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PART IV

ENVIRONMENTAL FIELD INVESTIGATIONS

edited by
Dorothy F. Soule
and
Mikihiko Oguri

Published by
The Allan Hancock Foundation
Harbors Environmental Projects
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Los Angeles, California 90007

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Volume IV

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Allan Hancock Foundation Marine Research Vessel, Golden West, at USC Marine Facility, Berth 186, Los Angeles Harbor, photograph by John Soule.

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART IV.

ABUNDANCE, DISTRIBUTION, SEASONALITY, AND PRODUCTIVITY OF THE FISH POPULATIONS IN LOS ANGELES HARBOR, 1972-73

by
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ABSTRACT. Between May 24, 1972 and October 1973, 76 trawls were made in Los Angeles-Long Beach Harbor. A total of 57,647 fish were collected for an overall average of 738.5 fish/trawl. If larval fishes are excluded, the average 423.2/trawl is still exceptionally high, with a fish density of one fish per 8.9 square meters, the highest recorded locally. The diversity and richness within the harbor ($\overline{X}_D = 1.29$, $\overline{X}_R = 10$) approximates that recorded for similar depths outside of the harbor. Three areas of distribution are recognized within the harbor: an area rich in flatfishes; an area of high croaker abundance; an area demarcated by the presence of rockfishes. The area rich in croakers seems to correlate with nutrient enrichment (sewage) and perhaps low oxygen tension. The ecological parameters of harbor species are discussed as possible factors in abundance and distributional statistics. Changes in seasonal abundance are documented with fewer fishes present in winter than summer. The standing crop of fishes in the harbor is estimated between 700,000 - 1,600,000 kg. The annual productivity is estimated at 56 per cent of the standing crop or 392,000 - 896,000 kg. This represents 7.3 - 16.5 g/m^2.

ABUNDANCE, DISTRIBUTION, SEASONALITY, AND PRODUCTIVITY OF THE FISH POPULATIONS IN LOS ANGELES HARBOR, 1972-73

INTRODUCTION. In May 1972, Chamberlain conducted a 13-station survey of the outer Los Angeles Harbor. Chamberlain's study (1973a) was the first to deal specifically with these fish populations. Stephens, Gardiner, and Terry (1973) presented data comparing Chamberlain's results to those obtained in a three year survey of the demersal fish populations of San Pedro Bay. This present report deals with a continuing analysis of Los Angeles Harbor fishes that began with Chamberlain's study and has utilized Chamberlain's as well as additional stations. This study is still in progress, and the data here cited include the period from May 24, 1972 through October 1973. The thrust of this portion of the study has been to analyze the patterns of distribution shown by these fish populations within the harbor, to analyze abundance and diversity, to ascertain whether populations show seasonal variance, and to attempt to define areas of high or low productivity within the harbor. This study has been supported by U.S.C.-Sea Grant and the Occidental College VANTUNA Oceanographic Program. SCCWRP has supported our preliminary productivity studies. We wish to thank Dr. John McAnally, Chemistry, and Dr. Joseph Humphrey, Economics, for directing many of our harbor cruises. The following Occidental College students participated in collection of specimens and data: Cassie Cusick, John Helly, Laurie Post, Shuichi Ishikawa, Marc Lyde, and Lowell Ching.

All trawls were made with a 16' headrope, 19' footrope Marinovich semi-balloom otter trawl, using a 50' bridle. The body of the net was 1½" stretch #9 nylon mesh with a ½" stretch knotless nylon liner. The otter boards were 24" x 12". Each trawl was for ten minutes (winch not operating). As all depths were shallow, trawl duration is considered close to ten minutes.

HARBOR VS. SAN PEDRO BAY. Table 1 lists by family the 65 species of fishes taken during this study. This represents about half the number of species reported by Chamberlain (1974) in his check list of Los Angeles-Long Beach Harbor fishes, but it includes the majority of common resident species. In order to supplement out trawling study, three diving stations along the inner rocky face of the middle breakwater, and three gill net stations (middle breakwater and Cerritos Channel) were added to our data and are included

Table 1 Fishes taken in Los Angeles Harbor 1972-73

- CYNOGLOSSIDAE
  - *Symphurus atricauda*
- BOTHIDAE
  - *Citharichthys stigmaeus*
  - *C. sordidus* *
  - *Paralichthys californicus*
  - *Xystreurys liolepis*
  - *Hippoglossina stomata*
- PLEURONECTIDAE
  - *Pleuronichthys verticalis*
  - *P. decurrens*
  - *P. ritteri* *
  - *Parophrys vetulus*
  - *Hypsopsetta guttulata*
  - *Glyptocephalus zachirus* *
- SCIAENIDAE
  - *Genyonemus lineatus*
  - *Seriphus politus*
  - *Cheilotrema saturnum* *
- EMBIOTOCIDAE
  - *Cymatogaster aggregata*
  - *Phanerodon furcatus*
  - *Hyperprosopon argenteum*
  - *Embiotoca jacksoni*
  - *Damalichthys vacca*
  - *Rhacochilus toxotes*
  - *Hypsurus caryi* +
- ENGRAULIDAE
  - *Engraulis mordax*
  - *Anchoa compressa*
  - *A. delicatissima*
- BATRACHOIDIDAE
  - *Porichthys myriaster*
  - *Porichthys notatus* *
- GOBIIDAE
  - *Lepidogobius lepidus*
  - *Coryphopterus nicholsi* +
- SCORPAENIDAE
  - *Sebastes auriculatus* *
  - *S. goodei*
  - *S. miniatus*
  - *S. mystinus* +
  - *S. paucispinis*
  - *S. rubrivinctus* *
  - *S. saxicola*
  - *S. serranoides*
  - *Scorpaena guttata*
- SERRANIDAE
  - *Paralabrax clathratus* +
  - *P. maculatofasciatus* *
  - *P. nebulifer*
- COTTIDAE
  - *Leptocottus armatus*
  - *Artedius notospilotus*
  - *Clinocottus analis* +
  - *Scorpaenichthys marmoratus* +
- CLINIDAE
  - *Neoclinus uninotatus*
  - *N. stephensae* +
  - *Gibbonsia elegans* +
  - *G. metzi* +
  - *Heterostictus rostratus* +
- STROMATEIDAE
  - *Peprilus simillimus*
- AGONIDAE
  - *Odontopyxis trispinosa*
- OPHIDIIDAE
  - *Chilara taylori*
- SYNODONTIDAE
  - *Synodus lucioceps*
- SYGNATHIDAE
  - *Sygnathus sp.*
- GIRELLIDAE
  - *Girella nigricans* +
- SCORPIDIDAE
  - *Medialuna californiensis* +
- POMACENTRIDAE
  - *Hypsypops rubicundus* +
  - *Chromis punctipinnis* +
- LABRIDAE
  - *Pimelometopon pulchrum* +
  - *Oxyjulis californica* +
- HEXAGRAMMIDAE
  - *Hexagrammos decagrammus* +
- SQUALIDAE
  - *Squalus acanthias*
- MYLIOBATIDAE
  - *Myliobatis californica*
- TORPEDINIDAE
  - *Torpedo californica*

* taken only once in trawls
\+ seen diving or taken in the gill nets, not in otter trawls

here. A total of 76 trawls were made during this period. Figure 1 illustrates the stations utilized in this report. Table 2 presents the distribution by species at each trawling station, including total and average number per trawl and fidelity (regularity of occurrence). The total fish per station, average per trawl, richness, and diversity are presented in Table 3. A total of 57,647 fish were taken in this study ($\bar{x}$/trawl = 738.5). This total includes all specimens and is highly biased by our 1973 July-September collections which include 25,487 young, just settling white croakers (*Genyonemus*), most of which probably would not have survived in this concentration. If the settling croakers are removed, the total becomes 32,160 or an average of 423.2 fish per trawl. This figure is considerably higher than the mean catch in our San Pedro Bay trawls and almost doubles the figure from Chamberlain's original data (221 fish per trawl). Based on an area of 3,770 m^2 per trawl, the density of one fish per 8.9 m^2 of substrate is the highest recorded for trawling studies in the San Diegan Warm Temperate. Mearns, Allen, Sherwood, and Gammon (1973) recorded a median catch of 494 fish per trawl off Palos Verdes (21 stations, 9 November to 11 December 1972), but this survey used a 40' trawl and the estimated area of each trawl was 10,160 m^2 (SCCWRP 1973) so the density of fish is relatively low; one fish per 20.6 m^2. The same stations at Palos Verdes during May-June (1972) had an even lower catch per trawl of 214 fish (Mearns, Allen, and Sherwood 1973) or a density of one fish per 47m^2.

The richness and diversity of fishes in Los Angeles Harbor (Table 3) can be compared with 19 of the 54 SCCWRP stations cited above that were from a similar depth, shallower than 30 meters. The average richness for the SCCWRP sample was 11 species (range 6-17) with an average Shannon-Weaver diversity index of 1.28 (range 0.44-1.94). The average richness in the harbor is 10 species (range 4-18) while the Shannon-Weaver diversity averages 1.29 (range 0.65-2.08). It appears that the diversity and richness within the harbor is at about the same level as adjacent waters of a similar depth. SCCWRP (1973) cites considerably higher mean diversity indices for the Southern California Bight, but these represent variations in depth to 400 meters which would certainly increase total diversity.

Our trawling stations have taken 48 species, 39 of which have been taken repeatedly. Stephens, Gardiner, and Terry (1973) report 65 species from San Pedro Bay which occasionally occur as shallow as 25 meters, but of these, only 51 are considered shallow water species. Thirteen of these shallow

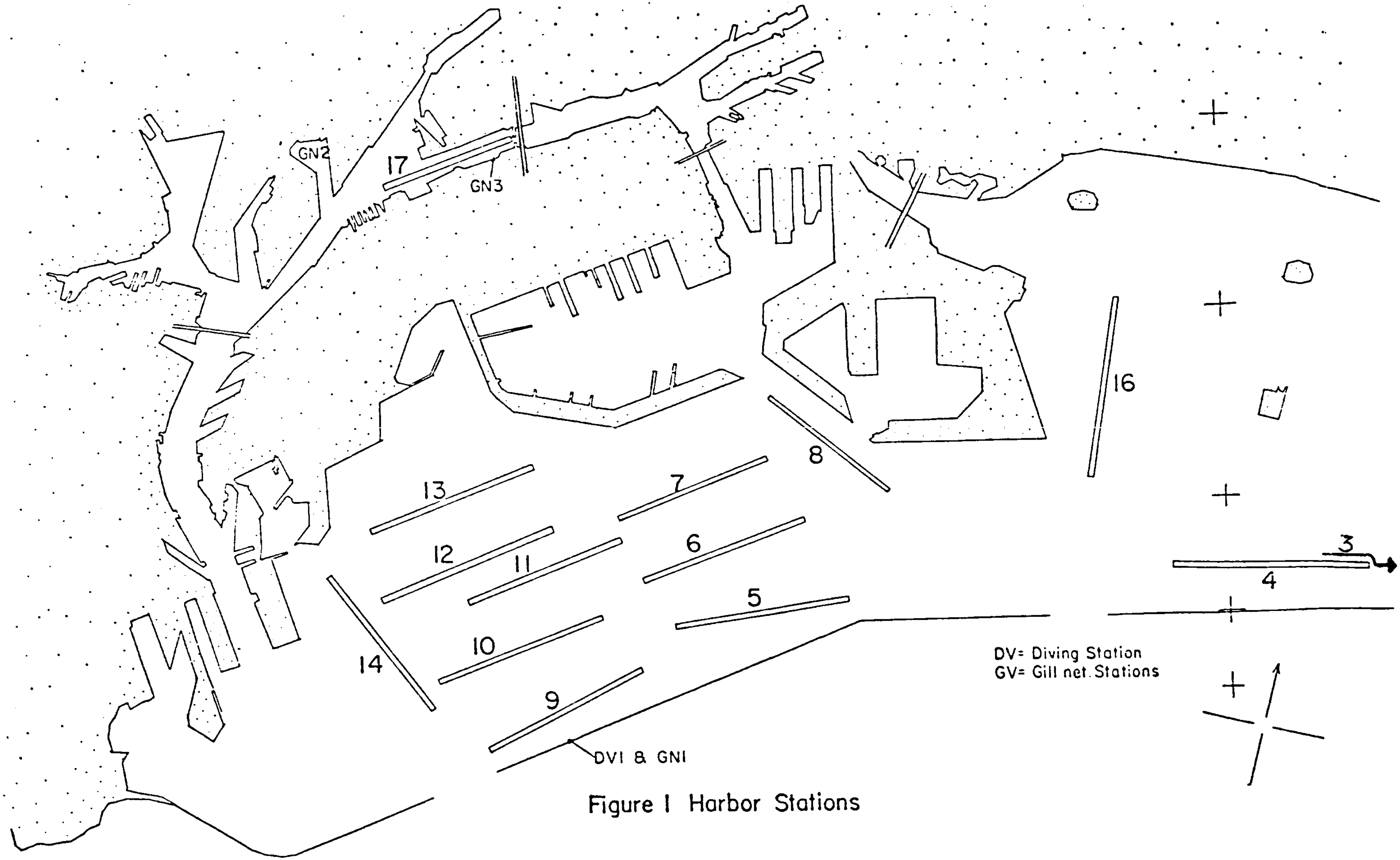

Figure I Harbor Stations

Distribution and regularity of occurrence of fish by station in Los Angeles Harbor.

Table 2.

	Station 3 (N=5)			Station 4 (N=6)			Station 5 (N=6)			Station 6 (N=7)			Station 7 (N=4)			Station 8 (N=8)			Station 9 (N=6)			Station 10 (N=6)		
	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F
S. atricauda	650	130.0	5	432	72.0	6	685	114.2	6	481	68.7	7	280	70.0	4	857	107.1	8	438	73.0	6	217	36.2	6
C. stigmaeus	54	10.8	4	25	4.2	3	63	10.5	5	522	74.6	7	99	24.8	4	45	5.6	4	532	88.	6	479	119.8	6
C. sordidus																								
P. californicus	1	.2	1	2	.3	2				1	.1	1				1	.1	1				3	.5	2
X. liolepis							1	.2	1										1	.2	1	1	.2	1
H. stomata										1	.1	1							3	.5	2	1	.2	1
P. verticalis	1	.2	1	1	.2	1	8	1.3	2	28	4.0	4	9	2.2	4	2	.2	2	54	9.0	6	41	6.8	5
P. decurrens										12	1.7	2	2	.5	1				15	2.5	3	24	4.0	3
P. ritteri																			1	.2	1			
P. vetulus	1	.2	1	1	.2	1				1	.1	1							1	.2	1	10	1.7	2
H. guttulata																			1	.2	1	1	.2	1
G. zachirus																			2	.4	1			
G. lineatus	37	7.4	3	182	30.3	6	82	13.7	4	134	19.1	5	78	19.5	4	1146	143.3	7	116	19.3	2	129	21.5	3
(juveniles)	2066			3111			3424			755			2913			1472			301			1509		
S. politus	45	9.0	3	70	11.7	5	47	7.8	3	223	31.8	5	45	11.2	4	725	90.6	8	11	1.8	2	2	.3	2
C. saturnum																								
E. mordax	596	119.2	3	454	75.7	2	707	117.8	3	1051	150.1	5	641	160.2	3	1453	181.6	7	787	131.2	2	255	42.5	1
A. delicatissima										1	.1	1				66	8.2	3						
A. compressa																1	.1	1						
C. aggregata	128	25.6	5	105	17.5	4	72	12.0	4	217	31.0	7	44	11.0	3	31	3.9	5	113	18.8	6	527	87.8	4
P. furcatus	193	38.6	5	146	24.3	5	94	15.7	5	216	30.9	6	195	48.8	4	423	52.9	8	118	19.7	5	92	15.3	4
H. argenteum																						2	.3	1
E. jacksoni	3	.6	2							1	.1	1	1	.2	1				3	.5	2	9	1.5	2
D. vacca	1	.2	1	1	.2	1																		
R. toxotes	1	.2	1							5	.7	2				2	.2	1	1	.2	1	3	.5	1
P. myriaster	50	10.0	5	75	12.5	5	60	10.0	5	72	10.3	7	46	11.5	4	30	3.8	5	11	1.8	3	11	1.8	2
P. notatus							1	.2	1															
L. lepidus	30	6.0	3	50	8.3	5	93	15.5	5	101	14.4	4	59	14.8	4	32	4.0	4	10	1.7	2	4	.7	2
S. miniatus	5	1.0	1	5	.8	1	14	2.3	2	119	17.0	5	17	4.2	2	168	21.0	6	10	1.7	3			
S. serranoides	3	.6	1	46	7.6	1	8	1.3	1	2	.3	1	6	1.5	1	2	.2	1	5	.8	1			
S. saxicola	5	1.0	1				20	3.3	1	29	4.1	2	2	.5	1				2	.3	1			
S. paucispinis	1	.2	1				26	4.3	3	9	1.3	2	1	.2	1	3	.4	1						
S. goodei	1	.2	1													2	.2	1						
S. auriculatus																								
S. rubrivinctus																1	.1	1						
S. guttata	2	.4	1																4	.7	3			
P. nebulifer																								
P. maculatofasciatus																								
L. armatus																								
A. notospilotus																2	.2	2						
P. simillimus																								
O. trispinosa	1	.2	1							3	.4	2	1	.2	1	8	1.0	2	1	.2	1			
C. taylori							6	1.0	2				1	.2	1	3	.4	3						
S. luciceps				1	.2	1	11	1.8	1	1	.1	1	1	.2	1				4	.7	2			
N. uninotatus																						1	.2	1
Sygnathus sp.										2	.3	1	1	.2	1	10	1.2	2						
Squalus acanthias																3	.4	2						
Myliobatis californica	1	.2	1							1	.1	1												
Torpedo californica																								

Distribution and regularity of occurrence of fish by station in Los Angeles Harbor.

Table 2.

	Station 11 (N=5)			Station 12 (N=4)			Station 13 (N=8)			Station 14 (N=6)			Station 16 (N=3)			Station 17 (N=2)			Totals (N=76)		
	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F	N	$\bar{x}$	F
S. atricauda	106	21.2	5	223	55.8	4	298	37.2	8	208	34.7	6	227	75.7	3	1	.5	1	5102	67.1	75
C. stigmaeus	437	87.4	5	226	56.5	4	30	3.8	2	1010	168.3	6	200	66.7	3				3723	49.0	59
C. sordidus							1	.1	1										1	.01	1
P. californicus	1	.2	1	5	1.2	2	4	.5	2	3	.5	3	1	.3	1				22	.29	16
X. liolepis	2	.4	1				1	.1	1	1	.2	1							7	.09	6
H. stomata																			5	.07	4
P. verticalis	47	9.4	5	12	3.0	4	6	.8	2	70	11.7	6	4	1.3	3				283	3.7	45
P. decurrens	12	2.4	3							15	2.5	3							80	1.0	15
P. ritteri	12	2.4	3																1	.01	1
P. vetulus										6	1.0	1							31	.41	10
H. guttulata				1	.2	1				6	1.0	3							9	.12	6
G. zachirus																			2	.03	1
G. lineatus	114	22.8	2	226	56.5	3	2292	286.9	8	58	9.7	5	54	18.0	2	49	24.5	2	4697	61.8	56
(juveniles)	3939			1543			2445			205			238			1566			25,487	335.4	
S. politus	12	2.4	2	15	3.8	3	834	104.2	7	115	19.2	3	7	2.3	2	21	10.5	2	2172	28.6	51
C. saturnum	1	.2	1																1	.01	1
E. mordax	571	190.3	114.2	997	249.2	3	1638	204.8	7	188	19.7	3	533	177.6	2				9871	129.9	44
A. delicatissima							134	16.8	1										201	2.6	5
A. compressa							33	4.1	1	50	8.3	1				1	.5	1	85	1.12	4
C. aggregata	231	46.2	4	120	30.0	3	164	20.5	7	333	55.5	5	10	3.3	2	53	26.5	2	2148	28.5	61
P. furcatus	108	21.6	3	193	48.2	4	114	14.2	6	151	25.2	5	31	10.3	2	37	18.5	2	2111	27.8	64
H. argenteum				1	.2	1	25	3.1	4	1	.2	1							29	.38	7
E. jacksoni	9	1.8	3	11	2.2	2	14	1.8	3	10	1.7	5				2	1.0	1	63	.83	22
D. vacca							1	.1	1	1	.2	1							4	.05	4
R. toxotes	2	.4	1	8	1.6	1	1	.1	1										23	.30	9
P. myriaster	21	4.2	3	18	4.5	3	32	4.0	5	8	1.3	3	3	1.0	1	4	2.0	2	441	5.8	53
P. notatus																			1	.01	1
L. lepidus	12	2.4	1				2	.2	1	8	1.0	2	9	3.0	2	2	1.0	1	412	5.4	36
S. miniatus													1	.3	1				339	4.5	15
S. serranoides	2	.4	1				4	.5	1				1	.3	1				79	1.0	10
S. saxicola				1	.2	1													59	.78	7
S. paucispinis	1	.2	1	4	1.0	1													45	.59	10
S. goodei																			3	.04	2
S. auriculatus							1	.1	1										1	.01	1
S. rubrivinctus										1	.2	1							1	.01	1
S. guttata																			6	.08	4
P. nebulifer				1	.2	1										1	.5	1	2	.03	2
P. maculatofasciatus										1	.2	1							1	.01	1
L. armatus	1	.2	1	1	.2	1	1	.1	1	1	.2	1							4	.05	4
A. notospilotus																			2	.03	2
P. simillimus				4	1.0	1				2	.3	1							6	.08	2
O. trispinosa													1	.3	1				15	.20	8
C. taylori							1	.1	1	1	.2	1							12	.16	8
S. luciceps	7	1.4	2							2	.3	1	7	2.3	1				34	.45	10
N. uninotatus																			1	.01	1
Sygnathus sp.							2	.2	2				3	1.0	2				18	.24	9
Squalus acanthias	2	.4	1																6	.08	3
Myliobatis californica																			2	.03	2
Torpedo californica				1	.2	1	1	.1	1										3	.04	2

Table 3. Fish abundance, richness (R) and Shannon-Weaver diversity (D) by station in Los Angeles Harbor.

Station	No. fish	No. trawls	$\bar{x}$ per trawl	No. less young *G. l.*	$\bar{x}$ less young *G. l.*	R	Maximum R per trawl	Minimum R per trawl	Average R	Maximum D	Minimum D	$\bar{x}$ D
3	3887	5	777.4	1821	364.2	23	16	6	10.2	2.0190	1.1409	1.4066
4	4879	6	813.2	1768	294.7	17	14	6	8 7	1.8369	1.0340	1.3723
5	5383	6	897.2	1959	326.5	19	14	4	8.8	2.0867	.8612	1.5065
6	3844	7	549.1	3089	441.3	25	18	7	10.7	2.0542	1.0173	1.5139
7	4415	4	1103.8	1502	375.5	21	16	11	12.5	1.7811	.9955	1.5095
8	6415	8	801.9	4943	617.9	25	17	5	10.8	2.0196	1.3094	1.4918
9	2585	6	430.8	2284	380.7	24	13	6	10.5	1.4669	.7577	1.1791
10	3316	6	552.7	1807	301.2	20	16	4	8.3	1.5689	.6472	1.0023
11	5659	5	1131.8	1720	344.0	21	15	6	10.4	1.9087	.7496	1.2681
12	3623	4	905.8	2080	520.0	21	14	4	11.2	1.7909	.9946	1.4378
13	8119	8	1014.9	5674	709.2	25	13	7	9.1	2.0118	.7740	1.3233
14	2455	6	409.2	2250	375.0	25	14	4	11.3	1.7849	.9141	1.4668
16	1330	3	443.3	1092	364.0	16	16	6	9.7	1.2899	1.1334	1.2324
17	1737	2	868.5	171	85.5	10	8	6	7	1.5269	1.4993	1.5131
Total	57,647	76	758.5	32,160	423.2							

San Pedro Bay species have not been taken in the harbor while seven harbor species were not reported in the San Pedro Bay study.

The abundance ranking of species within the harbor has now changed from that reported by Chamberlain (1973). The 11 most abundant species and their per cent score are listed below in order of overall abundance. The figure in parentheses is the percentage when recruited post-larval *Genyonemus* are excluded from the data. *Genyonemus lineatus*, 52.4 (14.6); *Engraulis mordax*, 17.1 (30.7); *Symphurus atricauda*, 8.9 (15.9); *Citharichthys stigmaeus*,6.5 (11.6); *Seriphus politus*, 3.8(6.8); *Cymatogaster aggregata*, 3.7(6.7); *Phanerodon furcatus*, 3.6(6.6); *Porichthys myriaster*, .76 (1.4); *Lepidogobuis lepidus*, .7 (1.3); *Sebastes miniatus*, .6 (1.1); *Pleuronichthys verticalis*, .5 (.9). It should be noted that this ranking is strictly numerical and ignores relative biomass completely (see productivity data). The only changes in ranking resulting from exclusion of larval white croakers occur in the top three species. The ranking becomes *Engraulis*, *Symphurus*, and *Genyonemus*. Anchovies and young white croakers, which make up 69 per cent of the catch by number, are plankton feeders, and their abundance probably reflects the nutrient enrichment of the harbor. The only significant change in overall abundance in these data as compared to Chamberlain's preliminary study is the increase in northern anchovies (15th to 2nd), white croakers (3rd to 1st), and queenfish (10th to 5th).

DISTRIBUTION WITHIN THE HARBOR. There is an uneven distribution within Los Angeles Harbor. Figure 2 illustrates this overall pattern of distribution. We recognize three distributional areas in our trawling pattern: an area at the western end of the outer harbor that is generally high in flatfish species (Stations 9, 10, 11, 12, and 14) but relatively low in fish abundance; an area from the eastern opening of the harbor to the mouth of Fish Harbor and probably including Cerritos Channel (Stations 3, 4, 8, 13, and 17) that has few flatfish species, is relatively low in richness but high in abundance of certain species, particularly croakers; an area adjacent to the middle breakwater that is high in rockfish abundance. Figure 3 graphically compares abundance with richness by stations. Figures 4 and 5 map abundance and richness within the harbor. The regional abundance of indicator species in the harbor is graphed in Figures 6, 7, 8, and 9. In these graphs, average is taken as the mean abundance of that species in all 76 trawls. The maxima and minima represent extreme ranges for each species.

Average abundance can be quantified by the use of Table 2. Figure 6 represents the typical distribution pattern for flatfishes as represented by the speckled sanddab, *Citharichthys stigmaeus*, the hornyhead turbot *Pleuronichthys verticalis*, and the curlfin turbot *P. decurrens*. All three species are most abundant at Stations 9, 10, 11, and 14 and lowest at Stations 3, 4, 5, 8, and 13. All are absent from Cerritos Channel (Station 17). *Symphurus atricauda*, the California tonguefish (Figure 7), shows almost the opposite distribution. It is most abundant at the eastern end of the harbor and least abundant at Stations 10, 11, and 14. This is the only species that has 100 per cent fidelity and is the only flatfish taken in any numbers at Stations 8 and 13 and is the only one taken in Cerritos Channel (one specimen). Figure 8 graphs the distribution of two sciaenids, *Genyonemus lineatus*, the white croaker, and *Seriphus politus*, the queenfish. Both show extreme abundance at Stations 8 and 13 and relatively low abundance elsewhere. The distribution of two embiotocids, the shiner perch, *Cymatogaster aggregata*, and the white seaperch, *Phanerodon furcatus*, are graphed in Figure 9. These wandering and schooling species are less predictable than the others previously cited though it is interesting that often when one species is extremely abundant, the other is relatively low in abundance. Figures 10 and 11 map the distribution and abundance of the sciaenids and flatfish in the harbor. The rockfishes, family Scorpaenidae, also show a distinctive intraharbor distribution. Their center of abundance is at Station 6 (Figure 12). The more common species, vermilion rockfish *Sebastes miniatus*, and olive rockfish *S. serranoides*, are found from the eastern end of the harbor, Station 3, to Station 9 which is located at the western end of the middle breakwater, and are rarely taken at Stations 10-14. Two additional bottom fish, the speckled midshipman, *Porichthys myriaster*, and the bay goby, *Lepidogobius lepidus*, show a high co-abundance (Figure 13). Both species show the greatest abundance at Stations 5, 6, and 7 and are also relatively abundant at the eastern end of the harbor (Stations 3 and 4).

The richness (number of species) and Shannon-Weaver diversity indices (Table 3) vary throughout the harbor. Richness as an index of diversity does not take into account relative abundance, while the Shannon-Weaver index is largely a measure of evenness of distribution. The incongruity of these measures is illustrated at Station 17 where only seven species are found, all in low abundance, but the highest Shannon-Weaver diversity (1.5.) is recorded. It seems to us that an interesting statistic is generated by the product of average richness and the Shannon-Weaver index. In this case,

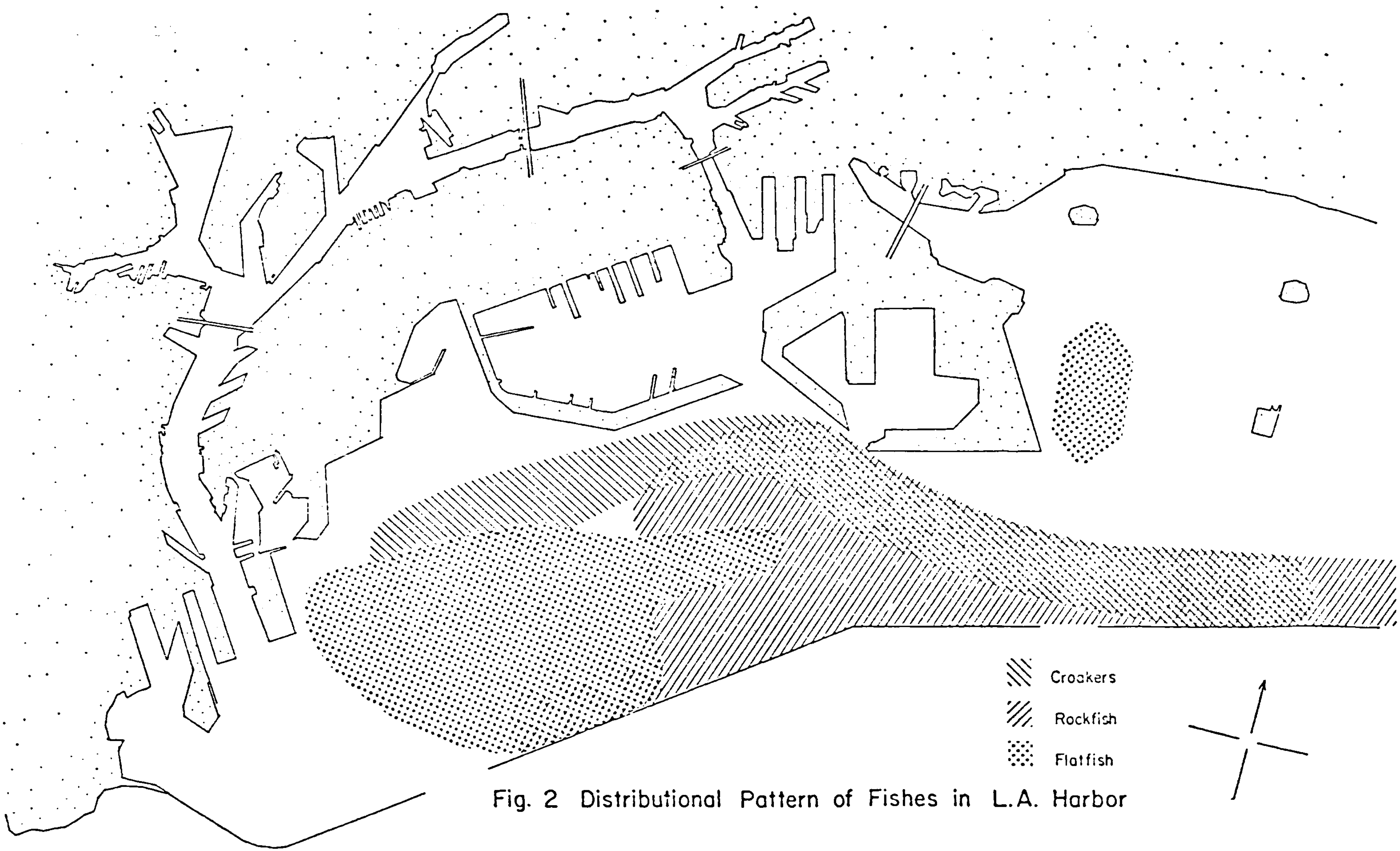

Fig. 2 Distributional Pattern of Fishes in L.A. Harbor

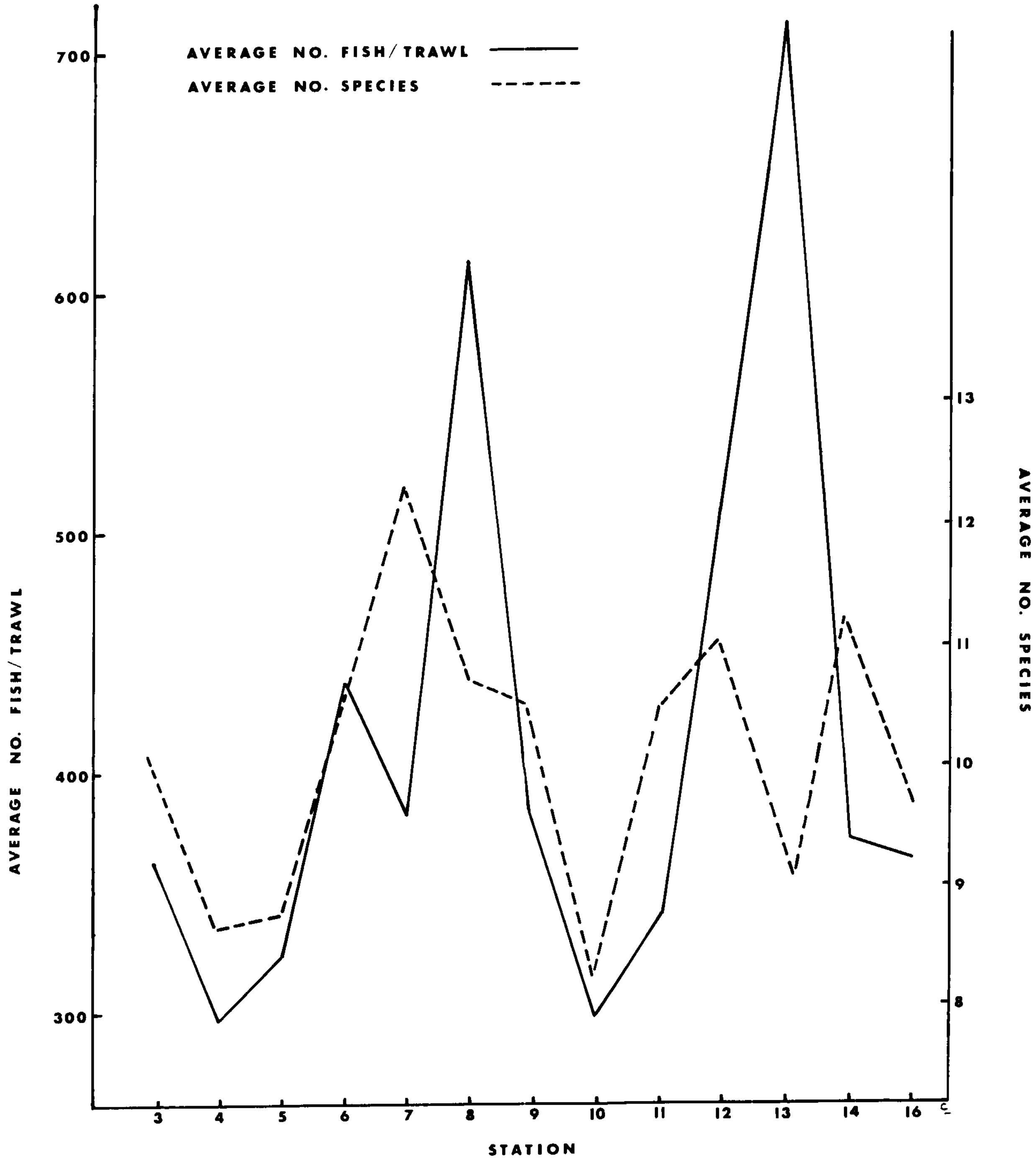

Figure 3. Variation in average trawl size and number of species with station in Los Angeles Harbor.

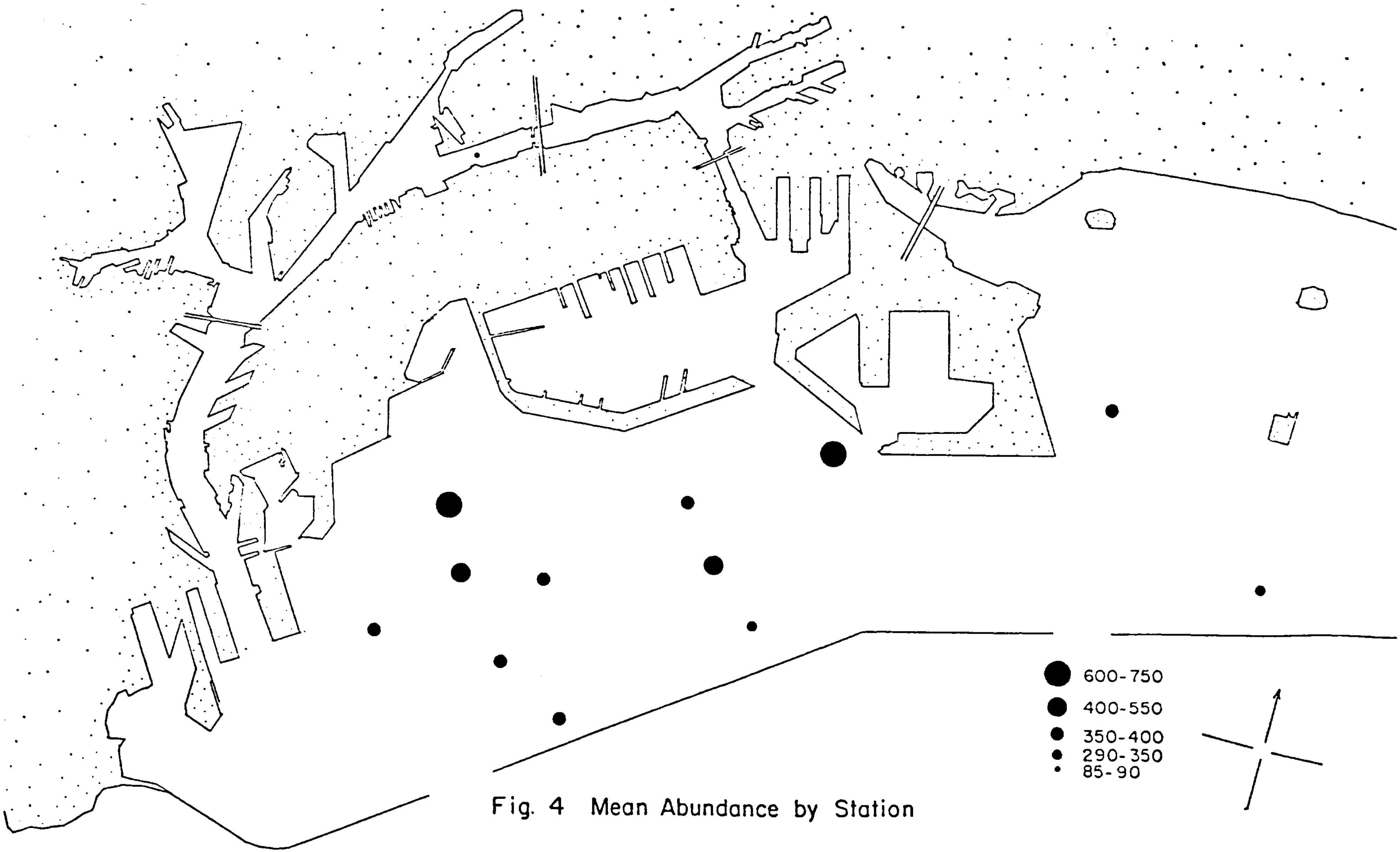

Fig. 4 Mean Abundance by Station

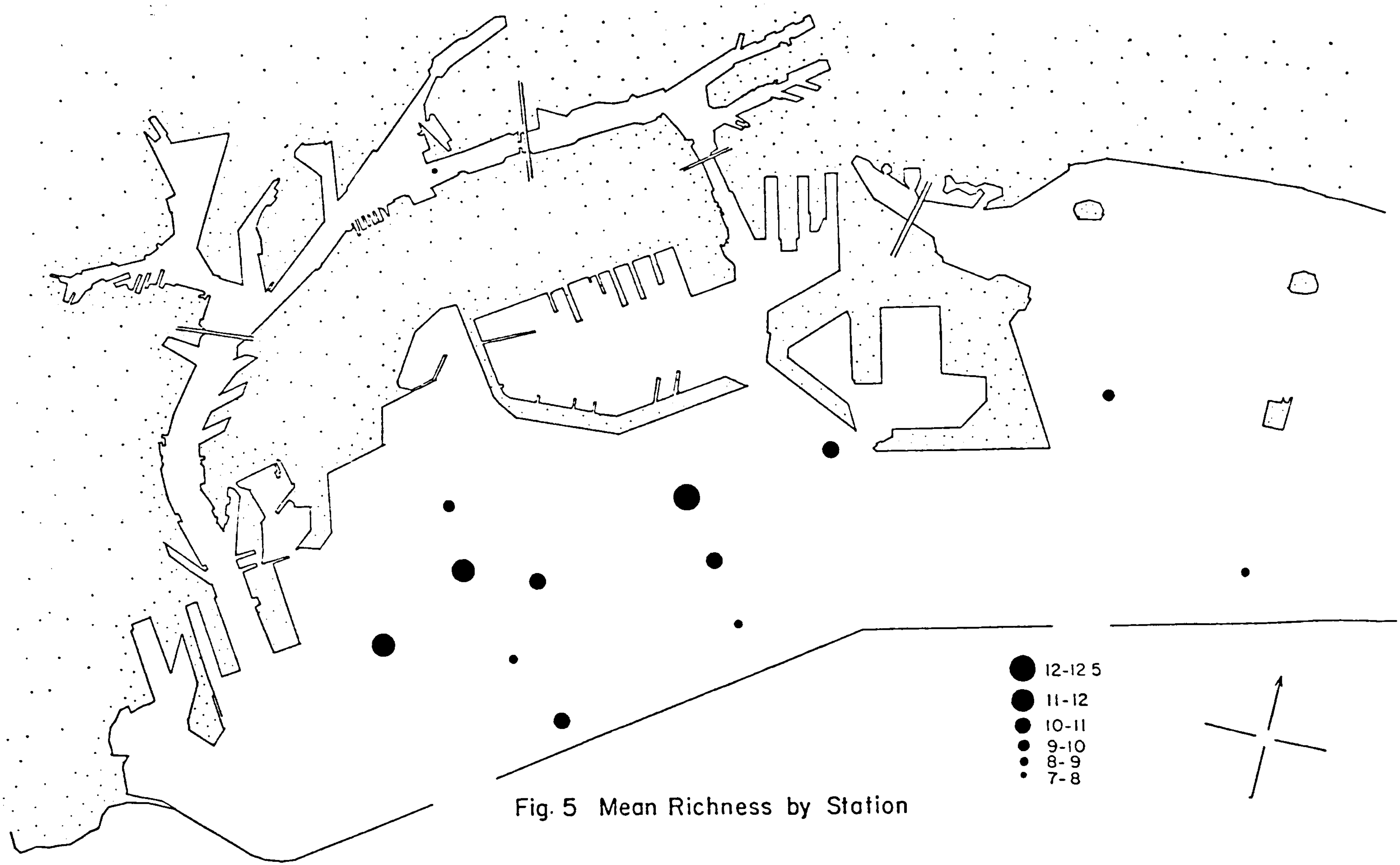

Fig. 5 Mean Richness by Station

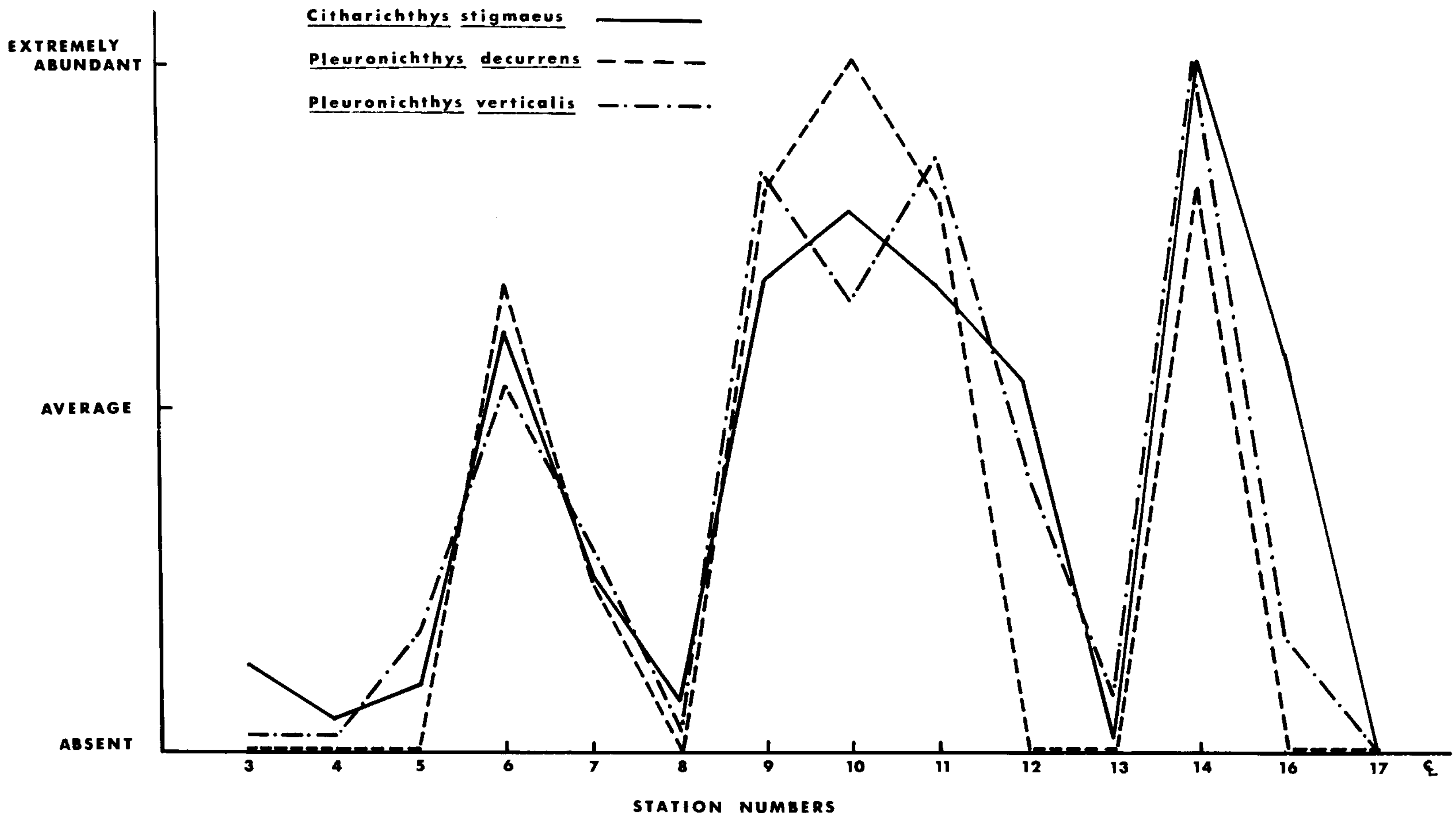

Figure 6. Differences in relative abundance of three flatfish species with station.

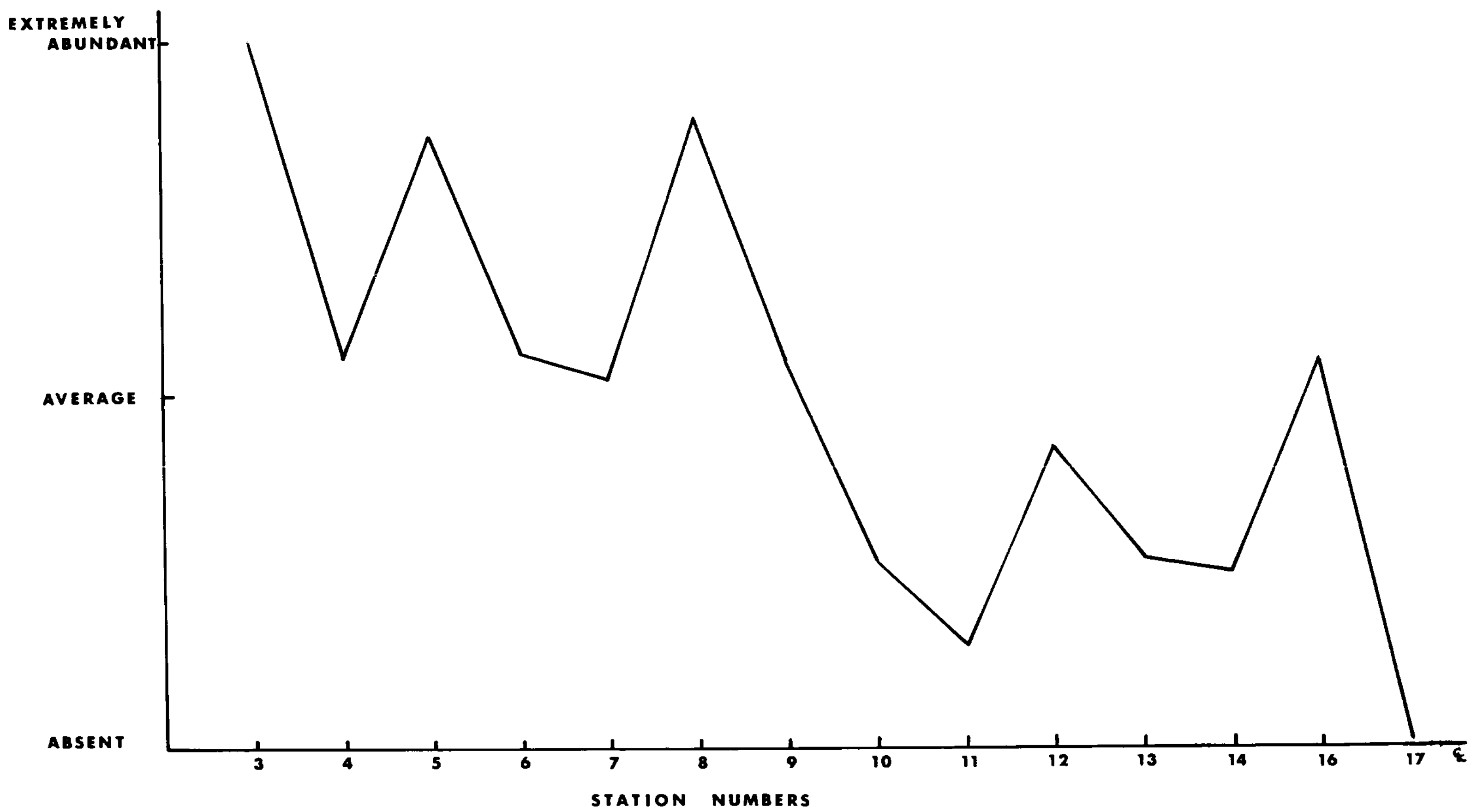

Figure 7. Differences in the relative abundance of *Symphurus atricauda* with station.

16

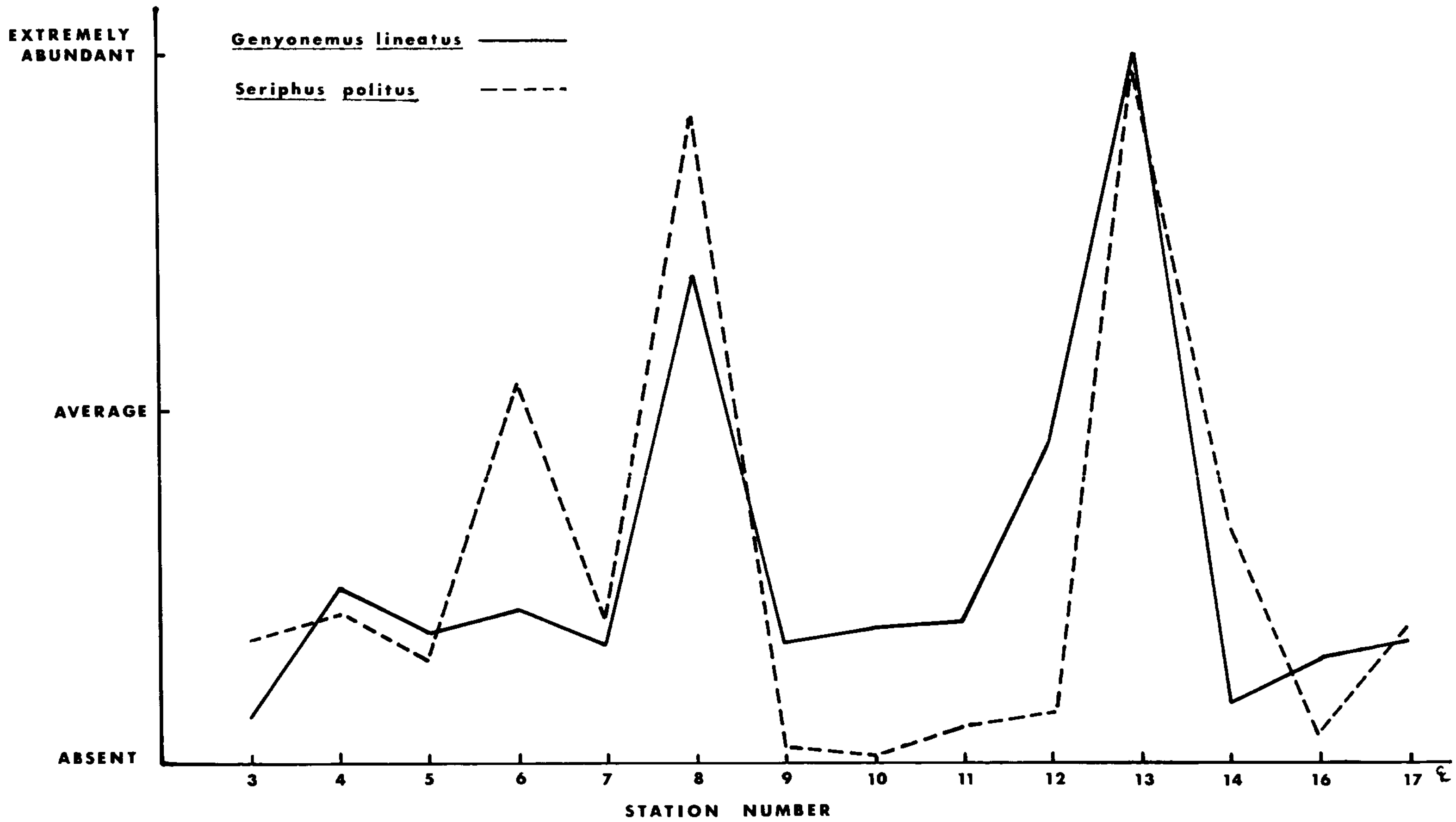

Figure 8. Differences in relative abundance of croakers with station.

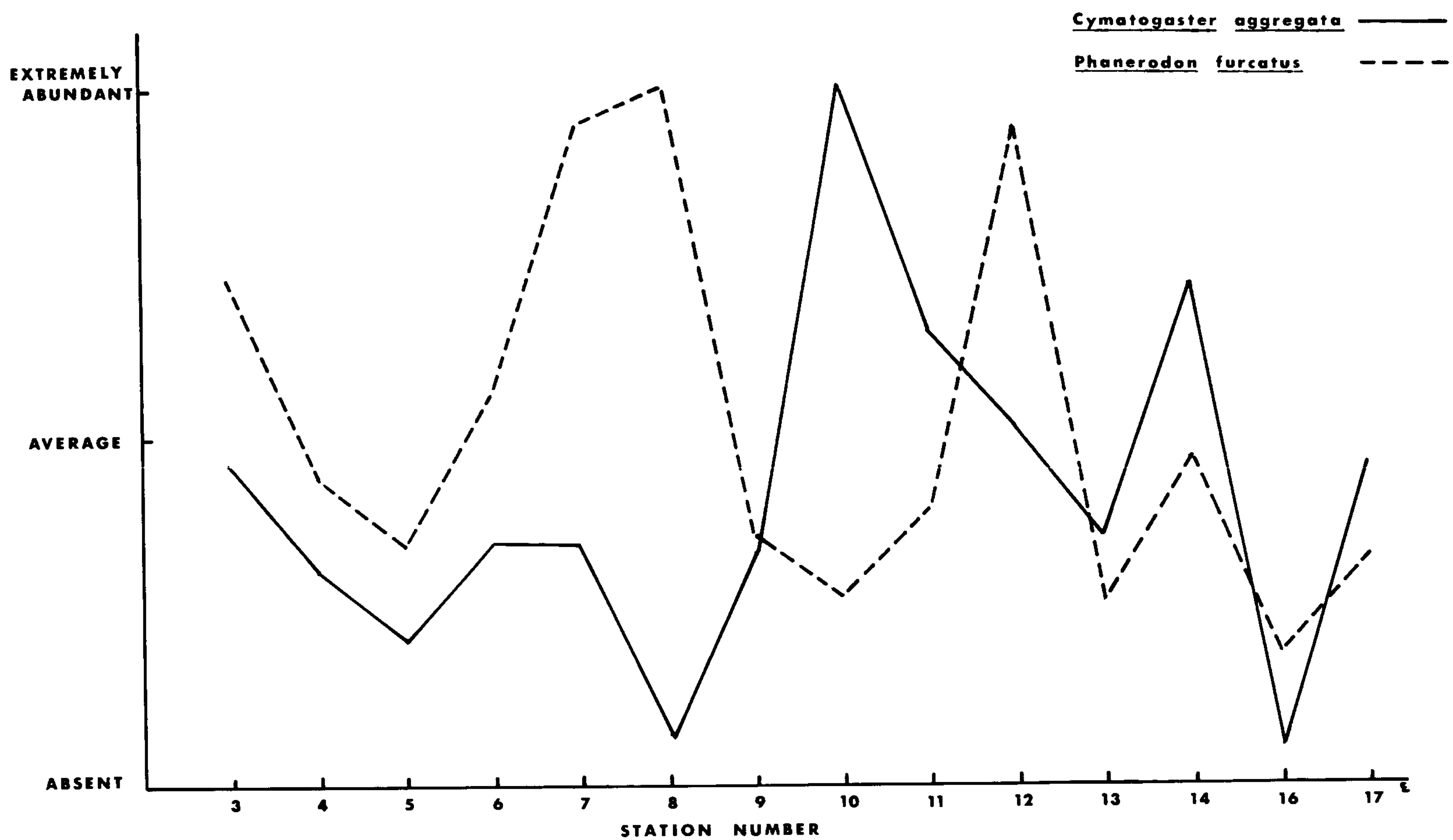

Figure 9. Differences in relative abundance of two surf perch species with station.

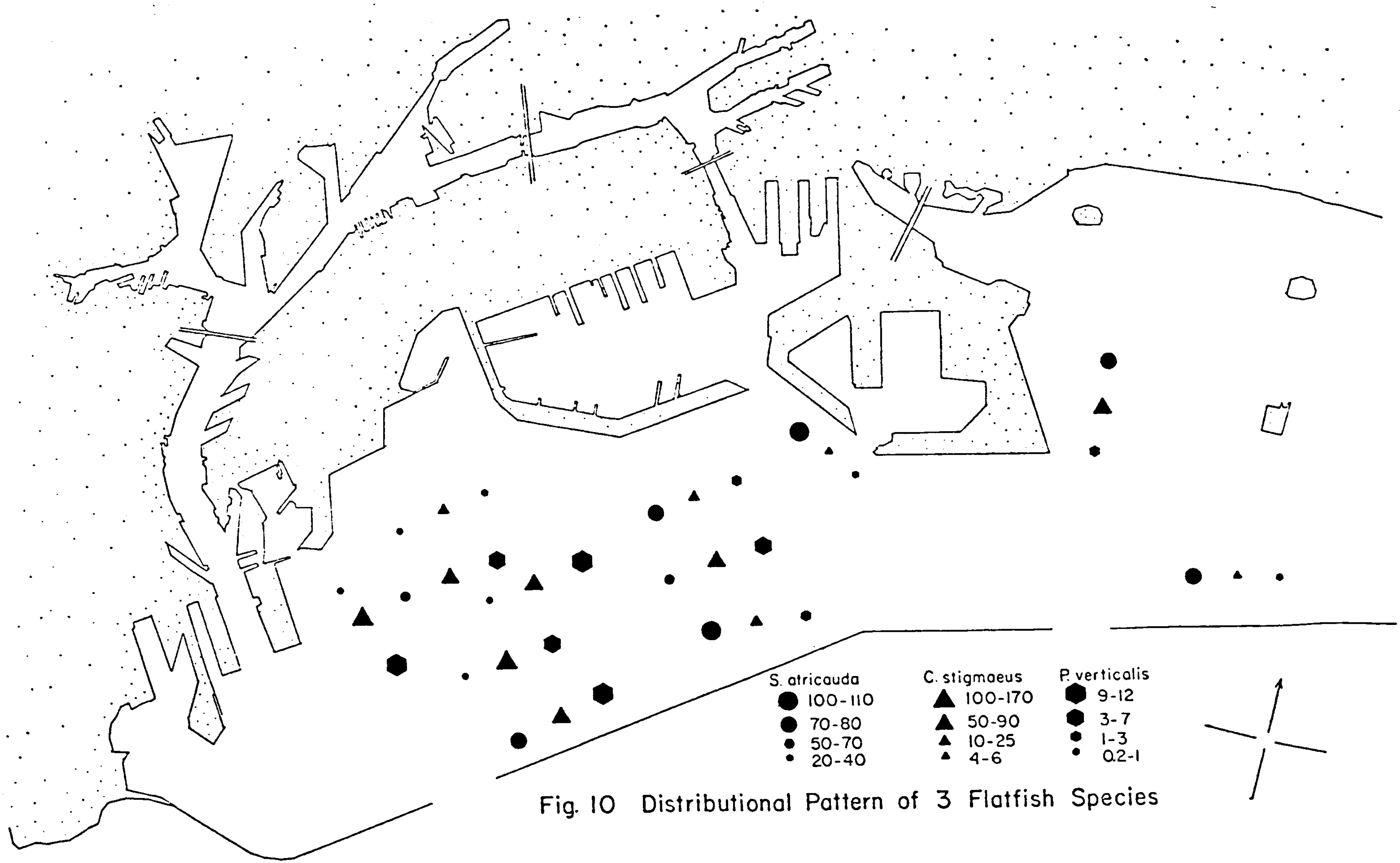

Fig. 10 Distributional Pattern of 3 Flatfish Species

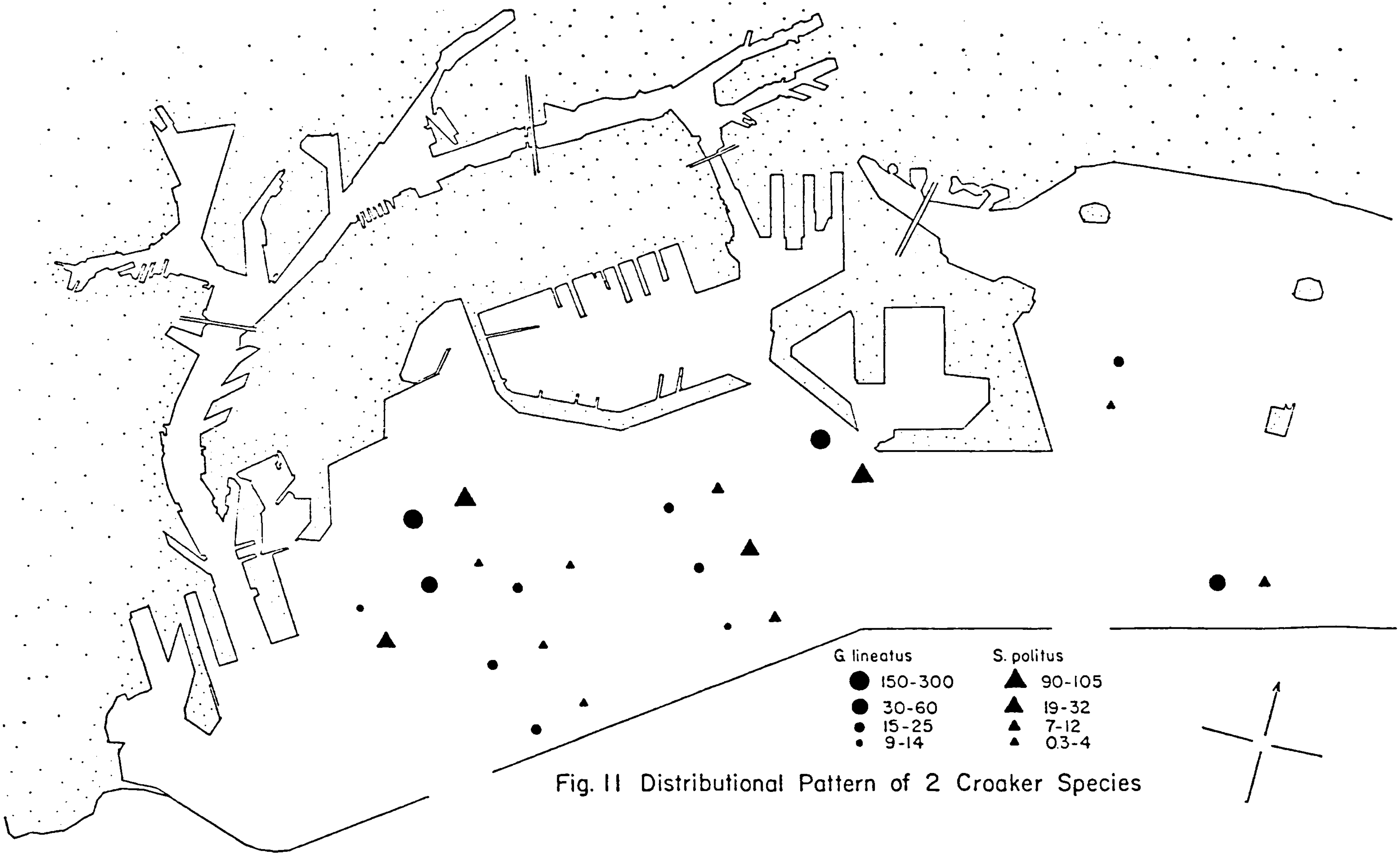

Fig. 11 Distributional Pattern of 2 Croaker Species

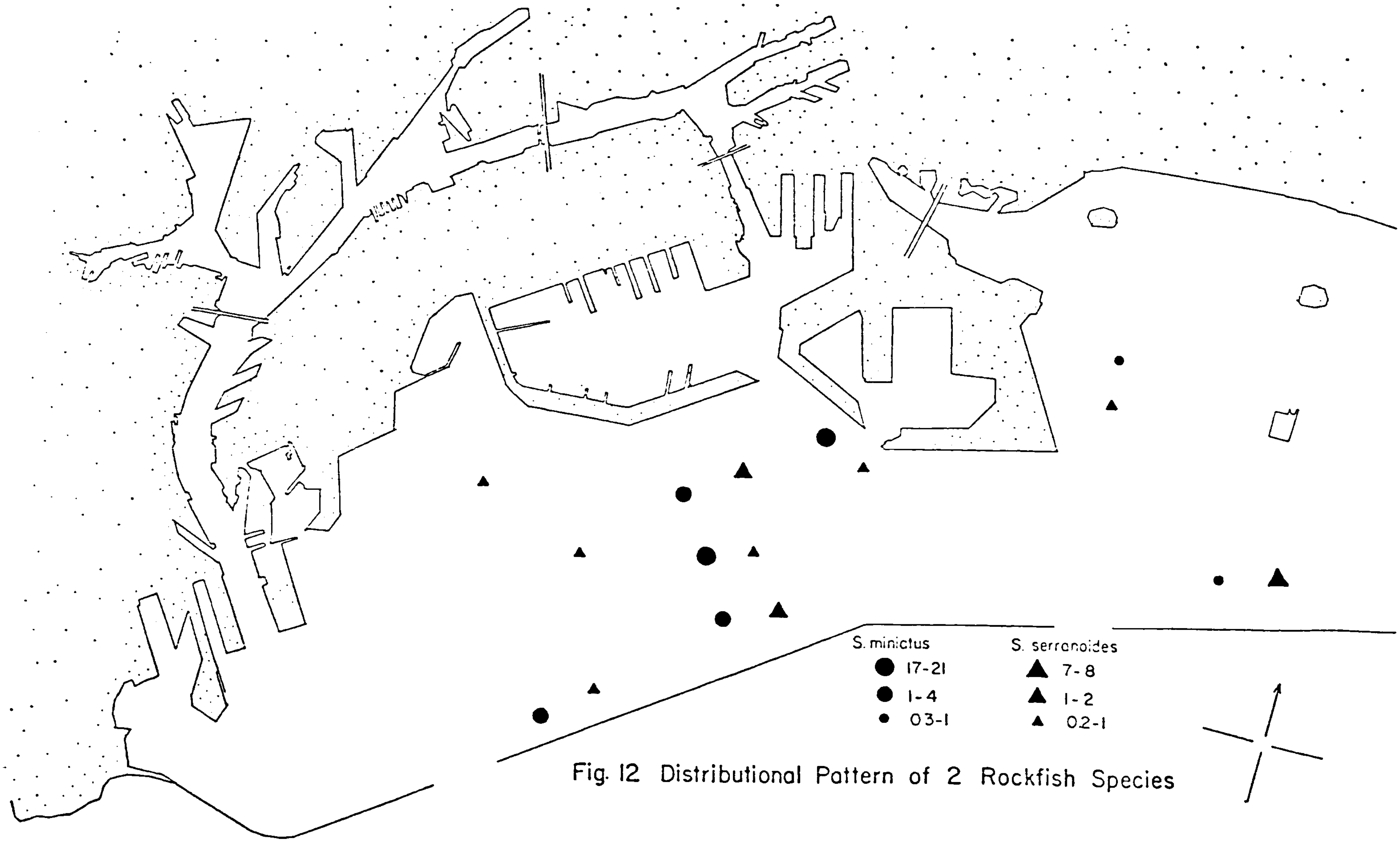

Fig. 12 Distributional Pattern of 2 Rockfish Species

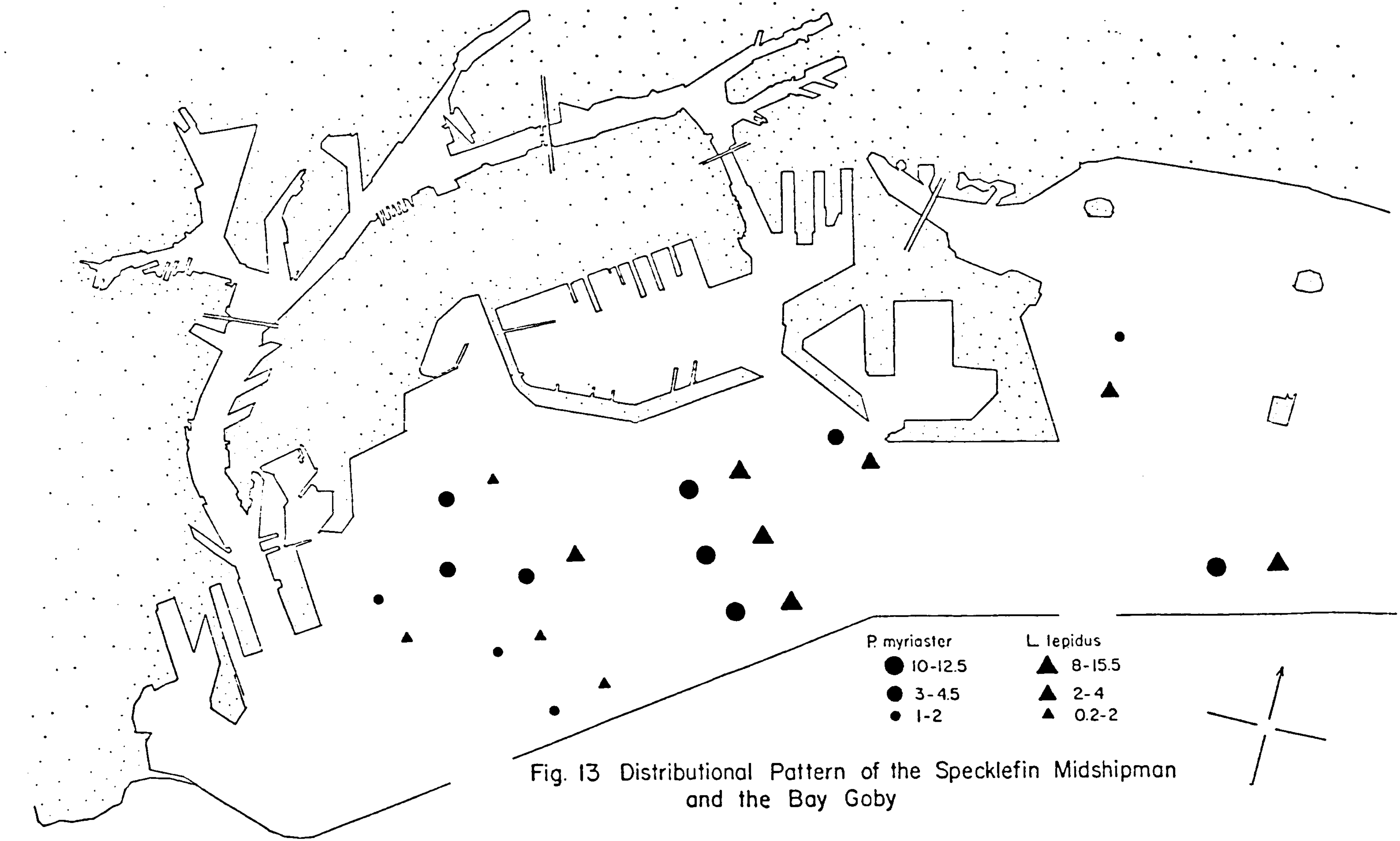

Fig. 13 Distributional Pattern of the Specklefin Midshipman and the Bay Goby

Station 7 demonstrates the highest diversity, with Stations 14, 6, 8, and 12 also high. The lowest diversity is shown at Stations 10 and 17. It is significant that the highest diversity appears to occur at areas where our regional distributional areas intersect (see Figure 2). The low diversity and abundance at Station 10 has not been reconciled.

SEASONALITY AND UNUSUAL ABUNDANCE. The monthly change in average catch and richness per trawl is graphed in Figure 14. This graph includes all specimens taken from October 1972 to October 1973. The exaggerated abundance of fish between July and October 1973 largely reflects white croaker recruitment. It is interesting that this remarkable recruitment in 1973 represents an extremely successful year class and that settling *Genyonemus* were abundant at all stations, not following the adult distributional pattern. Recruitment occurred in 1972 but at a much reduced level as evidenced by the October-November 1972 abundance of *Genyonemus*. In our latest collection (November 9, 1973) there were approximately 2,500 white croakers at Station 13, but croakers were no longer present at Stations 7 and 10, which represents the normal distributional pattern. Figure 15 illustrates the change in white croaker populations (1972-1973). The new year class in July 1973 makes up 97 per cent of the population, which considerably alters the per cent composition by year class. If, however, the fishes smaller than 60 mm are excluded from the graph, the structure of the population is unchanged. It will be interesting to follow the effect of this year class on the overall structure of the population for the next few years.

Seasonality is reflected in overall abundance but may be masked by abundance cycles that are not in phase. Figures 16-19 graph variations in abundance of some characteristic harbor species. There is a high degree of variation in these graphs. Since the species show uneven distribution in the harbor, a great deal of variation is introduced into the data simply by our monthly choice of stations. It is still evident that the majority of these species are less abundant in the winter that during the remainder of the year. A number of factors could contribute to this seasonal variation. The obvious ones are attrition and seasonal movement. Since most temperate species spawn in spring and early summer, recruitment during these months would account for increased abundance. The winter months, just prior to recruitment, should represent the period when a species has been reduced by all controls to its lowest density. Much of the seasonality demonstrated here probably reflects this annual attrition. The fact that richness also decreases in the winter (Figure 14), however, indicates that some species are probably leaving the harbor during this period. If this is the case, both factors would be acting together during the same period.

Seasonal movements are known to occur in some of the indicator species. Most of the rockfishes in the harbor are juveniles, and these fishes tend to move to deeper waters as adults. The bimodal distribution in *Sebastes* (Figure 16) reflects late fall emigration and spring recruitment. *Citharichthys* (Figure 17) prefers cool water (Ford 1965), and its distribution within the harbor reflects proximity to open water circulation. The seasonal decrease in this species correlates well with the fall overturn and the disappearance of the thermocline, which results in increased bottom water temperatures. The only species that demonstrates a decreased population in the summer is the queenfish, *Seriphus politus* (Figure 18). In the summer we have taken this species in great numbers in very shallow water (Belmont Shores--beach seine and Cerritos Channel--gill net). It is possible that its disappearance from our trawling stations represents an inshore migration of this species. Figure 19 includes three species, the two embiotocids *Cymatogaster* and *Phanerodon* and the anchovy *Engraulis*. All three are schooling species during at least part of the year. *Cymatogaster* is known to form migrating schools in the winter which move to deeper water (Wiebe 1968). Terry (MS) found that in King Harbor, California, at least some schools wintered in shallow rather than deep water. Some individuals in Los Angeles Harbor apparently do not migrate at all in the winter. *Phanerodon* prefers cool water (Terry, *ibid.*), and its lower winter abundance may again reflect the fall overturn.

Northern anchovies are known to make large scale migration (Vrooman, Paloma, and Jordan 1966). According to Frey (1971) they are present along submarine excarpments in the summer and fall, surfacing at night and seeking a depth of between 300-600 feet during the day. Spring schools are supposed to be at the surface in the day and dispersed at night. Northern anchovies occur in our trawling samples irregularly. Our largest samples have been in October and July. In both cases, the majority of the catch is made up of Age Class 0 fish. As northern anchovies are known to spawn all year, with peaks in spring and fall, certain growth stages of first year fish may utilize the harbor as a nursery. It should be noted, however, that otter trawls will only be effective in capturing anchovies when they are near the bottom. As

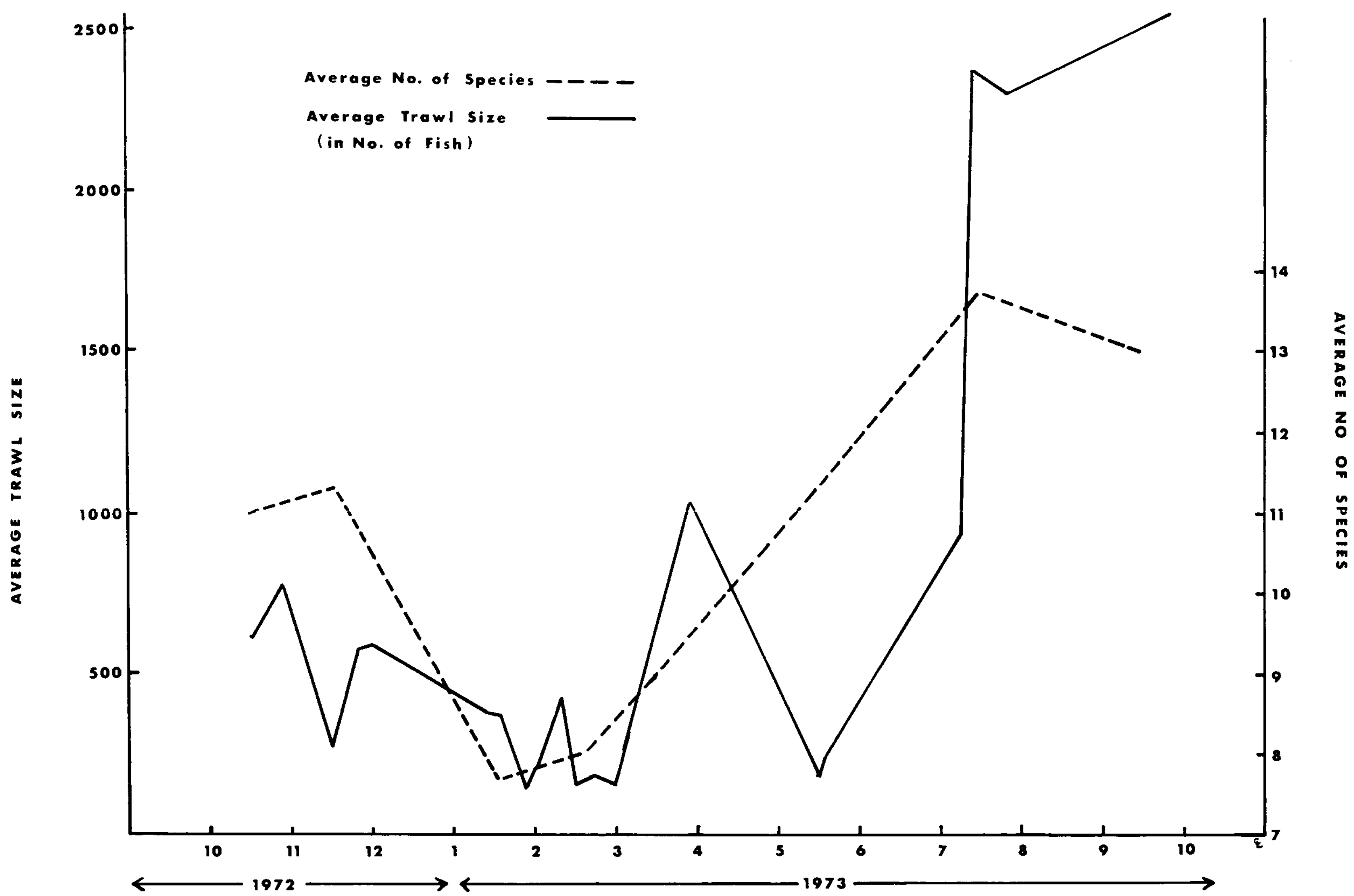

Figure 14. Variation in average trawl size and number of species with date.

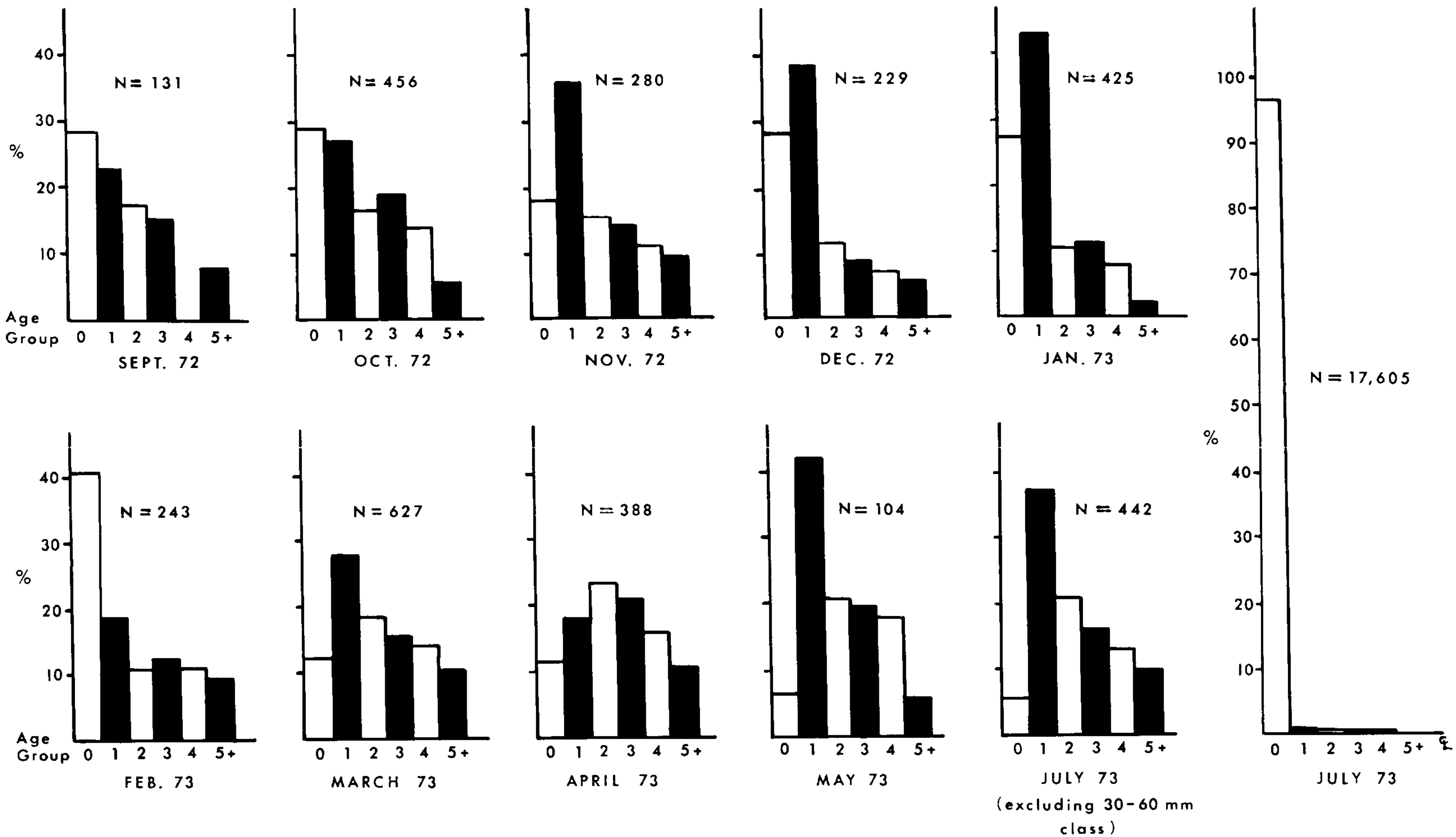

Figure 15. Monthly population structure of the White Croaker, 9/72 - 7/73

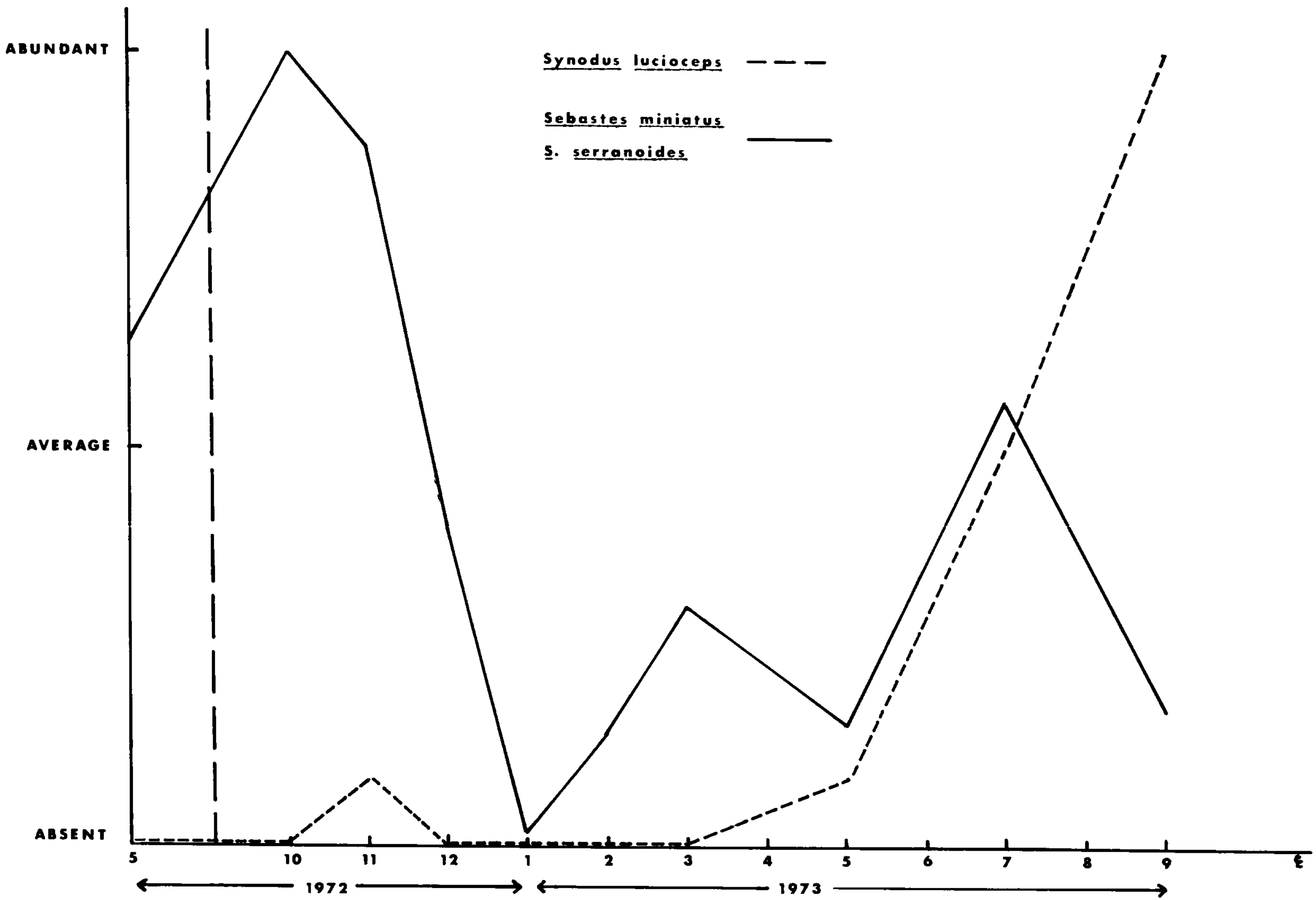

Figure 16. Monthly differences in relative abundance of the rockfishes *Sebastes miniatus* and *S. serranoides* and the lizardfish *Synodus lucioceps*.

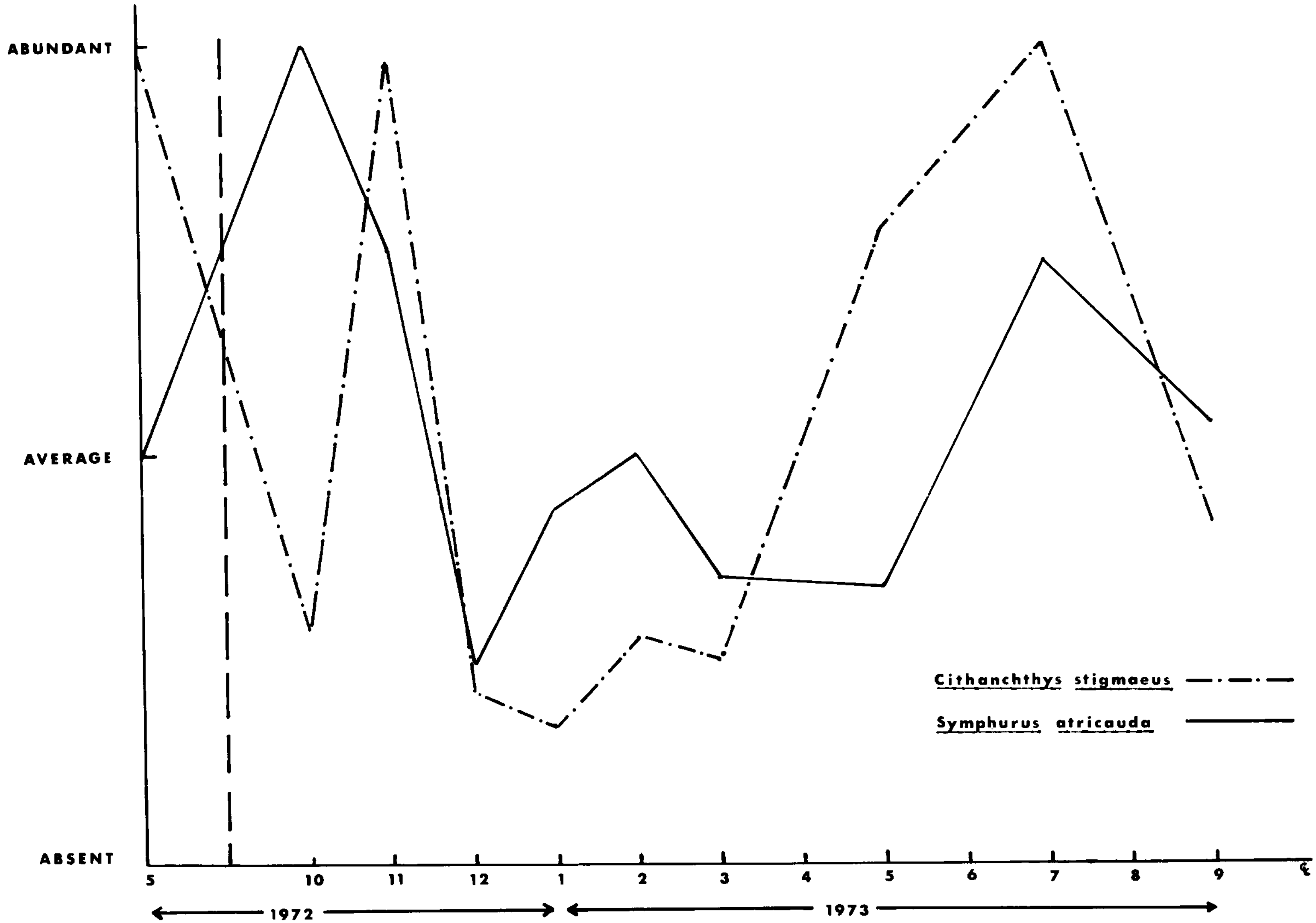

Figure 17. Monthly differences in relative abundance of two flatfish species.

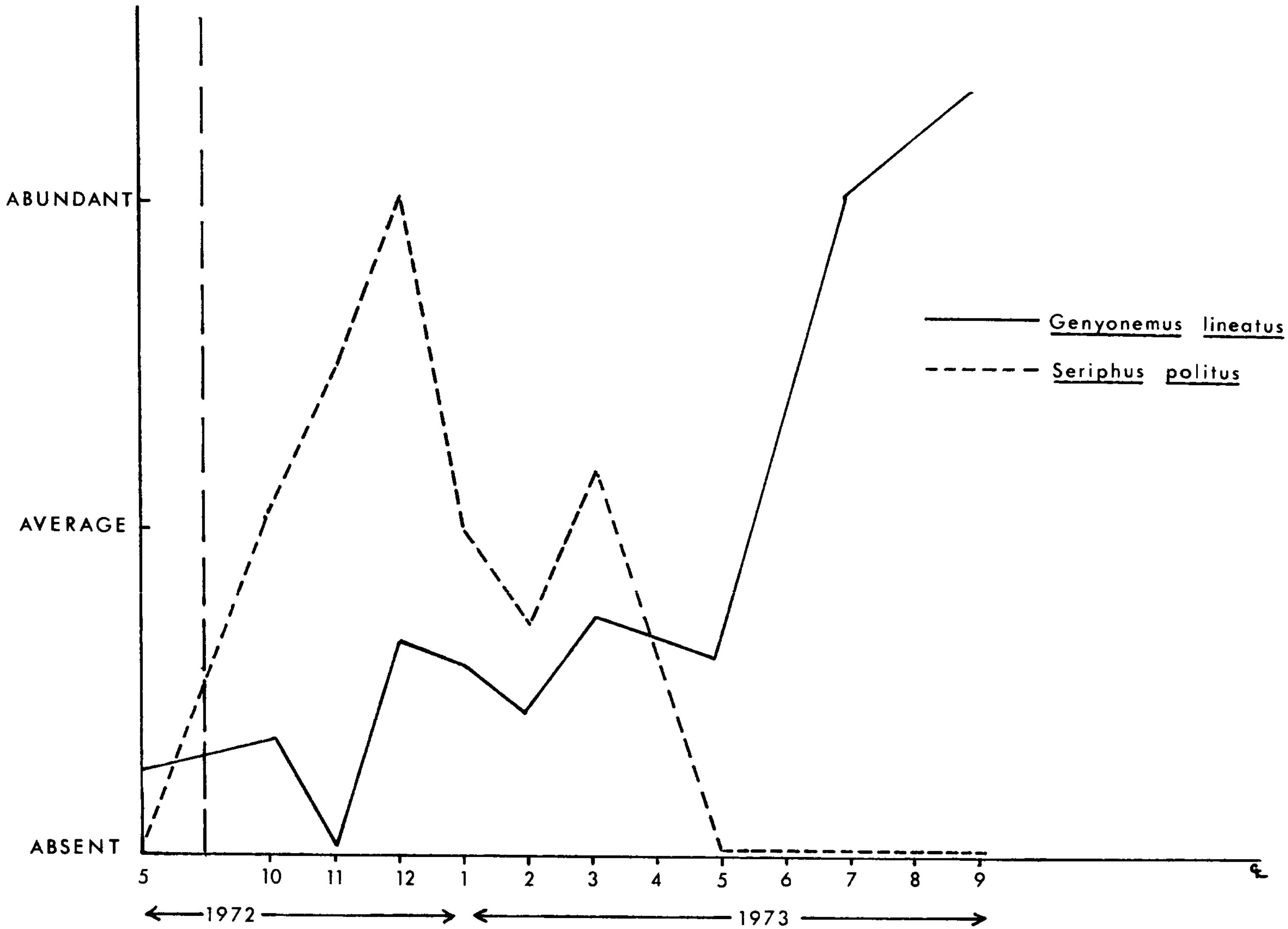

Figure 18. Monthly differences in relative abundance of croakers.

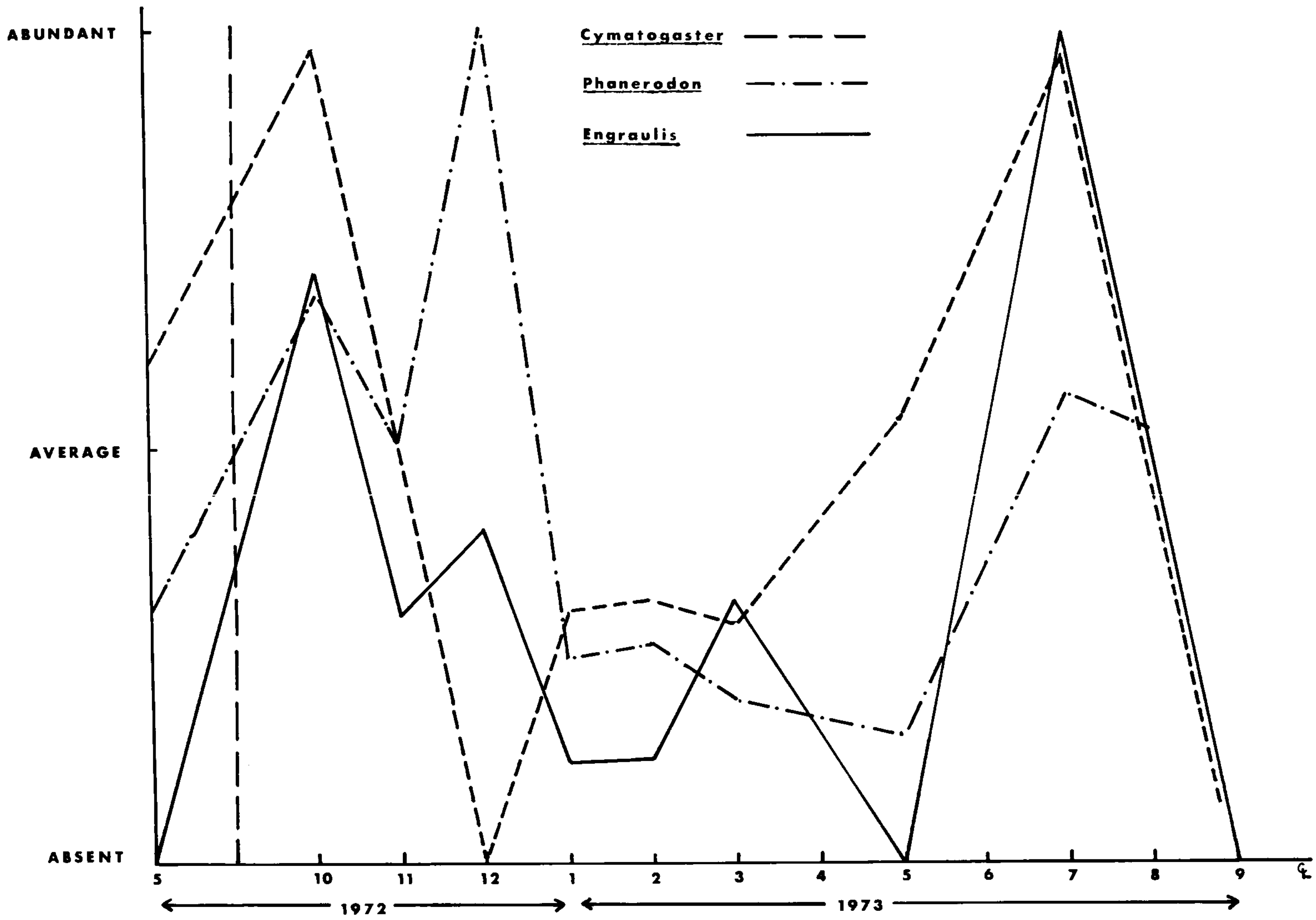

Figure 19. Monthly differences in relative abundance of *Cymatogaster aggregata*, *Phanerodon fercatus* and *Engraulis mordax*.

our trawls were all made during the day, the effectiveness depends upon the behavior of the school. Adult anchovies are taken regularly by bait fishermen in the harbor at night.

FACTORS LIMITING DISTRIBUTIONAL OR COMMUNITY PATTERNS IN THE HARBOR. If we examine the ecological parameters of the more abundant species within the harbor, it is apparent that a number of obviously different spatial and energy requirements are involved in their distribution. It is possible to separate species into groups which hold different positions in the water column. Most of the harbor species can be assigned to one of these five general categories. The first category includes the obligate benthic species, or those forms that spend a majority of their existence in contact with the substrate, including all of the flatfishes and the bay goby, *Lepidogobius*. A second category includes species which spend a considerable portion of their existence on the substrate but feed in the water column, i.e., *Porichthys myriaster, Sebastes miniatus, Paralabrax nebulifer, Synodus lucioceps,* etc. The California halibut *Paralichthys* is almost marginal between these categories, but we prefer to include it in the first. A third category involves species that generally live above the substrate but feed on benthic organisms, i.e. white croakers, many surfperches, and perhaps some rockfishes. The fourth and fifth categories are strictly water column fish and epipelagic species including *Engraulis, Atherinops,* stripetail rockfish, and possibly the queenfish. Table 4 categorizes the dominant harbor species in this fashion. Within each spatial category, differences in activity patterns and feeding preference can serve to separate species ecologically. For example, the anchovy is the only non-descriminate plankton feeder in the harbor. The other common epipelagic species, the topsmelt, is a descriminate plankton feeder. Therefore, while anchovies may feed day and night, topsmelt are diurnal feeders. Similarly, among the flatfishes, the most abundant species are small crustacean feeders (*Symphurus* and *Citharichthys*), but morphological evidence suggests that *Symphurus* may be nocturnal, possibly olfactory feeding form while *Citharichthys* is known to feed diurnally and has large, well-developed eyes. Certainly, the piscivorous halibut is not ecologically competitive with the turbots (*Pleuronichthys*), and each turbot species has morphological differences that suggest different feeding patterns. Likewise, benthic feeders, such as *Genyonemus* and *Phanerodon*, may complete with flatfishes for food while water column predators such as *Paralabrax* and *Sebastes* may utilize the same food as the

Table 4. Spatial relationships of fishes in soft bottom community.

Category	Description	Species
A	obligate benthos	*Symphurus atricauda*
		Citharichthys stigmaeus
		Pleuronichthys verticalis
		P. decurrens
		Paralichthys californicus
		Lepidogobius lepidus
B	facultative benthos	*Porichthys myriaster*
		Sebastes miniatus
		Scorpaena guttata
		Paralabrax nebulifer
		P. maculatofasiatus
		Synodus lucioceps
		S. serranoides (adults)
C	benthos feeders	*Genyonemus lineatus*
		Phanerodon furcatus
		Embiotica jacksoni
		Damalichthys vacca
		Seriphus politus?
D	water column fish	*Cymatogaster aggregata*
		Sebastes saxicola
		S. goodei
		S. serranoides (juveniles)
		Seriphus politus?
E	epipelagic fish	*Engraulis mordax*
		Atherinops affinis

benthic *Paralichthys*. Unfortunately, the biology of most of the harbor species is only superficially understood and any generalizations as to the effect of competition and niche specialization on distributional patterns must be very tentative. It is interesting to note, however, what appears to be mutual exclusion in the harbor between *Citharichthys* and *Symphurus*, the two small crustacean feeding flatfishes. If the seasonal distribution of these species is compared (Figure 17) during a significant number of months, the abundance figures are often reciprocal. If the abundance is examined at individual stations, there is also often a reciprocal relationship. Figure 20 graphs the abundance of these two species at Stations 9, 10, 13, and 14. At Stations 9 and 10 the relative abundance shifts seasonally while at Stations 13 and 14 the dominance of one species is generally maintained. In the latter case, it seems reasonable to suggest that differences in substratel conditions control the distribution of these species. *Symphurus* is the only species of fish found at all stations in the harbor, and the only flatfish that is present regularly at the two stations dominated by croakers (Stations 8 and 13). It appears likely that *Symphurus* can tolerate water of low dissolved O_2 concentration and high organic levels in the substrate. If this is the case, it is also possible that the seasonal variations in abundance at Stations 9 and 10 reflect changing conditions of the water mass. The possibility of some mutual exclusion at least from occupying of the same substratum can, however, not be excluded.

The abundance of *Genyonemus* and *Seriphus* at Stations 13 and 8 coupled with the low frequency of flatfish species suggests that these substrates are limiting to obligate benthic species but are rich in nutrients which support swimming grazers. The proximity of Station 13 to the sewage and cannery outfalls of Terminal Island (Fish Harbor) indicated that bottom conditions here may be rich in organic materials and, therefore, low in oxygen tension. Such a substrate often suggests a rich polychaete fauna (i.e. *Capitella*) which could attract a large population of those grazers able to exploit this food source. Suprabenthic grazers such as white croakers should be better adapted to these conditions than truly benthic species, as they could move in and out of the anaerobic layer of water adjacent to the substrate while feeding. Truly benthic species would find it difficult to tolerate the probable low oxygen tension. The condition at Station 8 is more difficult to analyze. This station occupies the dredged channel at the entrance to the naval base. The depth of this channel exceeds that of the adjacent harbor waters. Station 8 may represent

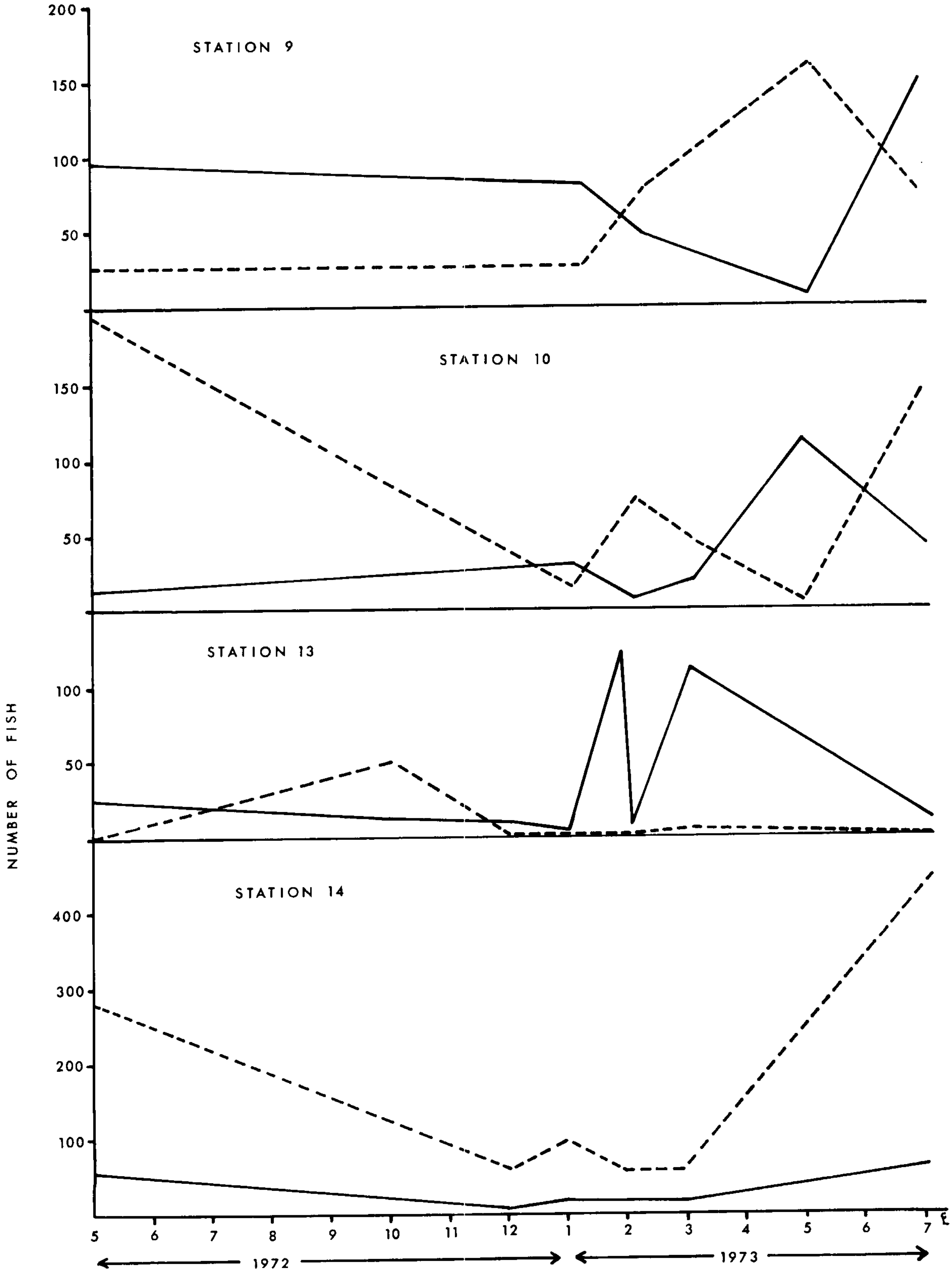

Figure 20. Mutual occurance of *Symphurus atricauda* (____) and *Citharichthys stigmaeus* (----) at four stations in L.A. Harbor.

an area whose accumulated debris may produce conditions similar to those suggested for Station 13. It is significant to note that whereas this latter station is relatively low in richness and Shannon-Weaver index, Station 8 ranks high in both categories. It is also interesting that the drogue studies of Los Angeles Harbor (Soule and Oguri 1972) indicate a pattern of water entering the Long Beach end of the harbor which passes over Station 8 and terminates at Station 13. This water pathway corresponds to the area of low flatfish abundance seen in Figure 2 (Stations 3, 4, 8, and 13). All of the condictions applied to Station 13 also appear applicable to Cerritos Channel. Our trawls and gill nets in this area were dominated by the two croaker species. Two *Lepidogobius* and one *Symphurus* were the only obligate benthic fishes. We feel that areas lacking obligate benthic species and rich in croakers probably represent anaerobic, organically rich benthic conditions.

By contrast, the areas of high flatfish diversity at the west end of the harbor do not show unusual fish abundance and probably represent areas not modified by nutrient accumulation either because of distance from the outfall or due to current scouring.

PRODUCTIVITY. The weight of the standing crop of fishes at out 13 stations in outer Los Angeles Harbor was measured July 11-13, 1973. The total weight of fishes was 279.8 lbs (172,429 g) or an average weight per trawl of 29.2 lbs (13,257 g). As previously indicated by numbers of fish, there was considerable variation by station. This variation partly follows the previously described harbor regions: Station 13 was extremely productive, 55 lbs (24,970 g) while the least productive was Station 9 with 16 lbs (7,264 g). In order to convert our earlier data which records fish lengths to weights, it is necessary to derive a length-weight relationship for each species. Weight can be related to length: $W = KL^3$ (Weatherley 1972). The calculated K values for 14 species are presented in Table 5. The values represent average values and it should be noted that they are at best an approximation. With this conversion, weights of previous trawls can be estimated. Using the weight estimates derived from K values, number per species and $\bar{x}$ length per species, our estimated weight came within four per cent of the shipboard measurement of weight for Station 12, July 1973. Table 6 compares the July weight data for the harbor with estimated data from Winter 1973 at six stations. The winter data is even more variable than that of the summer,

Table 5. K factor (length-weight) constant in 14 Los Angeles Harbor species.

Species	K x 10^{-5}
Symphurus atricauda	1.08
Citharichthys stigmaeus	1.60
Pleuronichthys verticalis	2.68
P. decurrens	3.17
Genyonemus lineatus	2.16
Seriphus politus	2.20
Engraulis mordax	0.88
Phanerodon furcatus	2.54
Cymatogaster aggregata	2.53
Porichthys myriaster	1.36
Lepidogobius lepidus	1.12
Sebastes miniatus (juveniles)	3.27
S. serranoides (juveniles)	2.00
Synodus lucioceps	0.912

Table 6. Summer-Winter standing crop estimates.

	Summer							Winter							
Station	*Wt. grams	Wt. g benthic	N benthic	Wt./fish total	Wt./fish benthic	% Benthic No.	% Benthic Wt.	Station	*Wt. grams	Wt. g benthic	N benthic	Wt./fish total	Wt./fish benthic	% Benthic No.	% Benthic Wt.
3	10,482/14,074	2,959	314	4.8	33.4	10.6	74.5	3	4,863/4,949	220	211	22.5	23.1	95.9	98.3
4	5,564/10,079	3,842	303	2.6	18.4	7.9	55.2								
5	7,288/9,897	1,815	338	5.5	21.6	18.6	73.6	5	4,941/5,085	306	296	16.6	16.7	96.7	97.2
6	10,431/12,258	1,533	253	8.0	29.6	16.5	85.1								
7	10,423/15,118	3,710	172	4.1	60.6	4.6	68 9								
8	13,522/16,117	2,086	416	7.7	32.5	19.9	83.9	8	32,600/34,688	1,292	1,185	26.8	27.5	93.5	94.0
9	6,366/7,264	888	270	8.2	23.6	30.4	87.6								
10	7,572/9,988	2,536	772	3.9	9.8	30.4	75.8								
11	13,563/17,025	2,888	329	5.9	41.2	11.4	79.7	11	2,043/2,043	70	70	29.2	29.2	100	100
12	12,996/15,118	2,748	325	5.5	40.0	11.8	86.0								
13	20,207/24,970	3,809	243	6.6	83.2	6.4	80.9	13	17,693/17,797	605	592	29.4	29.9	97.9	99.4
14	9,521/9,988	1,024	693	9.8	13.7	67.7	95.3								
16	9,225/10,669	1,067	337	10.0	27.3	31.5	86.5	16	2,225/2,225	95	95	23.4	23.4	100	100
$\bar{x}$	10,538/13,256	2,377	366	6.3	33.5	20.5	79.5	$\bar{x}$	10,923/11,123	431	408	24.7	25.0	97.3	98.2

* Benthic wt./total wt.

with one trawl (Station 8) being the heaviest we have recorded, twice as productive as the next largest winter trawl and more than three times the winter average. Two trawls (Stations 11 and 16) had few fish, 70 and 95 respectively, and low productivity. The average winter productivity is slightly less than that in the summer, but the similarity in weight is not reflected in mean number of fish, 2,377 summer to 431 winter.

Most of these fish in the summer population are juvenile white croakers ($\bar{x}$ = 1,575) and anchovies ($\bar{x}$ = 436), but their weight represents a relatively small portion of the total ichthyomass, together about 21 per cent. If these pelagic fishes are eliminated from the samples, the summer-winter benthic mass is almost identical (10,538 to 10,928), slightly in favor of the winter population. The winter population lacks juvenile croakers and has relatively few anchovies and, therefore, the benthic weight is 98 per cent of the total weight. Without croakers and anchovies, there are more fish per trawl in the winter collections. However, this average does not truly represent the winter average (see seasonality) and is biased by Stations 8 and 13, the two most productive in the harbor. The average weight of each benthic fish in the winter is 25.3 while in the summer it is 28.8 g. Considering that each trawl covers 3,770 m^2, the average biomass per square meter is 3.5 g total (2.8 benthic) in the summer and 3.0 g total (2.9 benthic) in the winter. We estimate the total soft bottom area of the outer harbor as 54.600,000 m^2, so the total estimate of productivity of this harbor habitat ranges from 163,791-191,089 kg. Recent trawl studies (Ford *ibid.*) have indicated that an otter trawl captures between 12-22 per cent of the fishes in its path. This figure varies with the size of the net, but the lower figures would probably apply to our small trawls. Our estimate of maximum standing crop of fishes probably represents less than 30 per cent of the actual productivity. A better estimate might be the range between 636,963 kg (30 per cent fishing efficiency) and 1,600,000 kg (12 per cent fishing efficiency) or 11.7-29.3 g/m^2 from this soft bottom harbor habitat.

Standing crop estimates can be misleading as an estimate of productivity, as a standing crop may be the result of many years of production. The amount of this crop that is produced annually is a statistic that can be used to estimate harvestability. It is possible to develop an estimate of the annual productivity of this harbor habitat if we assume that all trawled fishes are endemic to the harbor. The while croaker, *Genyonemus*, makes up between 44 (winter) and 52 (summer) per cent of the fish biomass. The population structure, mortality, and fecundity of this species was recently estimated by Phillips, Terry, and Stephens (1972). Using this data, the productivity equations reviewed by Ricker (1968) and Weatherley (1972), and our harbor statistics, we can generate an estimate of the annual productivity of white croakers. Excluding larvae, the mean size of croakers (130 mm, 47.5 g) is near the end of the second year of growth (AG1), which is the numerically dominant age group. However, from the standpoint of biomass, AG2 dominates. From the second through fifth years, white croakers increase in weight approximately 29 grams per year, and there is a 43 per cent annual mortality.

The instantaneous growth estimate (G) is the natural log of the biomass at the end of a time interval (one year) divided by the original biomass. Z represents the natural log of the annual mortality rate. The difference G-Z, is the net annual rate of increase of biomass. G-Z is positive through AG2 but becomes negative as G decreases in AG3. The highest productivity is in the first year of growth (AGO), even though the mortality rate durbng this year is 95 per cent, since the increase in mass from egg to 100 mm (17.5 g) is more than 100 times. For *Genyonemus* the total annual net productivity (AG)-AG5) is 41 per cent of the standing crop.

We do not as yet have age and growth data on the remaining harbor species (52% of the biomass). However, we estimate that six of these, *Lepidogobius*, *Sebastes miniatus* (juveniles), *Cymatogaster*, *Engraulis*, *Citharichthys*, and *Symphurus* would attain most of their growth (at least 90 per cent) in one season, while *Seriphus*, *Phanerodon*, *Porichthys*, and *Pleuronichthys* may approximate the pattern seen in *Genyonemus*. Total annual productivity in the harbor, therefore, can be considered to approximate: *Genyonemus* (48% of standing crop x 41% annual productivity) = 19.7%; annual species (30.6% standing crops x 90% annual productivity) = 27.5%; remaining non-annual species (21.4% standing crop x 41% annual productivity) = 8.8% or a total of 56% of the standing crop. This figure as annual productivity varies from 392,000-896,000 kg.

The maximum estimate of total annual productivity (1,600,000 kg) equals 889.9 metric tons and amounts to a yield of 146 lbs/acre (.07 tons/acre), or 16.3 g/m^2 (16.3 metric tons/km^2). The vast majority (93.2%) of this crop is in second or third order carnivores, productivity would be much higher at lower trophic level (i.e. anchovies).

The meaning of these figures is difficult to assess. If we consider the maximum productivity figure and value this at $1.00/lb, the annual value would be $1,973,568. However, only 48 per cent of the productive weight is made up by species that are presently utilized by fishermen (*Engraulis, Genyonemus, Seriphus, Phanerodon*, and *Pleuronichthys*). With the exception of the anchovy, none of the species is considered commercially important though white croakers and queenfish are sold as fresh fish. These species, however, are the staples of the inshore sport anglers (pier and small skiff) and have considerable recreational as well as nutritional value.

It is perhaps best to consider this productivity as usable protein. Ricker (1969) estimates that 20 per cent of a fish's weight is high quality protein. The maximum annual production of protein in the harbor would approach 179,200 kg. It is estimated that 36 g/day of protein are necessary for an adequate diet (13,140 g/year). The harbor, therefore, could produce enough protein to supply total annual protein needs for 13,638 persons.

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MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART IV.

A CHECKLIST OF FISHES FROM LOS ANGELES-LONG BEACH HARBORS

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ABSTRACT. The number of fish species known to inhabit or visit the Los Angeles-Long Beach Harbor complex has been more than doubled by recent investigations. This checklist presents 132 species from 48 families in a phyletic sequence. Geographic distribution and depth ranges are provided for each species along with harbor collection stations and the method of capture if known. Family, generic, specific and common names are indexed alphabetically. Each collection site is briefly described, its position given, and a list of fish collected before completion of the present breakwaters (1928), but not taken recently, are presented in two appendices.

ACKNOWLEDGMENTS. I would like to thank the follwing people for their help in compiling this checklist: Ron Williamson for providing information on a number of additional species gathered during his many years of fishing and diving in the harbor; Dr. John Stephens, Jr., Occidental College, for his comments and suggestions, additional species records, use of trawling data and other helpful assistance; Dr. Boyd W. Walker, University of California at Los Angeles, for the use of his Belmont Shores beach seine data collected over the past 20 years; Parke Young, California Department of Fish and Game, for the list of fish species collected during the Department's halibut study and Dr. Dorothy F. Soule, Allan Hancock Foundation, University of Southern California, for her comments and critical review.

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A CHECKLIST OF FISHES FROM LOS ANGELES-LONG BEACH HARBORS

INTRODUCTION. In 1928, Ulrey and Greeley presented a list of marine fishes collected at nine dredge and five trawl stations in Southern California within the area now enclosed by the outer Los Angeles-Long Beach Harbor breakwater. At the time of their collections, only the San Pedro portion of the breakwater existed, extending east about 2 miles from Cabrillo Beach. They collected or reported collections by contemporary workers of some 47 fish species from this vicinity, i.e., Cabrillo Beach to Alamitos Bay.

During the years 1956 to 1960, the California Department of Fish and Game conducted a study of the California halibut, *Paralichthys californicus*, in the Belmont Shores area of the harbor and adjacent ocean waters to the south. In addition to the halibut, 49 other species were collected (Parke Young, California Department of Fish and Game, Long Beach, California, per. comm.).

The United States Army Corps of Engineers has recently presented a list of over 50 species of fish that are thought to inhabit the Los Angeles-Long Beach Harbor (U.S. Army Corps of Engineers, MS, 1972), indicated in the species list herein by the annotation S3.

Recent collections and surveys have considerably increased the number of fish species now known to inhabit or to frequent the harbor. This checklist is an outgrowth of the need for current information on harbor fauna for environmental planning and management and ecosystem analysis.

Data obtained utilizing bottom trawls included that of Chamberlain (1973); John Stephens,Jr., Occidental College, pers. comm., (1972-1973); and Stephens *et al* in this publication, pp. 1-42. Unpublished data from gill netting and diving is from Stephens (1973, pers. comm.); beach seine records are courtesy of Boyd W. Walker, University of California, Los Angeles (pers. comm.), and shore angler observations were gathered by the author (HLA-HLG and S2 annotated fish).

The checklist, which includes 132 species in 48 families, follows the phyletic sequence of fish families, orders and classes as presented by the Committee on Names of Fishes of the American Fisheries Society (Bailey, *et al*, 1970). Common and scientific names also follow the American Fisheries Society list with a few exceptions which are noted with an asterisk (*) and are retained because of the more common usage in California. These exceptions follow Miller and Lea (1972). Range and depth distributions annotated under each species are also from Miller and Lea (1972).

The Los Angeles-Long Beach Harbor is an assemblage of various substrates including a sandy-mud bottom, rocky bottom, rock and concrete breakwaters, wood and concrete pilings, sandy beaches, estuaries, and small islands. At mean lower low water, depths in the outer harbor range from about 3 feet in shoal areas to a deep of 72 feet just across the Long Beach Channel from the entrance to the Southeast Basin. The average harbor depth is approximately 37 feet.

Given such varied habitats and the difficulty in taking adequate samples from some of these areas, undoubtedly the following list will be found to be incomplete and not without error or omission.

Figure 1 shows the bottom trawling stations (T1-T17), sport anglers fishing sites (HLA-HLG) and gill netting sites (GN1-GN3). Diving observations were made along the harbor side of the outer breakwaters by Ron Williamson (University of Southern California, pers. comm., S1 annotated fish) and by John Stephens, Jr., (Occidental College, pers. comm., DV1 annotated fish). Numbers and letters listed under each species and after the words "Los Angeles-Long Beach Harbor" refer to location and method of capture (see Figure 1 and Appendix A) if known. Collection methods, depths and positions are unavailable for S1 and S3 annotated fish.

Fish annotated with "U&G" are species which were listed as being taken in the harbor area by Ulrey and Greeley prior to 1928 (see Appendix B).

Family, generic, specific and common names are indexed alphabetically.

This checklist includes those fish taken or observed within the harbor west of an imaginary line running from Belmont Shores to the east end of the Long Beach breakwater, and the area north of the Long Beach, Middle and San Pedro breakwaters.

A very rough indication of the most abundant fish species is indicated by those annotated with the word "common." For more precise information on species abundance the reader is referred to Stephens, *et al*, elsewhere in the present publication.

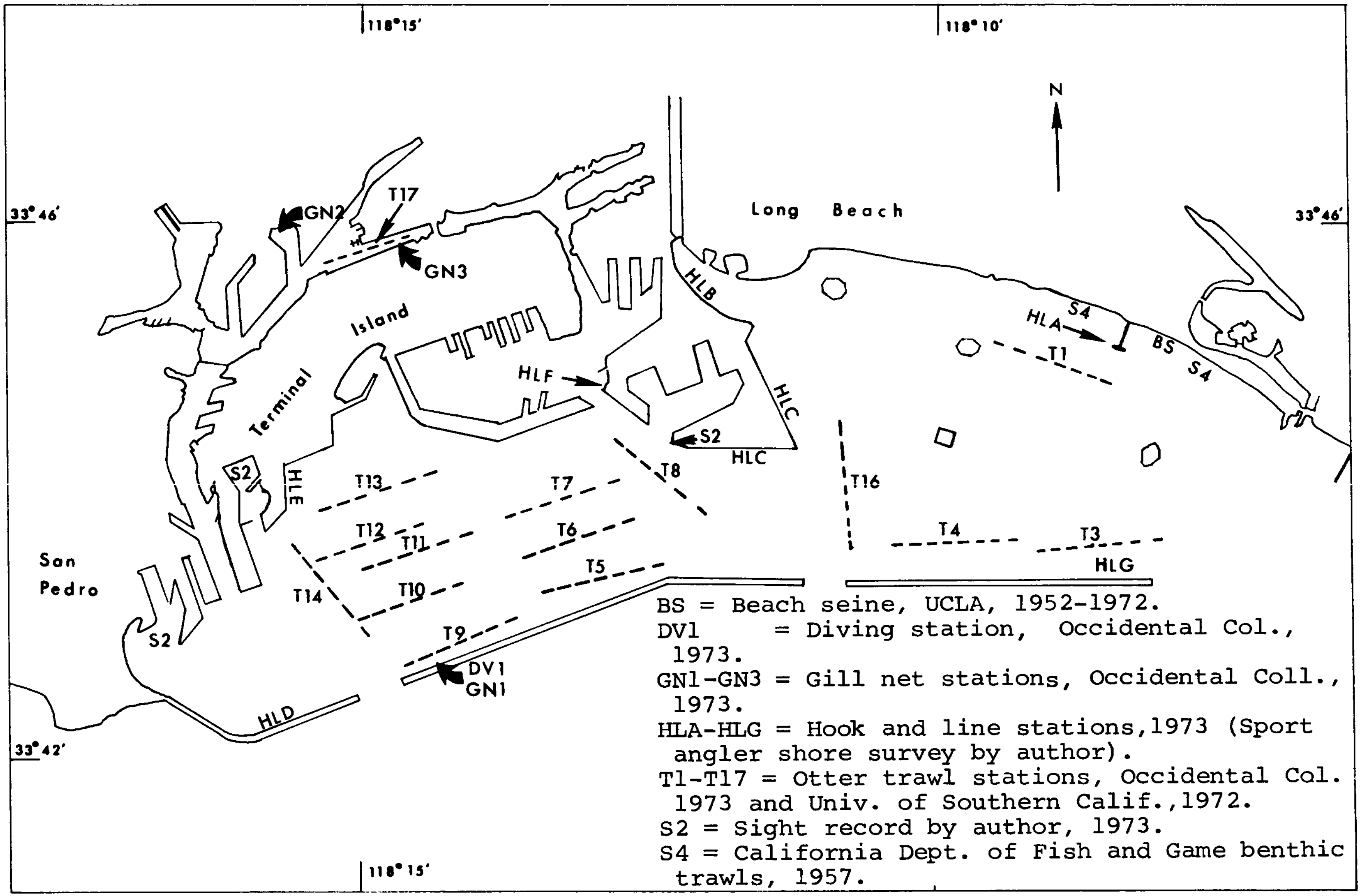

Figure 1. Location of Los Angeles - Long Beach Harbor Data Collecting Stations.

SYNOPSIS OF FAMILIES

Los Angeles-Long Beach Harbor Fish

Phylum Chordata

Class Chondrichthys - Cartilagenous fishes

Order Heterodontiformes

FAMILY HETERODONTIDAE - Bullhead Sharks

Hornshark . . . . *Heterodontus francisci* (Girard)

Gulf of California to Monterey Bay. Shallow to 492 feet. Los Angeles-Long Beach Harbor: S3.

Order Squaliformes

FAMILY CARCHARHINIDAE - Requiem Sharks

Soupfin shark . . . *Galeorhinus zygopterus* Jordan & Gilbert

Chile and Peru to Northern British Columbia, but not in the tropics. Near water surface. Los Angeles-Long Beach Harbor: S4.

Grey smoothhound . . . . *Mustelus californicus* Gill

Mazatlan, Mexico to Cape Mendocino, California. Shallow to 150 feet. Los Angeles-Long Beach Harbor: BS, HLA, Common.

Brown smoothhound . . . . *Mustelus henlei* (Gill)

Gulf of California to Humboldt Bay, California. Shallow. Los Angeles-Long Beach Harbor: HLA, S1.

Leopard shark . . . . *Triakis semifasciata* Girard

Mazatlan, Mexico, Gulf of California to Oregon. Bays and beaches. Los Angeles-Long Beach Harbor: BS, S3.

FAMILY SQUALIDAE - Dogfish sharks

Spiny dogfish . . . . *Squalus acanthias* Linnaeus

Temperate and Subtropical Atlantic and Pacific, Chile, Baja California to Alaska, Japan. Shallow to 1200 feet. Los Angeles-Long Beach Harbor: T8, T11.

FAMILY SQUATINIDAE - Angel Sharks

Pacific angel shark . . . . . . *Squatina californica* Ayres

Chile, Gulf of California to South East Alaska. Shallow water. Los Angeles - Long Beach Harbor: S4.

Order Rajiformes (Batoidei)

FAMILY PLATYRHINIDAE - Thornbacks*

Thornback . . *Platyrhinoidis triseriata* (Jordan & Gilbert)

Baja California to San Francisco. Shallow to 150 feet. Los Angeles - Long Beach Harbor: BS, S1.

FAMILY RHINOBATIDAE - Guitarfishes

Shovelnose guitarfish . . . . *Rhinobatos productus* (Ayres)

Gulf of California to San Francisco (recent records only to Capitola). Surface to 50 feet. Los Angeles - Long Beach Harbor: BS, S1.

FAMILY TORPEDINIDAE - Electric rays

Pacific electric ray . . . . . . *Torpedo californica* Ayres

Baja California to British Columbia. Shallow to 640 feet. Los Angeles - Long Beach Harbor: T7, T12, T13 (A number have been collected in other trawls but additional data is unavailable), Common.

FAMILY RAJIDAE - Skates

California skate . . . . . . *Raja inornata* Jordan & Gilbert

Baja California to Strait of Juan de Fuca. 60 to 2200 feet. Los Angeles - Long Beach Harbor: S1.

FAMILY DASYATIDIDAE*- Stingrays

Diamond stingray . . *Dasyatis dipterura* (Jordan & Gilbert)

Paita, Peru to Kyuhuat, British Columbia. Shallow to 55 feet. Los Angeles - Long Beach Harbor: BS, S3,S4.

California butterfly ray . . . . *Gymnura marmorata* (Cooper)

Peru to Point Conception. Shallow bays and beaches. Los Angeles - Long Beach Harbor: BS, S4.

Round stingray . . . . *Urolophus halleri* Cooper

Panama Bay to Humboldt Bay. To 70 feet. Los Angeles - Long Beach Harbor: BS, S1, S3, S4.

FAMILY MYLIOBATIDAE - Eagle rays

Bat ray . . . . *Myliobatis californica* Gill

Gulf of California to Oregon. To 150 feet. Los Angeles - Long Beach Harbor: BS, HLD, S1, S3, T3, T6, Common.

Order Chimaeriformes

FAMILY CHIMAERIDAE - Chimaeras

Ratfish . . . . *Hydrolagus colliei* (Lay & Bennett)

Gulf of California to South East Alaska. Shallow to 1200 feet. Los Angeles - Long Beach Harbor: S4.

Class Osteichthys - Bony Fishes

Order Anguilliformes (Apodes & Lyomeri)

FAMILY MURAENIDAE - Morays

California moray . . . . *Gymnothorax mordax* (Ayres)

Baja California to Point Conception. Shallow reef areas. Los Angeles - Long Beach Harbor: S1, S4, Common along inside of outer breakwaters (Ron Williamson, Univ. of So. Calif., pers. comm.).

Order Clupeiformes

FAMILY CLUPEIDAE - Herrings

Pacific sardine . . . . . . *Sardinops sagax caeruleus* Jenyns

Guaymas, Mexico to Kamchatka. Epipelagic. Los Angeles - Long Beach Harbor: BS, S3.

FAMILY ENGRAULIDIDAE - Anchovies

Deepbody anchovy . . . . *Anchoa compressa* (Girard)

Todos Santos Bay, Baja California to Morro Bay. Bays and estuaries. Los Angeles - Long Beach Harbor: BS, S3, T8, T13, T14, T17.

Anchoveta . . . . *Centengraulis mysticetus* (Gunther)

Sechura Bay, Peru to Los Angeles Harbor. Los Angeles - Long Beach Harbor: Not taken, may be introduction (see Miller & Lea, 1972, p. 56).

Pacific Herring . . . . *Clupea harengus pallasi* Valenciennes

Northern Baja California to Arctic Ocean and Japan. Inshore schooling fish. Los Angeles - Long Beach Harbor: BS.

Northern anchovy . . . . *Engraulis mordax* Girard

Cape San Lucas, Baja California to Queen Charlotte Island, British Columbia. Los Angeles - Long Beach Harbor: BS, S1, S3, T3-T16, Common.

Slough anchovy . . . . *Anchoa delicatissima* (Girard)

Magdalena Bay, Baja California to Belmont Shores, Long Beach Harbors. Estuaries and bay backwaters. Los Angeles - Long Beach Harbor: BS, T6, T8, T13.

Order Salmoniformes

FAMILY SALMONIDAE - Salmons and Trouts

Coho (Silver) salmon . . . *Onchorhynchus kisutch* (Walbaum)

Chamalu Bay, Baja California to Bering Sea to Japan. Anadromous. Los Angeles - Long Beach Harbor: S1, Rare.

Order Myctophiformes

FAMILY SYNODONTIDAE - Lizardfishes

California lizardfish . . . . . . *Synodus lucioceps* (Ayres)

Guaymas, Mexico to San Francisco. 5 to 150 feet. Los Angeles - Long Beach Harbor: S1, S4, T4-T7, T9, T11, T14, T16, U&G.

Order Batrachoidiformes

FAMILY BATRACHOIDIDAE - Toadfishes

Specklefin midshipman..*Porichthys myriaster* Hubbs & Schultz

Magdalena Bay, Baja California to Point Conception, California. Shallow to 414 feet. Los Angeles - Long Beach Harbor: BS, HLA, S1, S3, S4, T2-T17, Common.

Plainfin midshipman . . . . *Porichthys notatus* Girard

Gulf of California & Gorda Bank, Baja California to Sitka, Alaska. Surface to 1000 feet. Los Angeles - Long Beach Harbor: T5 (only one fish taken), Rare (may be seasonal), U&G.

Order Gadiformes (Anacanthini)

FAMILY GADIDAE - Codfishes

Pacific tomcod* . . . .*Microgadus proximus* (Girard)

Santa Monica Reef to Bering Sea. 40 to 1200 feet. Los Angeles - Long Beach Harbor: S3.

FAMILY OPHIDIIDAE - Cusk-eels

Spotted cusk-eel . . . . *Chilara taylori* (Girard)

San Cristobal Bay, Baja California to Northern Oregon. 4 to 800 feet. Los Angeles - Long Beach Harbor: T5, T7, T8, T13, T14.

Basketweave cusk-eel . . . . . . *Otophidium scrippsi* Hubbs

North of Guaymus, Mexico to Point Arguello. Depth 9 to 230 feet. Los Angeles - Long Beach Harbor: BS.

Order Atheriniformes

FAMILY BELONIDAE - Needlefishes

California needlefish . . . . . *Strongylura exilis* (Girard)

Peru to San Francisco. Shallow to about 300 feet. Los Angeles - Long Beach Harbor: Belmont shore. Summer 1972, Beach Seine, Occidental College.

FAMILY CYPRINODONTIDAE

California killifish . . . . . *Fundulus parvipinnis* Girard

Common in Bays of Southern California. Los Angeles - Long Beach Harbor: BS, U&G.

FAMILY ATHERINIDAE - Silversides

Topsmelt . . . . *Atherinops affinis* (Ayres)

Gulf of California to 4 mi. west of Sooke Harbor, Vancouver Island, B.C. Bays, sloughs, kelp beds. Los Angeles - Long Beach Harbor: BS, DV1, GN1, GN3, HLA, HLE, S1, S2 (dipnetted at Marina, Watchhorn Basin, San Pedro), Common.

Jacksmelt. . . . . *Atherinopsis californiensis* Girard

Santa Maria Bay, Baja California to Yaquina, Oregon. Inshore, bays, Los Angeles - Long Beach Harbor: BS, HLE, S1, S2 (dipnetted at marina, Watchhorn Basin, San Pedro).

California grunion . . . . *Leuresthes tenuis* (Ayres)

Magdalena Bay to San Francisco. Surface to 60 feet. Los Angeles - Long Beach Harbor: BS, S1, S2 (taken by dipnet at Marina, Watchhorn Basin, San Pedro), S3, Common.

Order Gasterosteiformes

FAMILY SYNGNATHIDAE - Pipefishes

Kelp Pipefish. . . . . . . *Syngnathus californiensis* Storer

Santa Maria Bay, Baja California to ca. San Francisco. Kelp Beds. Los Angeles - Long Beach Harbor: T8, U&G.

Pipefish . . . . *Syngnathus* sp.

BS, S3, T6, T7, T8, T13, T16.

Order Perciformes (Percomorphi; Acanthopterygii)

FAMILY SERRANIDAE - Sea basses

Kelp bass . . . . *Paralabrax clathratus* (Girard)

Magdalena Bay, Baja California to Columbia River. Surface to 150 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, HLA, HLC, S1.

Spotted sand bass. *Paralabrax maculofasciatus* (Steindachner)

Mazatlan, Mexico to Monterey, California, including Gulf of California. To 200 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, HLA, HLB, HLC, HLD, S1, S2 (Fish Harbor, Terminal Island), T14 (only one fish taken), Common.

Barred sand bass . . . . . . *Paralabrax nebulifer* (Girard)

Magdalena Bay, Baja California to Santa Cruz, California. Shallow to 600 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, HLC, S1, S3, S4, T12, T17.

Giant sea bass . . . . *Stereolepis gigas* Ayres

Gulf of California to Humboldt Bay. 18 to 100 feet. Los Angeles - Long Beach Harbor: S4.

FAMILY BRANCHIOSTEGIDAE - Tile fishes

Ocean whitefish . . . . . . *Caulolatilus princeps* (Jenyns)

Peru to British Columbia. Surface to 300 feet. Los Angeles - Long Beach Harbor: S3, S4.

FAMILY CARANGIDAE - Jacks and Pompanos

Jack mackerel . . . . *Trachurus symmetricus* (Ayres)

Magkalena Bay, Baja California to South East Alaska. Surface to 150 feet. Los Angeles - Long Beach Harbor: S1, S3.

FAMILY POMADASYIDAE - Grunts

Sargo . . . . *Anisotremus davidsoni* (Steindachner)

Magdalena Bay, Baja California to Santa Cruz, California. Surface to 130 feet. Los Angeles - Long Beach Harbor: BS, HLA, HLE, S3, S4, Common, U&G.

Salema . . . . *Xenistius californiensis* (Steindachner)

Peru to Monterey Bay, Depth 4 to 35 feet. Los Angeles - Long Beach Harbor: BS.

FAMILY SCIANIDAE - Croakers* or Drums

Black croaker . . . . *Cheilotrema saturnam* (Girard)

Magdalena Bay, Baja California to Point Conception. Surface to 150 feet. Los Angeles - Long Beach Harbor: BS, Dvl, Sl, S3, Tll (only one fish taken in 46 trawls).

White seabass . . . . *Cynoscion nobilis* (Ayres)

Magdalena Bay, Baja California to Juneau, Alaska. Surface to 400 feet. Los Angeles - Long Beach Harbor: BS, S3, S4.

White croaker . . . . *Genyonemus lineatus* (Ayres)

Magdalena Bay, Baja California to Vancouver Island, B.C. Surface to 330 feet. Los Angeles - Long Beach Harbor: BS, GN3, HLA, HLC, HLD, HLE, Sl, S2 (Fish Harbor, Terminal Island), S3, S4, Tl-Tl7, U&G. Common.

California corbina . . . . *Menticirrhus undulatus* (Girard)

Gulf of California to Point Conception. Surface to 45 feet. Los Angeles - Long Beach Harbor: BS, HLA, S3, S4.

Spotfin croaker . . . . . *Roncador sternsii* (Steindachner)

Mazatlan, Mexico to Point Conception. Surface to 50 feet. Los Angeles - Long Beach Harbor: BS, DVl, S3, S4.

Queenfish . . . . *Seriphus politus* Ayres

West of Uncle Sam Bank, Baja California to Yaquina Bay, Oregon. Surface to 800 feet. Los Angeles - Long Beach Harbor: BS, GN3, HLA, HLD, S1, S3, S4, T3-T17, U&G, Common.

Yellowfin croaker . . . . *Umbrina roncador* Jordan & Gilbert

Gulf of California to Point Conception. Surface to 150 feet. Los Angeles - Long Beach Harbor: BS, S1.

FAMILY KYPHOSIDAE - Sea chubs

Opaleye . . . . *Girella nigricans* (Ayres)

Cape San Lucas, Baja California to San Francisco. Intertidal to 95 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1, S3, U&G.

Halfmoon . . . . . *Medialuna californiensis* (Steindachner)

Gulf of California to Klamath River. Surface to 130 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1.

FAMILY EMBIOTOCIDAE - Surfperches

Barred surfperch . . . . . . *Amphistichus argenteus* Agassiz

Playa Maria Bay, Baja California to Bodega Bay. Surface to 130 feet. Los Angeles - Long Beach Harbor: BS, S3, S4.

Calico surfperch . . . . *Amphistichus koelzi* (Hubbs)

Arroyo San Isidro, Baja California to Shi Shi Beach, Washington. Surfact to 30 feet. Los Angeles - Long Beach Harbor: HLA.

Shiner surfperch . . . . . . *Cymatogaster aggregata* Gibbons

San Quintin Bay, Baja California to Port Wrangell, Alaska. Surface to 480 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, GN3, HLA, HLB, HLC, HLD, HLE, S2 (sight record, Marina, Watchhorn Basin, San Pedro), Common.

Pile surfperch . . . . *Damalichthys vacca* (Girard)

Guadalupe Island to Port Wrangell, Alaska. Surface to 150 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, HLA, HLE, S3, S4, T3, T4, T13-T14, Common.

Black surfperch . . . . *Embiotoca jacksoni* Agassiz

Point Abreojos, Baja California to Fort Bragg. Surface to 130 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, HLA, HLB, HLC, HLD, HLE, S1, S3, S4, T3, T6, T7, T9-T14, T17, Common.

Walleye surfperch . . . . . *Hyperprosopon argenteum* Gibbons

Point San Rosarito, Baja California to Vancouver Island. Surface to 60 feet. Los Angeles - Long Beach Harbor: BS, HLA, HLD, HLE, S1, S3, S4, T1, T12, T13, T14, Common.

Dwarf surfperch . . . . *Micrometrus minimus* (Gibbons)

Cedros Island, Baja California to Bodega Bay. Tidepools to 30 feet. Los Angeles - Long Beach Harbor: BS.

White surfperch . . . . *Phanerodon furcatus* Girard

Point Cabras, Baja California to Vancouver, B.C. Surface to 140 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, GN3, HLA, HLD, HLE, S4, T1-T17, U&G, Common.

Rubberlip surfperch . . . . *Rhacochilus toxotes* Agassiz

Thurloe Head, Baja California to Russian Gulch State Beach, Mendocino County, California. Surface to 150 feet. Los Angeles - Long Beach Harbor: BS, DV1, GN1, S3, S4, T2, T3, T6, T8-T13. T8-T13, Common.

Pink surfperch . . . *Zalembius rosaceus* (Jordan & Gilbert)

Gulf of California and San Cristobal Bay, Baja California to Drakes Bay. 30 to 300 feet. Los Angeles - Long Beach Harbor: S4.

Rainbow surfperch . . . . *Hypsurus caryi* (Agassiz)

Rio Santo Tomas, Baja California to Cape Mendocino. Surface to 130 feet. Los Angeles - Long Beach Harbor: DV1, GN1.

FAMILY POMACENTRIDAE - Damselfishes

Blacksmith . . . . *Chromis punctipinnis* (Cooper)

Point San Pablo, Baja California to Monterey Bay. Surface to 150 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1, S3.

Garibaldi . . . . *Hypsypops rubicundus* (Girard)

Magdalena Bay, Baja California to Monterey Bay. Surface to 95 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1, S3.

FAMILY LABRIDAE - Wrasses

Rockwrasse . . . .*Halichoeres semicinctus* (Ayres)

Gulf of California to Point Conception. Surface to 78 feet. Los Angeles - Long Beach Harbor: S1.

Senorita . . . . *Oxyjulis californica* (Gunther)

Cedros Island, Baja California to Sausalito (Recent only to Santa Cruz). Surface to 180 feet. Los Angeles - Long Beach: DV1, S1.

California sheephead . . . . *Pimelometopon pulchrum* (Ayres)

Cape San Lucas, Baja California to Monterey. Surface to 180 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S3.

FAMILY MUGILIDAE - Mullets

Striped mullet . . . . *Mugil cephalus* Linnaeus

Eastern Pacific, Galapagos Islands to Monterey. Surface to 400 feet. Los Angeles - Long Beach Harbor: BS, S3.

FAMILY SPHYRAENIDAE - Barracudas

California barracuda . . . . . . *Sphyraena argentea* Girard

Cape San Lucas, Baja California to Kodiak Island, Alaska. Surface to 60 feet. Los Angeles - Long Beach Harbor: BS, HLA, S1, S3.

FAMILY POLYNEMIDAE - Threadfins

Yellow bobo . . . . *Polydactylus opercularis* (Gill)

Callao, Peru to Monterey. Shallow inshore areas. Los Angeles - Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 168).

FAMILY CLINIDAE - Clinids

Spotted kelpfish . . . . *Gibbonsia elegans* (Cooper)

Magdalena Bay, Baja California to Point Piedras Blancas. Surface to 185 feet. Los Angeles - Long Beach Harbor: DV1.

Giant kelpfish . . . . *Heterostichus rostratus* Girard

Cape San Lucas, Baja California to British Columbia. Surface to 132 feet. Los Angeles - Long Beach Harbor: BS, HLC, DV1.

Sarcastic fringehead . . . . . *Neoclinus blanchardi* Girard

Cedros Island, Baja California to San Francisco. 10 to 200 feet. Los Angeles - Long Beach Harbor: S4.

Yellowfin fringehead . . . . . . *Neoclinus stephensae* Hubbs

Point San Hipolito to Monterey. 10 to 90 feet. Los Angeles - Long Beach Harbor: DV1 (sight record only).

Onespot fringehead . . . . *Neoclinus uninotatus* Hubbs

San Diego Bay to Bodego Bay. 10 to 90 feet. Los Angeles - Long Beach Harbor: BS, T10.

FAMILY BLENNIIDAE - Combtooth blennies

Rockpool blenny . . . . . . *Hypsoblennius gilberti* (Jordan)

Magdalena Bay, Baja California to Monterey. Intertidal to 80 feet. Los Angeles - Long Beach Harbor: HLA.

Mussell blenny . . .*Hypsoblennius jenkinsi* Jordan & Evermann

Puerta Marquis, Mexico to Coal Oil Point. Depth Intertidal to 70 feet. Los Angeles - Long Beach Harbor: BS.

FAMILY GOBIIDAE - Gobies

Longjaw mudsucker . . . . *Gillichthys mirabilis* Cooper

Gulf of California to Tomales Bay. Shallows of bays, mudflats. Los Angeles-Long Beach Harbor: S3.

Bay Goby . . . . *Lepidogobius lepidus* (Girard)

Cedros Island, Baja California to Vancouver Island, B. C. Shallow bays and to 200 feet. Los Angeles-Long Beach Harbor: DV1, GN1, S4, T3-T11, T13, T14, T16, T17, Common.

Blackeye goby . . . . *Coryphopterus nicholsii* (Bean)

South of Point Rompiente, Baja California to Skidegate Channel, Queen Charlotte Is., B.C. 5 to 80 feet. Los Angeles-Long Beach Harbor: DV1, T4-T8, T11, T14, Common.

Arrow goby . . . . *Clevelandia ios* (Jordan & Gilbert)

Gulf of California to Vancouver Island, B.C. Shallow areas of bays. Los Angeles-Long Beach Harbor: Dip-netted in Fish Harbor: S2.

Chameleon goby . . . . . *Tridentiger trigonocephalus* (Gill)

Los Angeles Harbor and in San Francisco Bay. Shallow bay areas. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 186).

FAMILY SCOMBRIDAE - Mackerels & Tunas

Slender tuna . . . . *Allothunnis fallai* Serventy

Warm seas, mostly in southern hemisphere; north to Los Angeles Harbor. Depth: Inshore pelagic. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 194).

Wavyback skipjack* . . . . *Euthynnus affinis* (Cantor)

Indo-Pacific, north to Los Angeles Harbor on our coast. Epipelagic. Los Angeles-Long Beach Harbor: Not taken in this study (see Miller and Lea, 1972, pg. 192).

Pacific bonito . . . . *Sarda chiliensis* (Cuvier)

Chile to Gulf of Alaska. Epipelagic. Los Angeles-Long Beach Harbor: HLA, HLC, S1, S3, Common.

Pacific (Chub) mackerel . . . . . *Scomber japonicus* Houttuyn

Transpacific, in eastern Pacific, Chile to Gulf of Alaska. Surface to 150 feet. Los Angeles - Long Beach Harbor: S1.

Monterey spanish mackerel . . . . . *Scomberomerus concolor* (Lockington)

Gulf of California to Soquel. Nearshore pelagic fish. Los Angeles - Long Beach Harbor: BS.

FAMILY STROMATEIDAE - Butterfish

Pacific butterfish . . . . . . *Peprilus simillimus* (Ayres)

Magdalena Bay, Baja California to Fraser River, B.C. 30 to 300 feet. Los Angeles - Long Beach Harbor: BS, HLA, HLD, S1, S4, T12, T14, Common.

FAMILY SCORPAENIDAE - Rockfishes

Spotted scorpionfish . . . . *Scorpaena guttata* Girard

Uncle Sam Bank, Baja California to Santa Cruz. Shallow to 600 feet. Los Angeles - Long Beach Harbor: S1, S3, S4, T3, T9, Common.

Brown rockfish . . . . *Sebastes auriculatus* Girard

Hipolito Bay, Baja California to South East Alaska. Shallow to 180 feet. Los Angeles - Long Beach Harbor: T13 (only one fish taken in 46 trawls).

Calico rockfish . . . *Sebastes dallii* (Eigenmann & Beeson)

Sebastian Viscaino Bay, Baja California to San Francisco. 60 to 830 feet. Los Angeles - Long Beach Harbor: S4.

Chilipepper . . . . *Sebastes goodei* (Eigenmann & Eigenmann)

Magdalena Bay, Baja California to Vancouver Island. Surface to 660 feet. Los Angeles - Long Beach Harbor: T3, T8.

Vermilion rockfish . . *Sebastes miniatus* (Jordan & Gilbert)

San Benito Islands, Baja California to Vancouver Island, British Columbia. Shallow to 660 feet. Los Angeles - Long Beach Harbor: T3-T9, T16.

Blue rockfish . . . . *Sebastes mystinus* (Jordan & Gilbert)

Point Santo Tomas, Baja California to Bering Sea. Surface to 300 feet. Los Angeles - Long Beach Harbor: DV1 (sighted only, not taken in 46 trawls), S1.

Boccacio . . . . *Sebastes paucispinis* (Ayres)

Point Blanca, Baja California to Kodiak Island, Alaska. Surface to 1050 feet. Los Angeles - Long Beach Harbor: T3, T5-T8, T11, T12, Common.

Grass rockfish . . *Sebastes rastrelliger* (Jordan & Gilbert)

Playa Maria Bay, Baja California to Yaquina Bay, Oregon. Intertidal to 150 feet. Los Angeles - Long Beach Harbor: DV1, HLC, S1.

Flag rockfish . . . *Sebastes rubrivinctus* (Jordan & Gilbert)

Cape Colnett, Baja California to Aleutian Islands. 100 to 600 feet. Los Angeles - Long Beach Harbor: T8 (only one fish taken in 46 trawls).

Striptail rockfish . . . . . . *Sebastes saxicola* (Gilbert)

Sebastian Viscaino Bay, Baja California to South East Alaska. 192 to 1320 feet. Los Angeles - Long Beach Harbor: T3, T5, T6, T7, T9, T12, Common.

Olive rockfish..*Sebastes serranoides* (Eigenmann & Eigenmann)

San Benito Island, Baja California to Redding Rock, Del Norte County. Surface to 480 feet. Los Angeles - Long Beach Harbor: DV1, GN1, T3-T9, T11, T13, T16, Common.

FAMILY HEXAGRAMMIDAE - Greenlings

Kelp greenling . . . . . . *Hexagrammos decagrammus* (Pallas)

La Jolla to Aleutian Islands, Alaska. Intertidal to 150 feet. Los Angeles - Long Beach Harbor: DV1, GN1.

Lingcod . . . . *Ophiodon elongatus* Girard

Point San Carlos, Baja California to Kodiak Island, Alaska. Surface to 1400 feet. Los Angeles - Long Beach Harbor: HLA.

FAMILY ZANIOLEPIDIDAE - Combfishes

Longspine combfish . . . . . . *Zaniolepis latipinnis* Girard

San Cristobal Bay, Baja California to Vancouver Island, B.C. 120 to 372 feet. Los Angeles - Long Beach Harbor: S4.

FAMILY COTTIDAE - Sculpins

Bonyhead sculpin . . . . *Artedius notospilotus* Girard

Point San Telmo, Baja California to Puget Sound. Intertidal to 150 feet. Los Angeles - Long Beach Harbor: BS, S4, T8.

Roughback sculpin . . *Chitonotus pugetensis* (Steindachner)

Santa Maria Bay, Baja California. Intertidal to 465 feet. Los Angeles - Long Beach Harbor: S4, U&G.

Wooly sculpin . . . . *Clinocottus analis* (Girard)

Ascuncion Point, Baja California to Cape Mendocino. Intertidal to 60 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1, U&G.

Pacific staghorn sculpin . . . .*Leptocottus armatus* Girard

San Quintin Bay, Baja California to Chignik, Alaska. Intertidal to 300 feet. Los Angeles - Long Beach Harbor: BS, HLA, S1, S3, T11, T12, T13, T14, Common.

Cabezon . . . . *Scorpaenichthys marmoratus* (Ayres)

Point Abreojos, Baja California to Sitka, Alaska. Intertidal to 256 feet. Los Angeles - Long Beach Harbor: DV1, GN1, S1, S3.

FAMILY AGONIDAE - Poachers

Pygmy poacher . . . . . . *Odontopyxis trispinosa* Lockington

Cedros Island, Baja California to South East Alaska. 30 to 1208 feet. Los Angeles - Long Beach Harbor: T3, T6-T9, T16, U&G.

Order Pleuronectiformes (Heterosomata)

FAMILY BOTHIDAE - Left-eye flounders

Pacific sanddab . . . . . . *Citharichthys sordidus* (Girard)

Cape San Lucas, Baja California to Bering Sea. 30 to 1800 feet. Los Angeles - Long Beach Harbor: T13 (only one fish taken in 46 bottom trawls), Rare, U&G.

Speckled sanddab . . *Citharichthys stigmaeus* Jordan & Gilbert

Magdalena Bay, Baja California to Montague Island, Alaska. 10 to 1200 feet (?). Los Angeles - Long Beach Harbor: BS, S3, T2-T14, T16, Common, U&G.

Longfin sanddab . . . . . *Citharichthys xanthostigma* Gilbert

Costa Rica to Monterey Bay. Depth 8 to 444 feet. Los Angeles - Long Beach Harbor: BS, U&G.

Rex sole . . . . *Glyptocephalus zachirus* Lockington

San Diego trough to Bering Sea. Depth 60 to 2100 feet. Los Angeles - Long Beach Harbor: BS.

Bigmouth sole. . *Hippoglossina stomata* Eigenmann & Eigenmann

Gulf of California to Monterey Bay. 100 to 450 feet. Los Angeles - Long Beach Harbor: S4, T6, T9, T10.

California halibut . . . . *Paralichthys californicus* (Ayres)

Magdalena Bay, Baja California to Quillayute River, B.C. Surface to 300 feet. Los Angeles - Long Beach Harbor: BS, HLA, HLE, S1, S3, T3, T4, T6, T7, T8, T10-T14, T16, U&G, Common.

Fantail sole . . . . . *Xystreurys liolepis* Jordan & Gilbert

Gulf of California to Monterey Bay. 15 to 260 feet. Los Angeles - Long Beach Harbor: BS, S4, T9, T10, T11, T13, T14, U&G.

FAMILY PLEURONECTIDAE - Right-eye flounders

Petrale sole . . . . *Eopsetta jordani* (Lockington)

Los Coronodos Islands, Baja California to Gulf of Alaska. 60 to 1500 feet. Los Angeles - Long Beach Harbor: S4.

Diamond turbot . . . . *Hypsopsetta guttulata* (Girard)

Magdalena Bay, Baja California to Cape Mendocino. 5 to 150 feet. Los Angeles - Long Beach Harbor: BS, S3, S4, T9, T10, T14, U&G.

English sole . . . . *Parophrys vetulus* Girard

San Cristobal Bay, Baja California to North West Alaska. 60 to 1000 feet. Los Angeles - Long Beach Harbor: BS, S3, S4, T3, T4, T6, T9-T11, T14, U&G.

C-O Turbot . . . . *Pleuronichthys coenosus* Girard

Cape Colnett, Baja California to South East Alaska. Shallow to 210 feet. Los Angeles - Long Beach Harbor: BS, Rare.

Curlfin turbot . . .*Pleuronichthys decurrens* Jordan & Gilbert

San Quintin Bay, Baja California to North West Alaska. 60 to 1140 feet. Los Angeles - Long Beach Harbor: BS, S3, S4, T6-T11, T13, T14, Common.

Spotted turbot . . . .*Pleuronichthys ritteri* Starks & Morris

Magdalena Bay, Baja California to Point Conception. 4 to 150 feet. Los Angeles - Long Beach Harbor: BS, S4, T9 (only one fish taken in 46 bottom trawls), U&G.

Hornyhead turbot..*Pleuronichthys verticalis* Jordan & Gilbert

Magdalena Bay, Baja Californai to Point Reys. 30 to 612 feet. Los Angeles - Long Beach Harbor: BS, S1, S3, S4, T2-T14, U&G.

FAMILY CYNOGLOSSIDAE - Tonguefishes

California tonguefish.*Symphurus atricauda* (Jordan & Gilbert)

Cape San Lucas, Baja California to Big Lagoon, Humboldt County. 5 to 276 feet. Los Angeles - Long Beach Harbor: BS, S3, S4, T2-T14, T16, T17, Common, U&G.

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APPENDIX A. LOS ANGELES - LONG BEACH HARBOR COLLECTING STATIONS

Collecting * Station No.	Location	Average Depth Mean LLW-feet		Position
T1	Belmont Pier	29	Start	33°45'27"N 118°10'16"W
			Fin.	33°45'09"N 118°08'55"W
T3	East End Long Beach Breakwater	50	Start	33°43'30"N 118°09'48"W
			Fin.	33°43'36"N 118°09'18"W
T4	Inside West End Long Beach Bkwtr.	55	Start	33°43'36"N 118°09'54"W
			Fin.	33°43'42"N 118°10'30"W
T5	Middle Breakwater	48	Start	33°43'30"N 118°12'24"W
			Fin.	33°43'23"N 118°13'27"W
T6	Middle Breakwater	48	Start	33°43'27"N 118°13'47"W
			Fin.	33°43'46"N 118°12'46"W

Collecting Station No.	Location	Average Depth Mean LLW-feet	Position	
T7	Naval Base Mole	37	Start	33°44'00"N 118°12'56"W
			Fin.	33°43'41"N 118°13'56"W
T8	Parallel to Long Beach Channel	58	Start	33°44'23"N 118°13'00"W
			Fin.	33°43'52"N 118°12'05"W
T9	West End of Middle Breakwater	46	Start	33°43'06"N 118°13'38"W
			Fin.	33°42'47"N 118°14'36"W
T10	West End Middle Breakwater	42	Start	33°43'02"N 118°15'17"W
			Fin.	33°43'02"N 118°14'16"W
T11	West End Middle Breakwater	30	Start	33°43'16"N 118°14'12"W
			Fin.	33°43'24"N 118°15'06"W
T12	Fish Harbor	20	Start	33°43'35"N 118°15'33"W
			Fin.	33°43'04"N 118°14'33"W
T13	Fish Harbor - Near Entrance	20	Start	33°44'10"N 118°14'27"W
			Fin.	33°43'06"N 118°15'22"W

Collecting Station No.	Location	Average Depth Mean LLW-feet		Position
T14	Parallel to Main Channel	65	Start	33°43'19"N 118°15'38"W
			Fin.	33°42'57"N 118°15'00"W
T16	Between Long Beach Entrance & Pier "J"	52	Start	33°43'38"N 118°10'40"W
			Fin.	33°44'36"N 118°10'40"W
T17	Cerritos Channel Between Lift Bridge & East Basin	40	Start	33°45'08"N 118°14'06"W
			Fin.	33°45'08"N 118°15'02"W
Diving Station:				
DV1	Inside West End of Middle Breakwater	46		33°42'42"N 118°14'30"W
Gill Net Stations:				
GN1	West End of Middle Breakwater	46		33°42'42"N 118°14'30"W
GN2	Velero Dock Area-Slip No. 5	30		33°45'58"N 118°15'34"W
GN3	Vantuna Dock Area-Cerritos Channel	30		33°45'50"N 118°14'42.5"W

Collecting Station No.	Location	Average Depth Mean LLW-feet	Position
Sport Angler Fishing Sites:			
HLA	Belmont Pier	18	33°45'19"N 118°08'52.5"W
HLB	Mouth of Los Angeles River	48	33°45'37"N 118°12'08"W
HLC	Pier "J"	44	33°44'19"N 118°11'07"W
HLD	Cabrillo Beach Fishing Pier	33	33°42'27"N 118°15'30"W
HLE	Fish Harbor, East Breakwater	16	33°44'05"N 118°15'37"W
HLF	Old Pierpoint Landing	23	33°44'47"N 118°12'52"W
HLG	Fishing Barge	42	33°43'28"N 118°08'17.5"W

*T1 - T16 = Otter Trawl Stations
DV1 - DV3 = Diving Stations
GN1 = Gill Net Station
HLA - HLG = Hook and Line Stations (Sport Anglers)

APPENDIX B. Fish species from Ulrey and Greeley (1928) not included in checklist because they have not been taken in recent collections from the harbor area. Scientific names in parenthesis are current taxonomy. Common names in parenthesis are current usage.

Brown ragfish, *Acrotus willoughbyi*
American shad, *Alosa sapidissima* (Wilson)
Coal fish (sablefish), *Anoplopoma fimbria* (Pallas)
California clingfish, *Arbaciosa (Gobiesox) rhessodon* (Smith)[1]
Reef finspot, *Auchenopterus (Paraclinus) intergripinnis* (Smith)[1]
Frigate mackerel, *Auxis thazard* (Lacepede)
Fanfish, *Brama raii (Pteraclis aesticola* Jordan & Snyder)
Deepwater blenny, *Cryptotrema corallinum* Gilbert
Shortfin corvina, *Cynoscion parvipinnis* Ayres (Not seen since 1930's along coastline, Miller and Lea, 1972)
Gilbert (bearded) clingfish, *Gobiesox papillifer* Gilbert
Bay blenny, *Hypsoblennius gentilis* (Girard)[1]
Yellowchin sculpin, *Icelinus quadriseriatus* (Lockington)
Gizzard shad, *Lophotes cepedianus* (Le Sueur)
Slender sole, *Lyopsetta exilis* (Jordon & Gilbert
Slimy snailfish, *Neoliparus mucusus (Liparis mucosus* Ayres*)*
(Pacific) snake eel, *Ophichthys (Ophichthus) triserialis* (Kaup)
Sharpnose surfperch, *Phanerodon atripes* (Jordon & Gilbert)
Ragfish, *Schedophilus heathi (Icosteus aenigmaticus* Lockington*)*
Greenspotted rockfish, *Sebastodes (Sebastes) chlorostictus* (Jordon & Gilbert)
Barred pipefish, *Syngnathus auliscus* (Swain)[2]
Bay pipefish, *Syngnathus leptorhynchus (griseolineatus* Ayres*)*[2]
Pithead sculpin, *Tarandichthys (Icelinus) cavifrons* Gilbert

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[1]Very probably present in Los Angeles-Long Beach Harbor but not seen or taken due to sampling methods in the present study.

[2]May be *Syngnathus sp.* in checklist.

INDEX

MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART IV.

PRIMARY PRODUCTIVITY IN THE OUTER LOS ANGELES HARBOR

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ABSTRACT. Measurements of primary productivity and phytoplankton pigments were made at a series of stations in Outer Los Angeles Harbor for the period of 1971 through August, 1973. One additional station, outside the breakwater, was also monitored during this period.

Productivity and assimilation ratios inside the breakwater were higher than those outside, with maximum productivity appearing at stations between the breakwater and the entrance to Fish Harbor on Terminal Island. The Fish Harbor stations varied considerably, possibly reflecting their isolation from the outer harbor areas. The station nearest the waste water effluent discharges most generally showed less production. This is attributed to the inhibitory effects of high concentrations of substances in the waste water.

Seasonal patterns, including the occurrence of phytoplankton blooms, are discussed particularly with regard to the seasonal alteration in patterns of artificial enrichment.

ACKNOWLEDGMENTS. Finds for these investigations were provided in part by the USC Sea Grant Program, Pacific Lighting Service Company, and the U.S. Army Corps of Engineers.

PRIMARY PRODUCTIVITY IN THE OUTER LOS ANGELES HARBOR

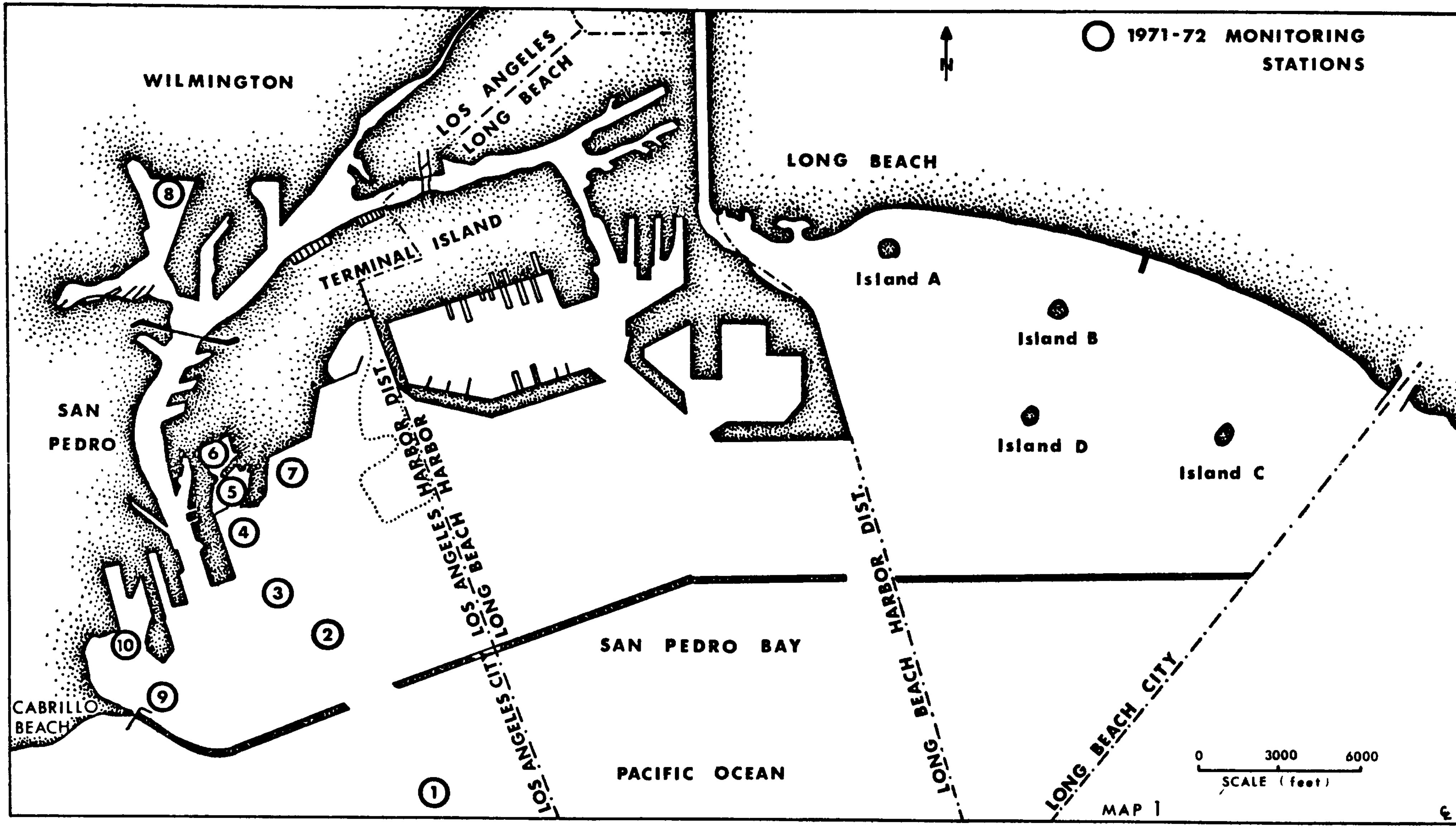
Data on productivity of the outer harbor were obtained by collecting samples at the seven stations shown in Map 1 at approximately monthly intervals. Three types of information were obtained; productivity, which is a measurement of the ability of organisms to convert non-living nutrients into living material photosynthetically; standing crop, which is reported here as chlorophyll *a* and gives information on the size of the population that is involved in the productivity being measured; and assimilation ratios, which give an index to the efficiency with which the standing crop is able to produce.

Primary productivity determinations were done by the isotopic carbon method. Duplicate clear and black plastic coated, 125 ml, glass stoppered bottles were filled with water from the sampling station. To each was added a known quantity of radioactive carbon as carbonate or bicarbonate. The bottles were then incubated at ambient sea water temperature under controlled illumination for about three hours. The contents of the bottles were then filtered, and the cells containing the assimilated radioactive carbon were retained on the filters. The proportion of this assimilated carbon was determined. The data are reported as milligrams of carbon fixed per hour of incubation per cubic meter of water sampled.

Standing crop determinations were made by measuring the quantity of chlorophyll *a* present per liter of water sampled. A known volume of water was filtered, and the pigments were extracted into 90% acetone from the cells retained on the filter. The pigments in the extract were then determined spectrophotometrically.

Assimilation ratios were not directly measured but were calculated by dividing the values determined for productivity by the value determined for chlorophyll *a* concentrations.

The productivity values reflect the ability of the population present, regardless of size, to produce organic material under the conditions prevalent in the waters sampled. This reflects the fertility of the waters being sampled and gives an index to the production and availability of food to organisms which require an organic substrate but cannot synthesize their own.


1971-72 MONITORING STATIONS
N
WILMINGTON
LOS ANGELES
LONG BEACH
LONG BEACH
TERMINAL ISLAND
SAN PEDRO
CABRILLO BEACH
Island A
Island B
Island D
Island C
LOS ANGELES HARBOR DIST.
LONG BEACH HARBOR
LOS ANGELES CITY
LONG BEACH
LONG BEACH HARBOR DIST.
LONG BEACH CITY
SAN PEDRO BAY
PACIFIC OCEAN
1
2
3
4
5
6
7
8
9
10
0
3000
6000
SCALE (feet)

MAP 1

The chlorophyll *a* values are used as a measure of the standing crop of the phytoplankton population present at the time and place of sampling. This does not give an enumeration of the numbers and species present, but does give a more easily and rapidly obtainable value. The quantity of pigment available to catalyze the conversion of non-living carbon sources into living material is not constant for different species or different cells, but is nevertheless an acceptable estimation of standing crop.

Assimilation ratio is defined as the capacity of a unit of the standing crop to assimilate non-living nutrient and convert it to living material. Determinants of this value include the physiological state of the organisms present, the availability of nutrients, and the presence of inhibiting or toxic substances. The values, as determined, do not identify the controlling factor but are a statement of the summation of all factors involved. As such, it can indicate a population stressed by limiting or inhibiting conditions or a population in the process of rapid growth.

The data are presented for all seven stations in Table 1, listing in order, productivity, chlorophyll *a*, and assimilation ratios. Assimilation ratios are also shown in Figure 2 for four of the seven stations. The stations selected are Station 1, outside the harbor and thus subject to the influence of less restricted currents and conditions outside the harbor; Station 2, immediately inside the harbor, is in an area of high productivity within the harbor; Station 4, at the entrance to Fish Harbor, is in an area less productive than Stations 2 and 3 and is partially influenced by Stations 5 and 7; and Station 7, near the two cannery waste outfalls and the sewage effluent line. Productivity data for some of these same stations appear in an earlier report (Soule and Oguri, 1973).

The same general seasonal patterns appeared in both the assimilation ratios shown and in the tabulated data. In July and August of 1971, high values reflected the warm season bloom that is often a red tide. This red tide appears to be a regularly recurring feature of the harbor. Similar blooms appeared in 1972 and 1973, at about the same time of year. The bloom in 1971 abruptly ended in September, showing assimilation ratios lower than would be expected in unstressed environmental conditions. These low values persisted through February 1972 and were succeeded by a marked increase in values. The spring bloom is a normal

Table 1. Primary productivity (P) as mg C/hr./m^3, Chlorophyll *a* (C) as mg Chl *a*/l, and assimilation ratios (A) at seven stations in outer Los Angeles Harbor, 1971-1973

1971

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	P				3.1	28.4	38.0	54.6	56.6	0.9	28.3	2.7	9.7
	C							4.8	3.3	0.4	7.5	1.7	3.4
	A							11.3	17.3	2.3	3.8	1.6	2.9
2	P				3.3	48.6	24.9	226.7	253.4	4.7	40.0	7.4	10.4
	C							18.2	18.5	1.0	10.0		1.9
	A							12.5	13.7	4.7	4.0		5.5
3	P				5.2	76.8	44.5	90.4	155.9	132.8	26.1	5.9	9.7
	C							4.8	16.4	18.7	23.6	1.3	2.4
	A							18.7	9.5	7.1	1.1	4.7	4.0
4	P				3.5	26.1	37.3	28.8	75.9	68.0	52.6	3.1	7.9
	C							3.9	6.6	15.2	8.9	1.1	2.4
	A							7.4	11.6	4.5	5.9	2.8	3.3
5	P				3.5	37.0	43.6	60.7	47.2	97.2	46.5	0.7	12.8
	C							5.4	5.6	14.9	22.9	2.8	7.7
	A							11.3	8.4	6.5	2.0	0.3	1.7
6	P				6.8	26.9	31.5	88.6	94.0	93.0	46.1	0.5	17.4
	C							6.3	11.9	12.0	24.3	2.7	13.7
	A							14.2	7.9	7.8	1.9	0.2	1.3
7	P				7.1	11.7	28.8	4.4	71.8	30.6	15.9	0.8	8.6
	C							3.1	8.5	18.1	14.8	2.7	4.6
	A							1.4	8.4	1.7	1.1	0.3	1.9

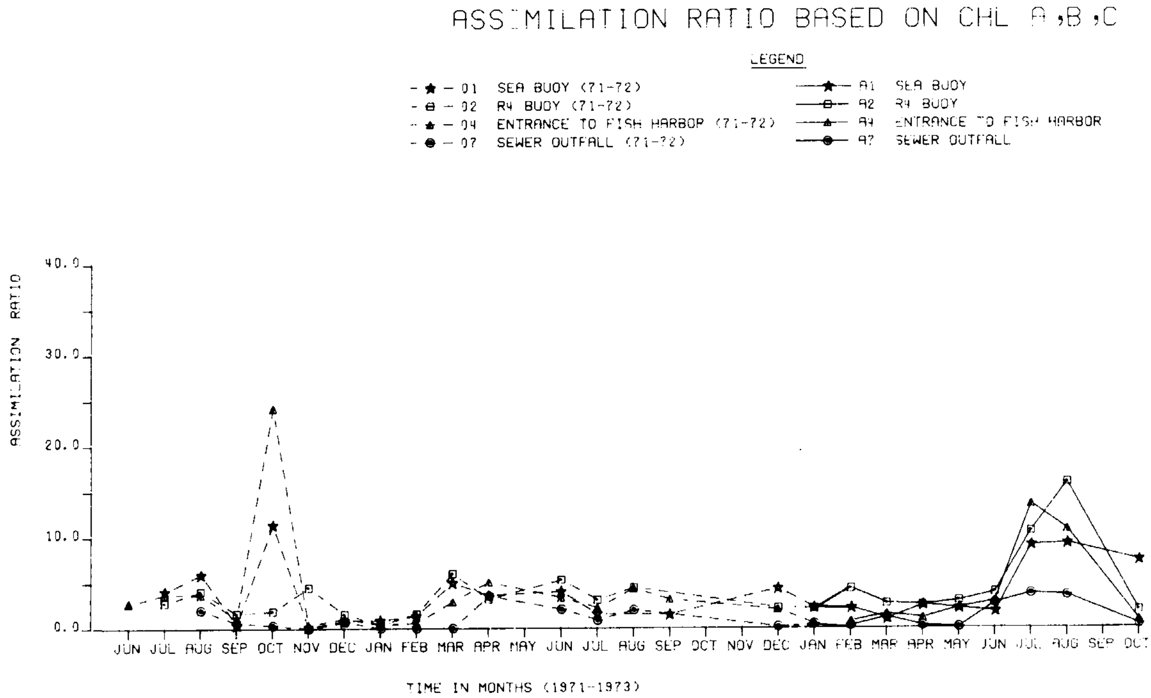
1972

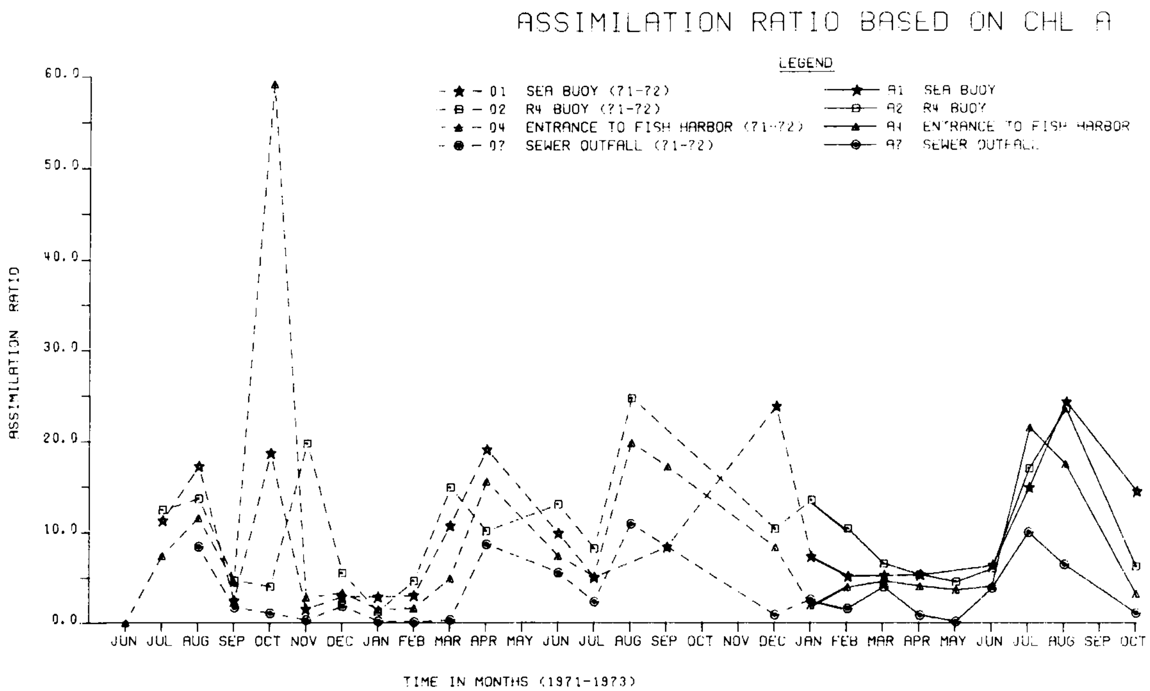
STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	P	6.9	11.7	10.4	23.0	-	15.6	4.1	0.7	2.7	2.8	4.0	4.3
	C	2.4	3.9	1.0	1.2	1.4	1.6	0.8	-	0.3	-	-	0.2
	A	2.9	3.0	10.7	19.1	-	9.9	5.0	-	8.4	-	-	23.9
2	P	8.3	11.2	20.8	4.6	-	38.5	32.5	11.9	36.7	38.7	3.4	3.1
	C	6.6	2.4	1.4	0.5	2.6	3.0	4.0	0.5	-	-	-	0.3
	A	1.3	4.7	14.9	10.2	-	13.1	8.2	24.7	-	-	-	10.4
3	P	10.2	12.4	13.9	23.6	-	29.0	21.0	19.5	106.1	31.7	3.8	4.8
	C	7.7	3.0	1.4	1.2	3.9	3.9	3.1	0.6	-	-	-	0.6
	A	1.3	4.1	9.7	19.9	-	7.4	6.7	32.0	-	-	-	7.8
4	P	7.2	13.9	7.6	22.1	-	28.5	17.7	15.5	13.5	43.3	7.0	4.1
	C	4.8	8.5	1.5	1.4	4.0	3.9	3.5	0.8	0.8	-	-	0.5
	A	1.5	1.6	4.9	15.6	-	7.4	5.1	19.8	17.2	-	-	8.4
5	P	7.1	19.5	46.8	56.8	-	29.2	27.1	7.4	19.7	45.8	6.2	5.2
	C	6.1	-	2.5	3.4	3.3	3.8	3.6	0.7	0.8	-	-	0.4
	A	1.2	-	18.6	16.8	-	7.7	7.6	10.9	26.1	-	-	11.9
6	P	6.9	25.9	21.8	23.5	-	24.4	20.5	5.5	24.4	39.4	13.1	7.0
	C	2.9	21.8	2.9	1.8	6.0	2.9	3.2	0.8	0.5	-	-	0.7
	A	2.3	1.2	7.4	13.3	-	8.6	6.5	6.6	50.9	-	-	9.9
7	P	0.5	0.8	0.3	20.1	-	11.7	8.0	9.6	2.1	23.3	1.0	0.5
	C	2.9	8.5	0.8	2.3	5.9	2.1	3.4	0.9	-	1.1	-	0.6
	A	0.2	0.1	0.3	8.7	-	5.5	2.3	10.9	-	21.2	-	0.9

1973

STATION		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	P	2.4	3.7	4.4	10.3	3.0	3.3	38.2	10.6				
	C	0.3	0.7	0.8	1.9	-	0.5	2.6	0.4				
	A	7.3	5.2	5.3	5.4	-	6.4	15.0	24.4				
2	P	2.3	8.4	14.2	10.8	33.1	30.1	81.8	89.1				
	C	0.2	0.8	2.2	2.0	7.2	5.0	4.8	3.8				
	A	13.6	10.5	6.6	5.3	4.6	6.0	17.1	23.7				
3	P	1.5	3.7	18.7	15.6	30.6	21.2	134.9	76.2				
	C	0.2	0.5	3.2	2.8	7.4	3.2	6.9	4.3				
	A	8.1	7.9	5.9	5.7	4.2	6.7	19.5	17.8				
4	P	1.4	2.0	16.7	4.6	20.2	35.9	159.7	76.6				
	C	0.7	0.5	3.6	1.1	5.5	8.7	7.4	4.4				
	A	2.0	4.0	4.6	4.1	3.7	4.1	21.6	17.6				
5	P	4.9	3.3	25.0	11.3	14.7	31.3	138.3	108.6				
	C	0.2	0.6	3.6	3.2	2.6	8.0	6.9	7.6				
	A	28.4	5.8	7.0	3.6	5.6	3.9	20.0	14.2				
6	P	1.5	3.6	19.7	16.5	17.9	56.4	104.6	66.9				
	C	0.5	0.6	4.3	3.9	1.3	13.3	7.0	5.5				
	A	3.4	5.9	4.6	4.3	13.9	4.3	14.9	12.2				
7	P	0.9	1.8	10.5	1.2	1.4	45.2	31.3	15.2				
	C	0.3	1.1	2.6	1.3	8.7	11.7	3.1	2.4				
	A	2.6	1.6	4.0	0.9	0.2	3.9	10.1	6.5				

Figure 2


ASSIMILATION RATIO BASED ON CHL A,B,C
LEGEND
01 SEA BUOY (71-72)
02 R4 BUOY (71-72)
04 ENTRANCE TO FISH HARBOR (71-72)
07 SEWER OUTFALL (71-72)
A1 SEA BUOY
A2 R4 BUOY
A4 ENTRANCE TO FISH HARBOR
A7 SEWER OUTFALL
ASSIMILATION RATIO
40.0
30.0
20.0
10.0
0.0
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT
TIME IN MONTHS (1971-1973)


ASSIMILATION RATIO BASED ON CHL A
LEGEND
01 SEA BUOY (71-72)
02 R4 BUOY (71-72)
04 ENTRANCE TO FISH HARBOR (71-72)
07 SEWER OUTFALL (71-72)
A1 SEA BUOY
A2 R4 BUOY
A4 ENTRANCE TO FISH HARBOR
A7 SEWER OUTFALL
ASSIMILATION RATIO
60.0
50.0
40.0
30.0
20.0
10.0
0.0
JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT
TIME IN MONTHS (1971-1973)

seasonal occurrence in Southern California coastal waters. However, the increase in values in the spring of 1973 was not as pronounced as in 1972 and is more evident in the tabulated data than in Figure 2. Following a brief reduction in productivity after the spring bloom in 1971, 1972, and 1973, the values again increased at the onset of the late summer-early fall bloom.

Station 1, located outside the breakwater but still under the influence of the harbor, was only moderately productive compared to Stations 2 and 3 but showed high assimilation ratios similar to those found at in-harbor stations. This suggests that the enrichment of the area by harbor waters takes place but that the population is generally dispersed too rapidly to build up to the levels that occur in the harbor.

Stations 2, 3, and 4 were definitely dominated by the harbor and showed closer relationship to one another than they did to Station 1. Differences between them are generally indicative of localized variations in environmental factors.

Stations 5 and 6 showed greater departures from the patterns exhibited by the others. This is attributed to the semi-enclosed character of outer and inner Fish Harbors, with greater isolation from the other stations. Because of poor flushing in the area, they are subject to more acute stress.

Station 7, nearest to the waste discharge lines, predictably showed the greatest amount of stress. Productivity, standing crop, and assimilation ratios were all low at this station during almost all sampling periods.

The general patterns of productivity, standing crop of photoplankton, and assimilation ratios are the result of a combination of factors including seasonal changes, location, and localized environmental alterations. In general, it appears that the population is not nutrient limited at any of the stations, but at certain locations shows evidence of inhibition.

The low assimilation ratios found at Station 7, particularly during fall and winter months, are undoubtedly due to inhibiting effects of the wastes discharged in the area. These wastes, either directly or following decomposition, disperse in the outer harbor, supplying nutrients in large quantities to the photosynthetic populations. The restricted exchange of water with areas outside the breakwater allows the resident populations to increase in size without being widely dispersed, resulting in the high levels of production and standing crop reported herein.

The material released into the harbor by the waste discharges near Station 7 is inhibitory within the areas of the high concentrations. The data indicate that, sporadically, other stations also experience some inhibition. The area is apparently very close, at all times, to the maximum capacity of the waters to process the material being introduced. The combination of the added load of material introduced during anchovy season, fall through winter, and the seasonal wind and weather conditions, which tend to reduce the already poor circulation, results in drastic overloading of the waters. This becomes evident in the reduced oxygen levels found.

In adjacent areas where receiving waters dilute the waste discharges, secondary production levels (Stephens *et al*, 1974) tend to confirm the nutrient qualities of the combined effluents. In this regard the combined effluents would be considered a resource, if loading capacities can be determining and observed.

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MARINE STUDIES OF SAN PEDRO BAY, CALIFORNIA. PART IV.

PRELIMINARY INVESTIGATIONS OF BENTHIC MARINE ALGAE FROM THE BREAKWATERS PROTECTING LOS ANGELES AND LONG BEACH HARBORS

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ABSTRACT. A total of 65 marine algal species were collected at twelve stations along the three breakwaters protecting Los Angeles and Long Beach Harbors (southern California). A reduced number of species was observed inside the breakwaters. Recommendations are made for the establishment of permanent stations along the breakwaters.

ACKNOWLEDGMENTS. Studies were supported in part by the U.S. Army Corps of Engineers and by the Harbors Environmental Projects of the Allan Hancock Foundation. Field work was supervised by Penny A. Pinter.

PRELIMINARY INVESTIGATIONS OF BENTHIC MARINE ALGAE FROM THE BREAKWATERS PROTECTING LOS ANGELES AND LONG BEACH HARBORS

INTRODUCTION. This paper presents a list of benthic marine algal species collected at twelve stations along the three sections of breakwaters protecting Los Angeles and Long Beach Harbors in southern California. The study was designed with two purposes in mind: 1) to establish a minimal baseline study, and 2) to serve as a preliminary reconnaissance of appropriate locations and methods for the establishment of permanent stations along the breakwaters. To my knowledge this is the first attempt to examine the marine algae of the harbor breakwaters.

The only previous studies of the algal flora from nearby areas were made at Point Fermin (Dawson, 1959, 1965a and b; Widdowson, 1971), roughly one-half mile southwest of the base of the San Pedro Breakwater. Dawson (1965a) additionally refers to collections of W.A. Setchell and N.L. Gardner made around the turn of the century. The present study has made no attempt at comparison with the Point Fermin collections due to several differences:

1) All of the previously recorded collections from Point Fermin were intertidal while the present study concentrated entirely on the subtidal.

2) Both Dawson and Widdowson sampled along transect lines, recording only larger algae which could usually be identified in the field. The present study has collected within a measured area and the specimens have been determined in the laboratory. All samples have been examined by microscope, resulting in records of many small forms which would be overlooked in field identification.

3) Collections were made in the present study by divers experienced in biological field procedures, who scraped samples of rock at selected intervals along the inside and outside of the breakwater. They were not phycologists.

METHOD. Twelve stations (Fig. 1) were sampled under the direction of Penny Pinter by Mark Hooper, Harold Porath, Kendal Robinson, and Penny Widell, using SCUBA apparatus.

The dates of collection were: 23 July 1973 (Sta. 1 and 2), 30 July 1973 (Sta. 3-6), 7 August 1973 (Sta. 7 and 8), 21 August 1973 (Sta. 9 and 10) and 27 August 1973 (Sta. 11 and 12).

Most collections were made on the face of the breakwater at a depth of about 10 feet. If algal cover was fairly extensive, all algae within a square meter quadrat were collected. If algal cover was sparse, clumps or patches were collected. In no case was more than one square meter sampled. Encrusting forms were not collected unless they were on easily removable rocks. Accompanying invertebrates were also collected for separate studies.

Algae were brought to the laboratory and either examined fresh or preserved in 5% formalin/sea water solution to be examined later. After examination, voucher specimens were retained in one or all of three forms: as microscope slides, wet collections, and pressed on herbarium sheets.

RESULTS. A tabulation of species recorded vs. station number is presented as Fig. 2. From this table it can be seen that a total of 65 species were found: 10 species of Chlorophycophyta, 6 species of Phaeophycophyta, and 49 species of Rhodophycophyta. Blue-green algae and diatoms were purposefully omitted from this study.

Voucher specimens were saved for each species at each locality. These are deposited in the Herbarium of the Allan Hancock Foundation (HAFH) with a second set in the herbarium of the author.

DISCUSSION. This study has provided a preliminary list of the algal flora of the breakwaters. It is not expected that the entire flora has been recorded, yet some trends seem obvious enough to be mentioned.

The bulk of the number of species was composed of very small to microscopic algae. Mostly these were observed as epiphytes on *Prionitis lanceolata* and *Gelidium robustum*, which were the dominant algae at eight stations.

The most abundant epiphytes, both in terms of numbers of individuals and also presence at many stations, were *Antithamnion defectum*, *Cryptopleura corallinara*, *Fauchea* *laciniata f. pygmaea, Goniotrichum elegans, Microcladia coulteri, Polysiphonia pacifica* var. *delicatula*, and *Pterosiphonia dendroidea*. These occurred almost exclusively as epiphytes, but with the exception of *Cryptopleura corallinara*, could also be found on rock.

An interesting phenomenon of dwarfism was observed in some of the above epiphytes. Fully reproductive individuals of less than a centimeter in height were encountered, while other individuals, apparently of the same species, which I have observed previously, would be 6 to 15 cm or larger before becoming reproductive. Culture and transplant studies of these species are being planned, as well as description of their morphology, in a later paper. The species to receive further study are *Fauchea laciniata f. pygmaea, Microcladia coulteri, Polysiphonia pacifica* var. *delicatula*, and *Pterosiphonia dendroidea*. In addition, studies will be made of *Chondria arcuata* and *Gigartina tepida* to determine if these might be dwarf forms of other recognized species.

Extraction and examination of data from Fig. 2 seem to indicate some general trends along the breakwater. No environmental factors other than depth were measured during this preliminary study, so causes of these trends are not definitely known.

First, it can be noticed that 25 of the 65 species encountered occurred at only one station. None of these was dominant, and most records were based on one to a very few plants. These species do not seem to contribute very much to our understanding of the flora at this point.

Two species were found only inside the breakwater at two or more stations: *Cladophora sp.* and *Erythrotrichia sp.* The outside of the breakwater proved richer with ten "one-sided species": *Ulothrix?, Bossiella orbigniana, Callithamnion sp., Ceramium sp., Chondria arcuata, Corallina officinalis* var. *chilensis, Cryptopleura corallinara, Fauchea laciniata f. pygmaea, Polysiphonia scopulorum*, and *Tiffaniella sp.*

If species found predominately on the outside of the breakwater (four or more occurrences outside vs. two or fewer occurrences inside) are added, the list can be expanded to include *Antithamnion defectum, Gelidium robustum* and *Gigartina tepida*. These 13 species would appear to be limited by the presence or absence of some factor within the breakwater which is not limiting on the outside.

Another category which can be recognized may be called "cosmopolitan species." These species were found at 3 or more stations, both inside and outside, i.e., greater than 50% of the localities. These species also have a wide distribution along the Pacific Coast. Seven species fit this category: *Ulva sp., Giffordia sp., Goniotrichum elegans, Microcladia coulteri, Polysiphonia pacifica* var. *delicatula, Prionitis lanceolata,* and *Pterosiphonia dendroidea.* In my experience these all seem to have a wide range of tolerance to varying environmental factors.

Further comparison of the inside to the outside of the breakwater shows a total of 42 species inside and 50 species outside. This does not appear significant. However, comparing the average number of species per station, 12.8 inside and 18.9 outside, shows a larger difference.

In general, the harbor side of the breakwater is not as rich in its flora as the ocean side. The precise causes of this difference are not known, but can possibly be defined by further study. The stations should be monitored at three or six month intervals (preferably three months) for a period of one to two years. This will allow identification of seasonal elements of the flora as well as observations of growth patterns. They may be remonitored thereafter every 5 to 10 years, or following environmental crises.

The integration of environmental parameters with the algal flora will certainly give much substance to the analysis of biological phenomena within this interesting area. The marine environment near such large metropolitan areas as Los Angeles needs much further study before the effects and implications of stress on marine organisms can be understood.

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FIGURE 1

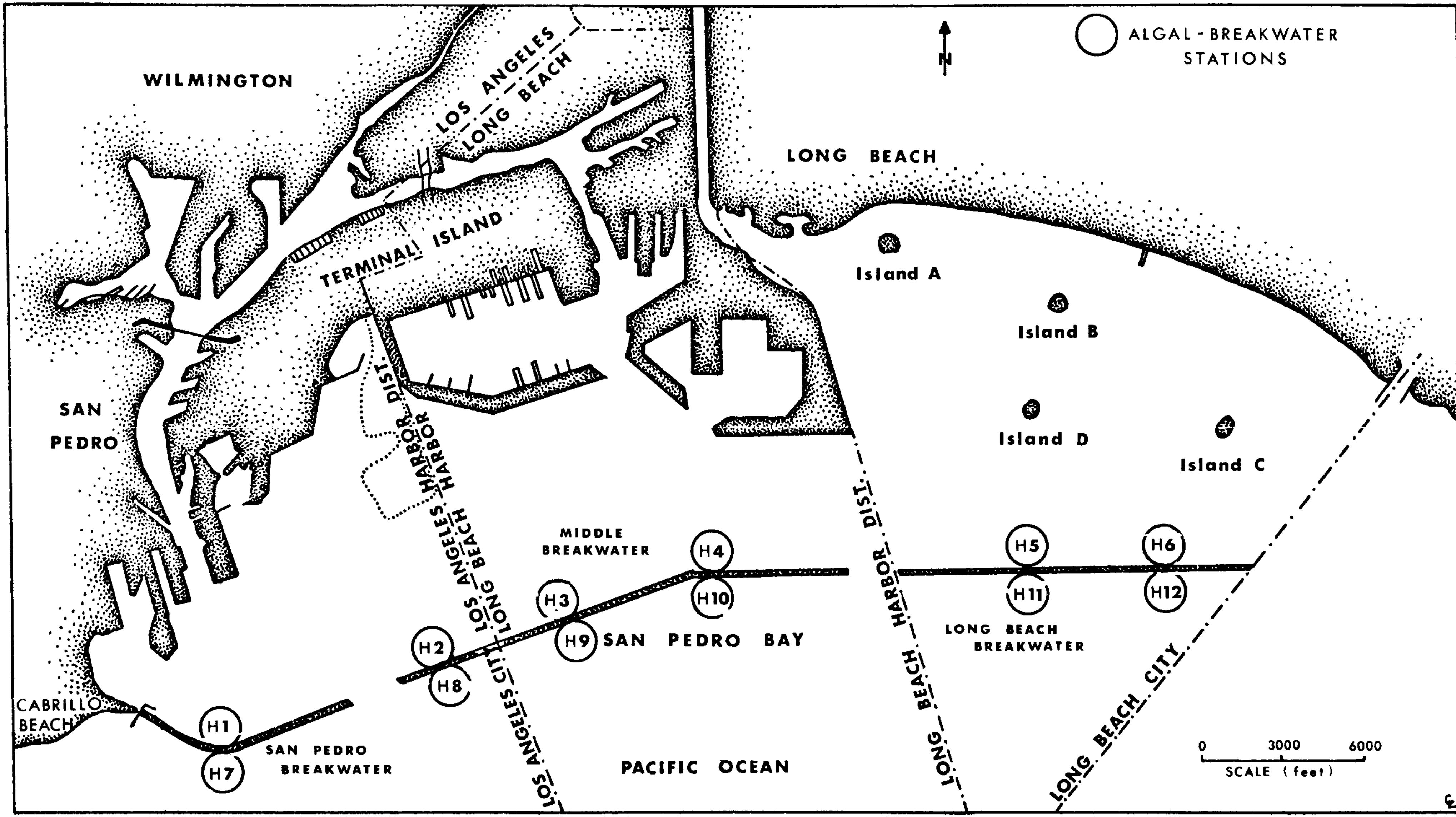
ALGAL-BREAKWATER STATIONS
N
WILMINGTON
LOS ANGELES
LONG BEACH
TERMINAL ISLAND
LONG BEACH
Island A
Island B
Island D
Island C
SAN PEDRO
LOS ANGELES HARBOR DIST.
LOS ANGELES CITY
LONG BEACH HARBOR
MIDDLE BREAKWATER
H1
H2
H3
H4
H5
H6
H7
H8
H9
H10
H11
H12
SAN PEDRO BAY
LONG BEACH HARBOR DIST.
LONG BEACH BREAKWATER
LONG BEACH CITY
CABRILLO BEACH
SAN PEDRO BREAKWATER
PACIFIC OCEAN
0
3000
6000
SCALE (feet)

FIGURE 2

ALGAE	STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
CHLOROPHYCOPHYTA:												
Cladophora albida			X									
Cladophora graminea	X											
Cladophora sp.		X		X								
Derbesia marina							X					
Enteromorpha prolifera	X										X	
Enteromorpha sp.						X						
Ulothrix (?)									X		X	
Ulva californica												X
Ulva lobata						X						
Ulva sp.	X	X			X			X	X		X	

X Indicates dominant alga at each station

FIGURE 2 (Continued)

ALGAE	STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
PHAEOPHYCOPHYTA:												
Dictyota flabellata	X								X			
Ectocarpus sp.						X						
Feldmannia sp.		X					X					
Giffordia sp.	X	X			X	X			X		X	X
Pachydictyon coriaceum												X
Sphacelaria sp.									X			
RHODOPHYCOPHYTA:												
Acrochaetium sp.		X		X							X	X
Anisocladella pacifica	X											
Antithamnion defectum	X						X	X	X	X	X	X
Antithamnionella breviramosa	X											
Bossiella orbigniana ssp. orbigniana										X	X	

FIGURE 2 (Continued)

ALGAE	STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Callithamnion sp.								X				X
Ceramium eatonianum				X							X	
Ceramium equisetoides							X					
Ceramium zacae											X	
Ceramium sp.							X			X		X
Chondria arcuata									X			X
Corallina officinalis var. *chilensis*							X		X			X
Corallina pinnatifolia		X		X	X	X			X		X	
Corallina vancouveriensis	X											
Cryptopleura corallinara							X	X	X	X	X	X
Dasya sinicola var. *abyssicola*	X											
Erythrotrichia carnea									X			
Erythrotrichia sp.	X				X							

FIGURE 2 (Continued)

ALGAE	STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Fauchea laciniata var. *pygmaea*							X		X		X	X
Faucheocolax attenuata												X
Gelidium coulteri					X							
Gelidium robustum					X		X		X	X	X	X
Gigartina armata/spinosa complex							X					
Gigartina canaliculata				X								
Gigartina leptorhynchos				X	X							X
Gigartina tepida		X				X	X	X	X		X	X
Gonimophyllum skottsbergii							X					
Goniotrichum cornu-cervi				X				X				
Goniotrichum elegans	X	X	X	X	X	X	X	X	X		X	X
Gymnogongrus platyphyllus				X			X					
Herposiphonia plumula var. *parva*									X			

FIGURE 2 (Continued)

ALGAE	STATIONS: Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Lithothamnion sp.										X		
Lophosiphonia villum			X						X			X
Microcladia coulteri	X			X	X		X	X	X	X		X
Murrayellopsis dawsonii			X						X			
Nienburgia andersoniana	X						X			X		
Pleonosporium abyssicola	X							X	X			
Pogonophorella californica	X											
Polysiphonia pacifica var. *delicatula*	X	X		X	X	X	X	X	X	X	X	X
Polysiphonia scopulorum								X			X	
Prionitis lanceolata	X			X	X		X	X	X	X		X
Pterocladia media		X	X						X			
Pterosiphonia dendroidea	X	X		X	X		X	X	X		X	X

FIGURE 2 (Concluded)

ALGAE	STATIONS											
	Inside Breakwater						Outside Breakwater					
	1	2	3	4	5	6	7	8	9	10	11	12
Rhodoglossum affine				X	X							X
Rhodymenia californica	X			X					X			X
Rhodymenia pacifica		X					X					
Sorella delicatula							X					
Tiffaniella sp.								X	X			
Veleroa subulata		X			X				X			
TOTALS	20	13	5	15	14	8	21	14	27	10	18	23