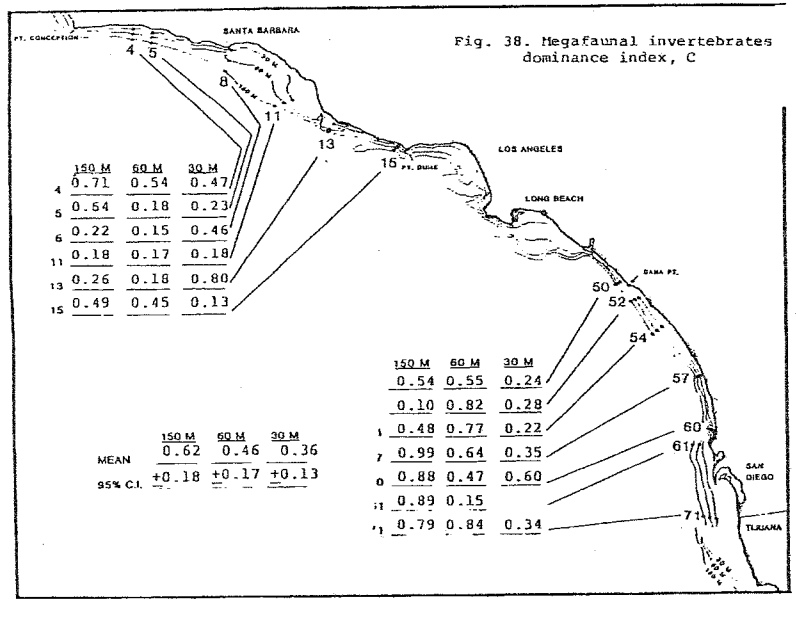


Fig. 38. Megafaunal invertebrates dominance index, C

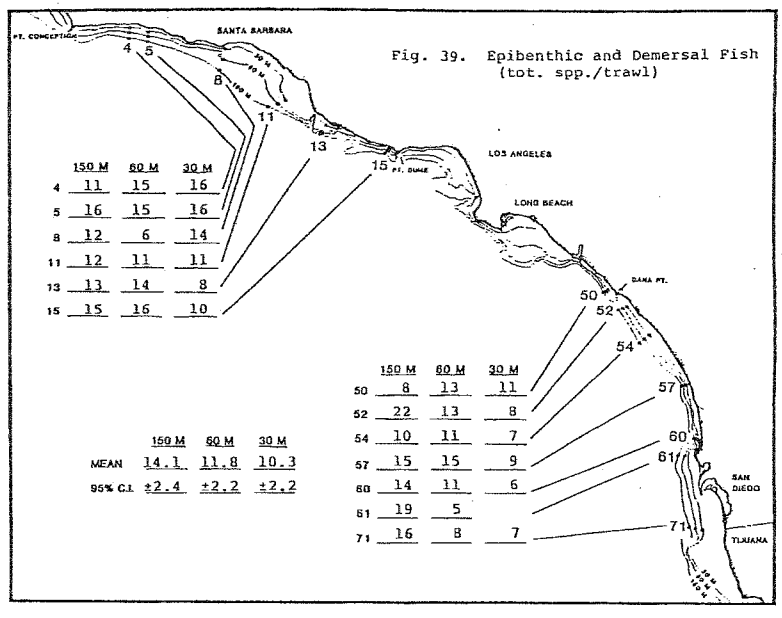


Fig. 39. Epibenthic and Demersal Fish (tot. spp./trawl)

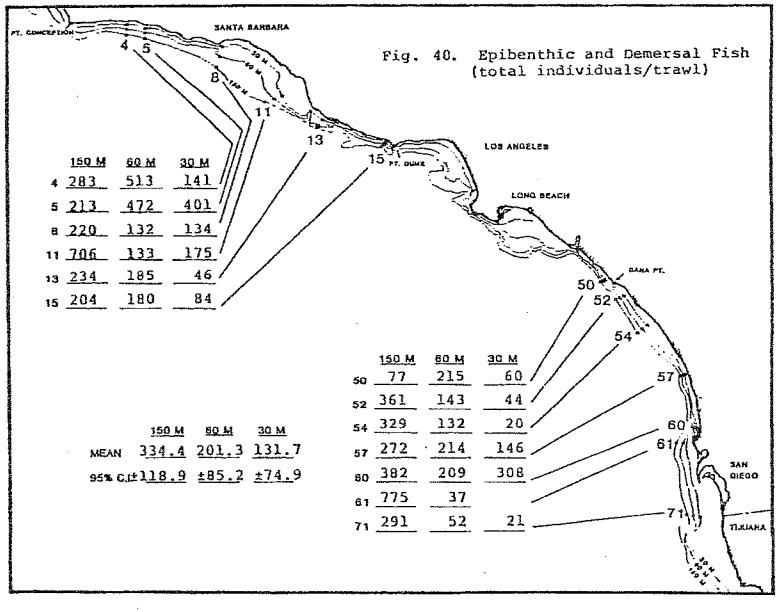


Fig. 40. Epibenthic and Demersal Fish (total individuals/trawl)

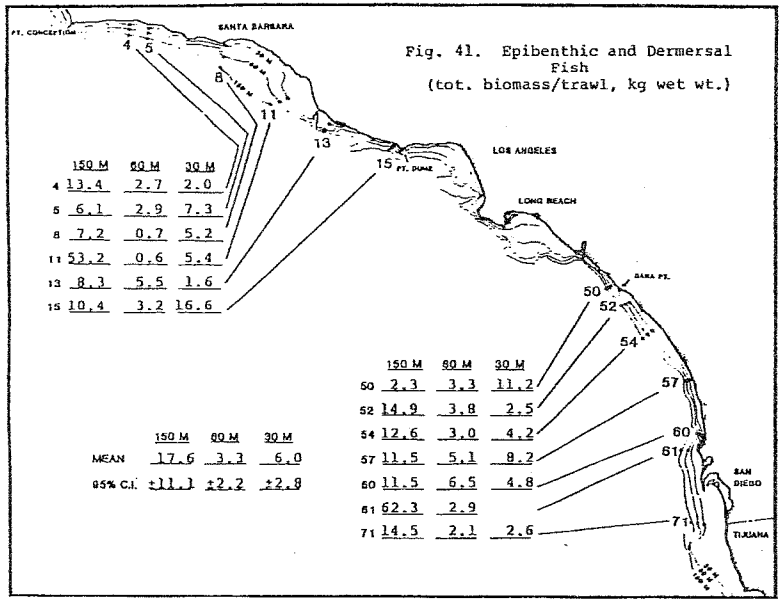


Fig. 41. Epibenthic and Dermersal Fish
(tot. biomass/trawl, kg wet wt.)

	150 M	60 M	30 M
4	13.4	2.7	2.0
5	6.1	2.9	7.3
8	7.2	0.7	5.2
11	53.2	0.6	5.4
13	8.3	5.5	1.6
15	10.4	3.2	16.6
50	2.3	3.3	11.2
52	14.9	3.8	2.5
54	12.6	3.0	4.2
57	11.5	5.1	8.2
60	11.5	6.5	4.8
61	62.3	2.9	
71	14.5	2.1	2.6
MEAN	17.6	3.3	6.0
95% C.I.	±11.1	±2.2	±2.8

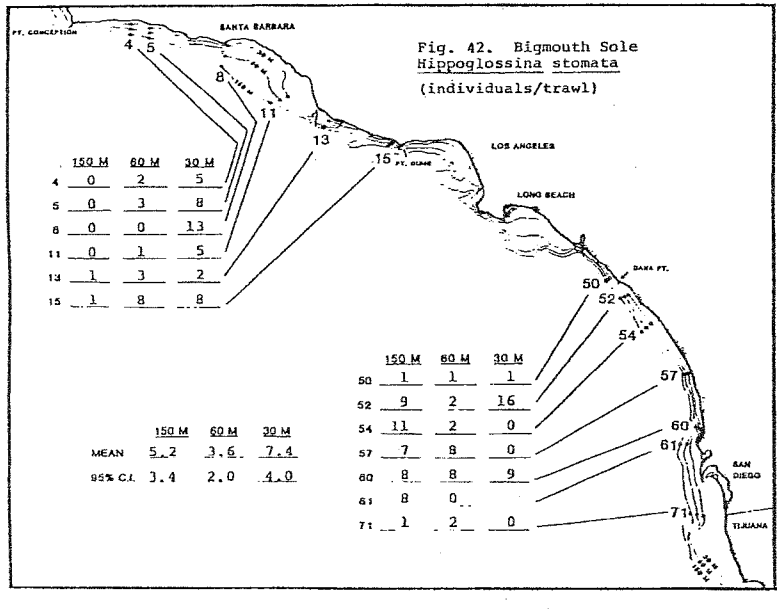


Fig. 42. Bigmouth Sole
Hippoglossina stomata
(individuals/trawl)

	150 M	60 M	30 M
4	0	2	5
5	0	3	8
8	0	0	13
11	0	1	5
13	1	3	2
15	1	8	8
50	1	1	1
52	9	2	16
54	11	2	0
57	7	8	0
60	8	8	9
61	8	0	
71	1	2	0
MEAN	5.2	3.6	7.4
95% C.I.	3.4	2.0	4.0

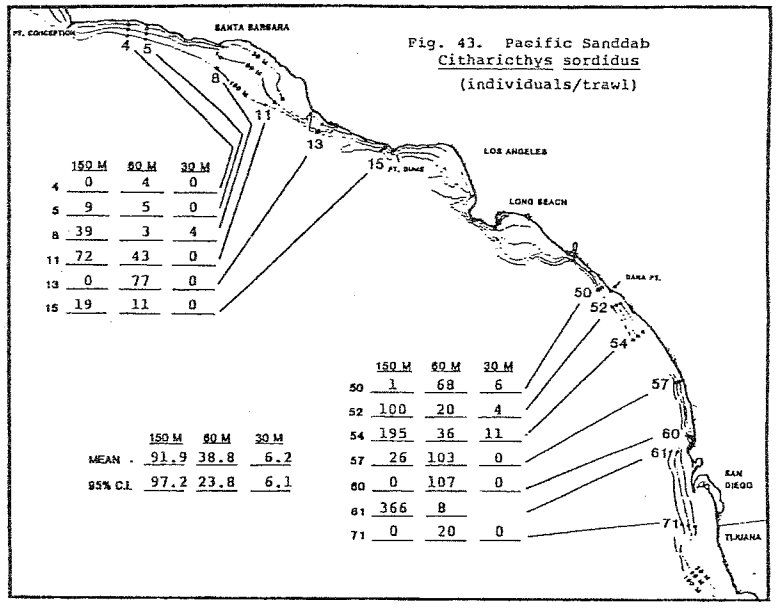


Fig. 43. Pacific Sanddab
Citharichthys sordidus
(individuals/trawl)

	150 M	60 M	30 M
4	0	4	0
5	9	5	0
8	39	3	4
11	72	43	0
13	0	77	0
15	19	11	0
50	1	68	6
52	100	20	4
54	195	36	11
57	26	103	0
60	0	107	0
61	366	8	
71	0	20	0
MEAN	91.9	38.8	6.2
95% C.I.	97.2	23.8	6.1

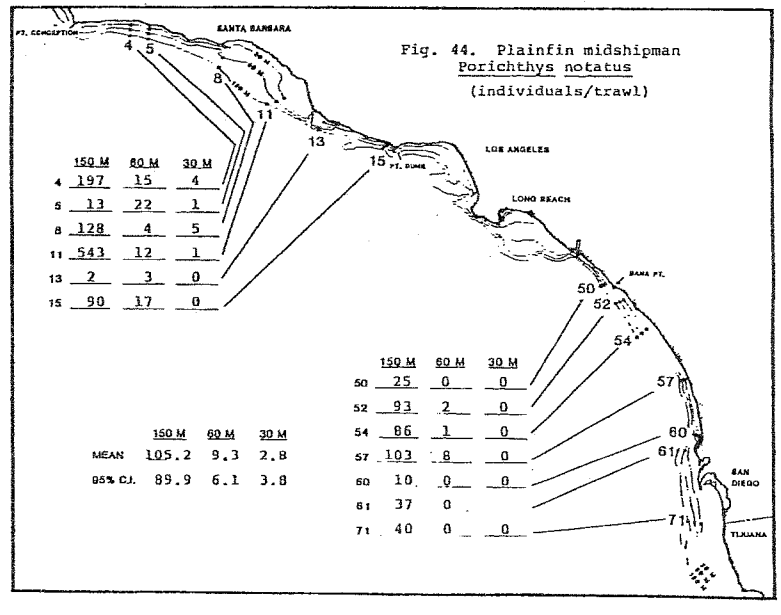


Fig. 44. Plainfin midshipman
Porichthys notatus
(individuals/trawl)

	150 M	60 M	30 M
4	197	15	4
5	13	22	1
8	128	4	5
11	543	12	1
13	2	3	0
15	90	17	0
50	25	0	0
52	93	2	0
54	86	1	0
57	103	8	0
60	10	0	0
61	37	0	
71	40	0	0
MEAN	105.2	9.3	2.8
95% C.I.	89.9	6.1	3.8

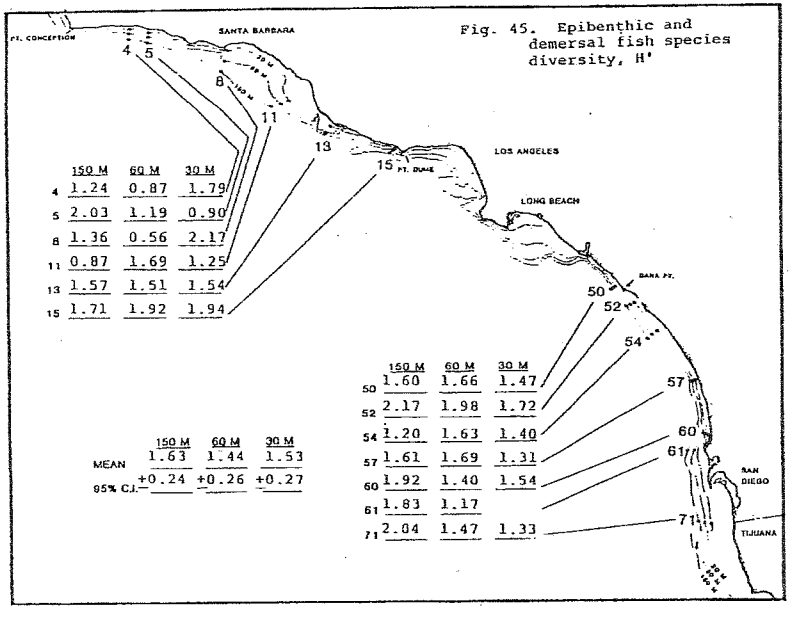


Fig. 45. Epibenthic and demersal fish species diversity, H'

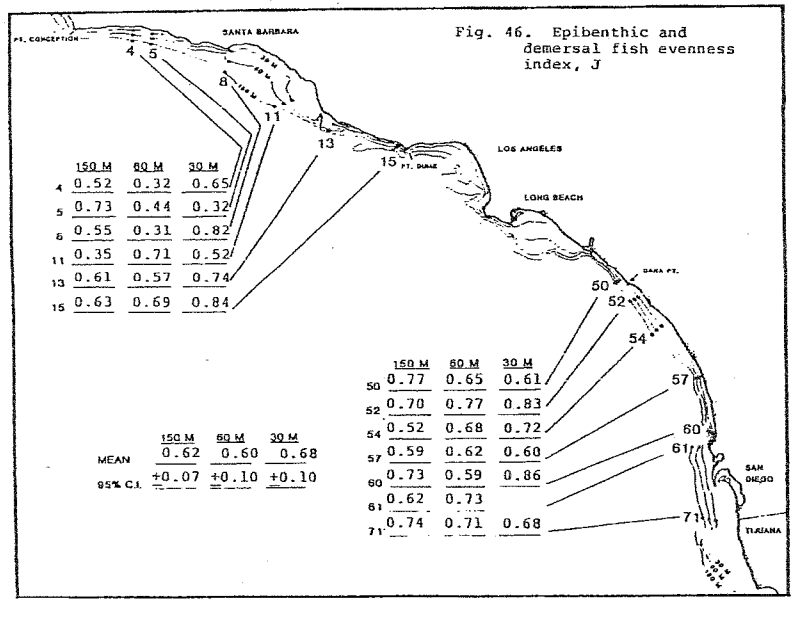


Fig. 46. Epibenthic and demersal fish evenness index, J

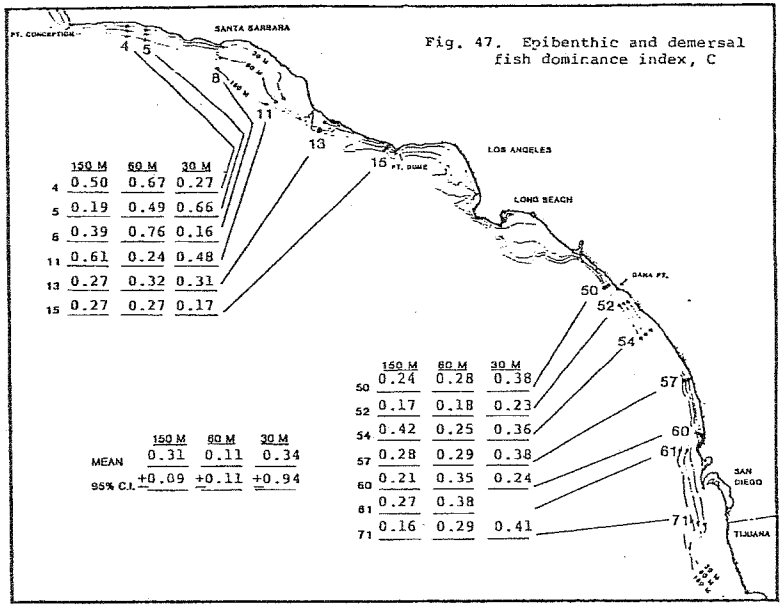


Fig. 47. Epibenthic and demersal fish dominance index, C

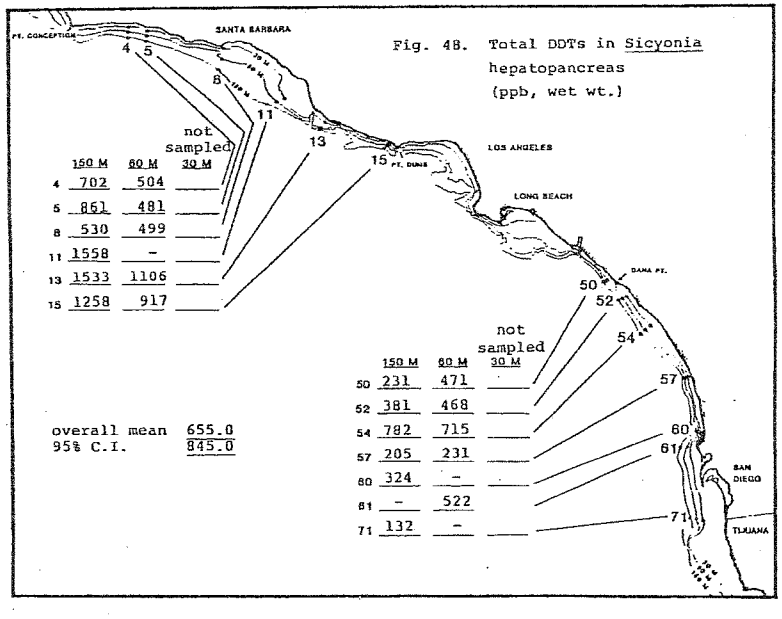


Fig. 48. Total DDTs in Sicyonia hepatopancreas (ppb, wet wt.)

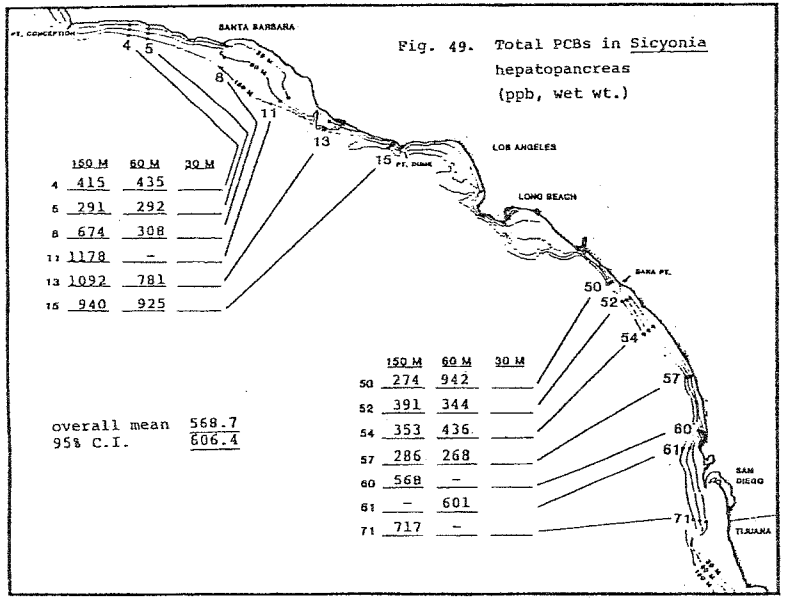


Fig. 49. Total PCBs in Sicyonia hepatopancreas (ppb, wet wt.)

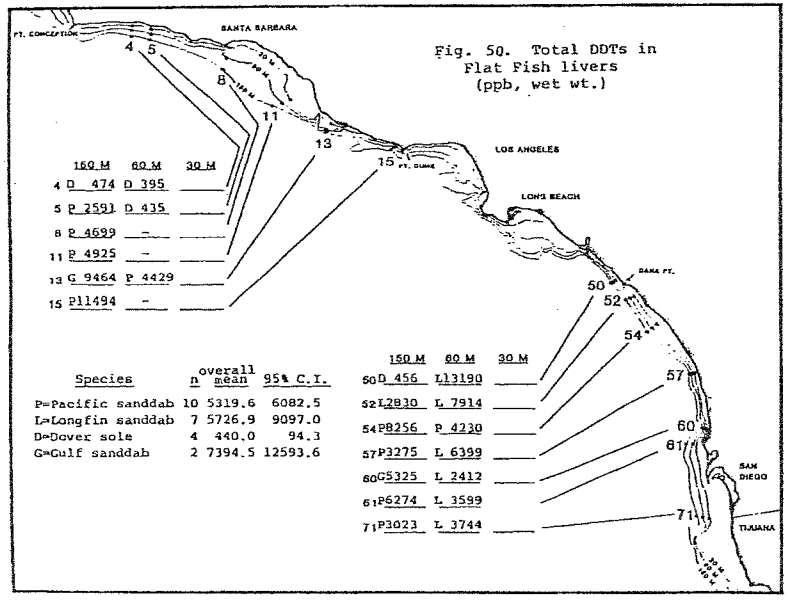


Fig. 50. Total DDTs in Flat Fish livers (ppb, wet wt.)

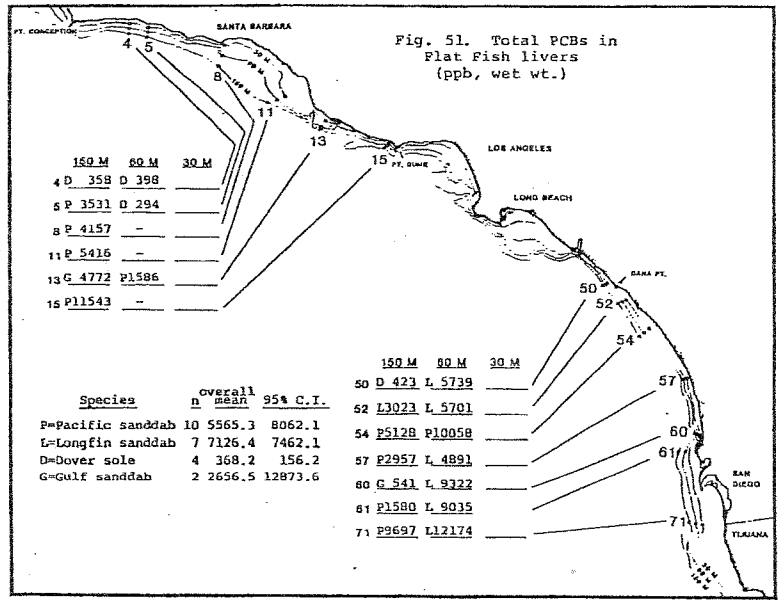


Fig. 51. Total PCBs in Flat Fish livers (ppb, wet wt.)

APPENDIX 5, TABLE 1
TRACE ORGANICS IN SEDIMENTS (ng/dry g[ppb])

Station	o,p' DDE	p,p' DDE	o,p' DDT	p,p' DDD	p,p' DDT	Aroclor 1242	Aroclor 1254	hexachlorobenzene	fluoranthene	pyrene	benz(a)anthracene	chrysene/triphenylene	benzo(a)pyrene	perylene	benzofluoranthenes
R4-30	3	13	1	4	<1	25	39	<1	<9	<9	<9	<9	<7	<7	<4
R4-60	<2	14	<2	8	<2	15	12	<2	<3	<3	<3	<3	<3	24	<4
R4-150	3	26	<2	8	<2	<8	24	<2	<2	<2	<3	<2	<2	11	<4
R5-30	<2	12	<2	8	2	<15	<11	3	<2	8	<3	<2	<2	84	<5
R5-60	<18	22	<3	<3	<5	<33	<38	<3	<12	<12	<12	<12	<10	<10	<5
R5-150	3	47	<2	16	<2	<10	45	<2	<2	<2	<3	<2	<2	29	<5
R8-30	<1	7	<1	<1	<1	<14	<13	.	<11	<11	<13	<11	<10	<10	<4
R8-60	<1	12	<1	3	<1	<13	<9	<1	<3	<1	<3	<3	<1	<1	<4
R8-150	3	30	<2	8	<2	<14	<8	<2	8	10	7	14	5	24	63
R11-30	<1	6	<1	1	<1	<3	8	<1	<7	<7	<8	<7	<7	<7	<4
R11-60	1	10	<1	3	1	<4	15	<1	<7	<7	<7	<7	<6	<6	<4
R11-150	<1	15	<1	3	<1	<13	<10	<1	<1	<1	<3	<1	<1	<1	<4
R13-30	1	12	<1	3	<1	<3	12	<1	<9	<7	<9	<9	<7	<7	<4
R13-60	1	12	<1	3	1	<4	12	<1	<7	<7	<9	<7	<7	<7	<4
R13-150	3	38	<2	12	<2	<8	60	3	<2	<2	<3	<2	<2	15	<4
R15-30	<1	14	<1	3	<1	<11	<9	<1	19	20	9	29	7	<1	63
R15-60	8	59	<2	12	<2	<14	39	<2	14	17	<3	17	12	12	56
R15-150	8	69	<2	16	<2	8	44	8	11	11	<3	<2	8	11	34
R50-30	<1	3	<1	<1	<1	<12	<9	3	26	23	<3	14	13	<1	66
R50-60	<2	16	<2	3	<2	14	14	<2	<2	<2	<3	<2	<2	<2	<5
R50-150	2	17	<2	2	4	<8	23	<2	<17	<17	<19	<17	<15	<15	<6
R52-30	<2	5	<2	2	<2	<5	6	<2	<11	<9	<11	20	<9	<9	<5
R52-60	2	14	<2	4	4	<4	14	<2	<11	<11	<11	<11	<9	<9	<5
R52-150	<2	14	<2	2	<2	<5	9	<2	<14	<13	<14	<14	<13	<13	<5
R54-30	<1	3	3	<1	<1	<4	<6	<1	<9	<9	<9	<9	<7	<7	<4
R54-60	2	7	<2	2	2	15	19	<2	<10	<8	<10	<10	<8	<8	<5
R54-150	<3	8	<1	<6	<6	<40	<47	<1	<7	<7	<7	<7	<6	<6	<4
R57-30	<1	1	<1	<1	<1	<4	<6	<1	<9	<7	<9	<9	<7	<7	<4
R57-60	<2	12	<2	3	<2	<7	17	<2	10	<5	<2	<2	<2	7	<5
R57-150	<2	12	<2	2	2	<8	12	<2	<16	<14	<16	<16	<14	<14	<6
R60-30	<1	<1	<1	<1	<1	<11	<9	<1	<1	<1	<3	<1	<1	<1	<4
R60-60	<1	<1	<1	<1	<1	<7	<6	<1	<1	<1	<3	<1	<1	<1	<4
R60-150	2	6	<2	<2	<2	<4	13	<2	<13	<12	48	77	<12	<12	<6
R61-60	<2	3	<2	<5	<6	<36	<41	<2	<6	<6	<6	<6	<6	<6	<5
R61-150	<1	3	3	3	<1	<9	3	3	<1	<1	<3	<1	<1	<1	<4
R71-30	<1	<1	<1	<1	<1	<4	<4	<1	<8	<7	<8	<8	<7	<7	<4
R71-60	<1	<1	<1	<4	<4	<32	<37	<1	<5	24	<5	<5	<5	<5	<4
R71-150	<1	3	<1	<1	<1	<7	12	<1	<1	<1	<3	<1	6	<1	13

APPENDIX 5, TABLE 2

TRACE ORGANICS IN SICYONIA HEPATOPANCREAS (ng/dry g [ppb])

Station	Hexa-Chloro benzene	Lin-dane	o,p' DDE	p,p' DDE	o,p' DDD	o,p' DDT	p,p' DDD	p,p' DDT	Aro-clor 1242	Aro-clor 1254
R4-60	<2	<3	<4	367	<4	32	<9	105	35	400
150	<2	<2	<3	590	<3	47	<7	65	<56	415
R5-60	<1	<1	12	340	2	42	<4	85	<35	292
150	<1	5	4	508	2	35	<3	312	<28	291
R8-60	<2	<3	<5	394	<4	35	<10	70	88	220
150	<1	<1	<2	482	<2	20	<4	28	<31	674
R11-60	----------none collected----------									
150	<8	2	26	1504	<13	28	<31	<38	<250	1178
R13-60	<5	10	13	1031	<8	<10	8	54	<166	781
150	<2	<2	1	1254	<3	80	<7	198	<55	1092
R15-60	<3	3	10	878	2	<4	3	24	<86	925
150	<1	<2	14	1194	<2	20	<5	30	42	898
R50-60	<2	<3	11	310	<4	<4	<9	150	<70	942
150	<1	<1	1	202	<2	5	3	20	<34	274
R52-60	<2	<2	1	359	<3	20	<6	88	35	309
150	<1	<1	<2	311	<1	22	<3	48	35	356
R54-60	<3	<4	22	356	<5	105	<13	232	174	262
150	2	3	16	671	5	17	15	58	<21	353
R57-60	<2	<2	2	184	2	3	12	28	<49	268
150	<1	<1	1	174	<1	13	<3	17	<23	286
R60-60	----------none collected----------									
150	<1	<1	2	262	<1	22	<3	38	<23	568
R61-60	<24	<32	<48	522	<40	<48	<96	<120	<786	601
150	----------none collected----------									
R71-60	----------none collected----------									
150	<1	<1	3	122	<1	2	<2	5	<18	717

APPENDIX 5, TABLE 3
TRACE ORGANICS IN FLATFISH LIVERS (ng/dry g [ppb])

Station	Species	Hexa-Chloro dane	Lin-dane	o,p' DDE	p,p' DDE	o,p' DDD	o,p' DDT	p,p' DDD	p,p' DDT	Aro-clor 1242	Aro-clor 1254
R4-60	DS	2	3	12	221	6	106	<8	50	61	337
150	DS	<2	1	32	307	1	108	8	18	<55	358
R5-60	DS	<2	<2	36	264	8	55	14	58	57	237
150	DS	14	98	248	2044	31	45	103	120	649	2882
R8-60	----------	----------	----------	----------	----------	none	collected	----------	----------	----------	----------
150	PS	2	27	101	2483	<1	469	<3	1646	1795	2362
R11-60	----------	----------	----------	----------	----------	none	collected	----------	----------	----------	----------
150	PS	3	123	398	3532	20	873	42	60	1522	3894
R13-60	PS	<1	30	51	2601	25	449	41	1262	20	1566
150	GS	1	94	300	7982	24	1080	3	75	2583	2189
R15-60	----------	----------	----------	----------	----------	none	collected	----------	----------	----------	----------
150	PS	<1	47	277	8550	51	1199	125	1292	284	11259
R50-60	LS	16	191	512	10274	304	710	21	1369	2838	2901
150	DS	<2	<3	22	319	6	61	<8	48	46	377
R52-60	LS	1	131	403	6820	19	490	13	169	2420	3281
150	LS	1	40	42	2378	8	168	85	149	436	2587
R54-60	PS	1	30	21	3319	10	340	208	332	670	9388
150	PS	1	2	72	5688	9	2223	122	142	766	4416
R57-60	LS	16	201	391	4653	102	990	<3	263	1979	2912
150	PS	2	17	20	2658	24	156	96	321	507	2450
R60-60	LS	58	405	103	2309	<2	<2	<4	<5	6950	2372
150	GS	1	90	222	4688	24	302	58	31	15	526
R61-60	LS	4	298	86	2864	63	184	107	295	3838	5197
150	PS	<1	191	296	4500	4	226	78	1170	111	1469
R71-60	LS	9	228	18	1863	635	96	72	1060	4037	8137
150	PS	1	198	274	2002	207	141	47	352	1054	8643

*DS=Dover Sole PS=Pacific Sanddab LS=Longfin Sanddab GS=Gulf Sanddab