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Environmental Baselines in Long Island Sound, 1972-73

R. N. Reid, A. B. Frame, and A. F. Draxler

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706. Food of western North Atlantic tunas (*Thunnus*) and lancetfishes (*Alepisaurus*). By Frances E. Matthews, David M. Damkaer, Leslie W. Knapp, and Bruce B. Collette. January 1977, iii + 19 p., 4 figs., 7 tables, 2 app. tables.

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718. Surface currents as determined by drift card releases over the continental shelf off central and southern California. By James L. Squire, Jr. December 1977, iii + 12 p., 2 figs.

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721. National Marine Fisheries Service survey of trace elements in the fishery resource. By R. A. Hall, E. G. Zook, and G. M. Meaburn. March 1978, iii + 313 p., 5 tables, 3 app. figs., 1 app. table.

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U.S. DEPARTMENT OF COMMERCE
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Environmental Baselines in Long Island Sound, 1972-73

R. N. REID, A. B. FRAME, and A. F. DRAXLER[1]

ABSTRACT

Quasi-synoptic surveys of water column temperature, salinity, nutrients and dissolved oxygen, sediment grain sizes and organic content, and benthic macrofauna were conducted throughout Long Island Sound in July-August 1972 and April and September 1973. Temperatures were fairly uniform both vertically and horizontally except for some vertical stratification in July-August 1972. Salinities increased gradually from east to west, while depth-related differences were minor. Concentrations of all nutrients measured indicated that inputs at the western end dominated nutrient distributions for the Sound. Dissolved oxygen decreased from east to west and with increasing water temperature. Bottom dissolved oxygen values below 2 mg/liter were recorded at several stations in the western Sound in summer 1972. As a rule, sediments of deep waters in the central and western Sound consisted of silts and clays, whereas sands predominated along the Long Island shoreline and in the eastern basin. Sediment organic matter reached highest values (to 10%) in the westernmost Sound. Three assemblages of benthic macrofauna were identified via cluster analyses of 1972 data: a bivalve (especially *Mulinia lateralis*) dominated group in muddy, deepwater regions; a shallow sandy assemblage in which the bivalves *Spisula solidissima, Tellina agilis,* and *Ensis directus* predominated; and a third assemblage transitional in both sediment characteristics and species composition, but with increased dominance by several polychaete species. The mud-bottom and transitional fauna underwent large decreases in numbers of species and individuals from 1972 to 1973.

INTRODUCTION

Long Island Sound (LIS) is a large (145 km long by 17 km maximum width) estuary bounded on the north by the states of New York and Connecticut and on the south by Long Island, N.Y. (Fig. 1). LIS is considered a highly impacted estuary (Bowman 1977), having been important for shipping and waste disposal for several centuries. LIS is also heavily used for recreational boating and swimming, and supports large recreational (Mohr 1976) and small commercial (McHugh 1977) fisheries.

Several comprehensive studies of the chemical oceanography of LIS exist (Riley et al. 1956, 1959, 1967; Hardy 1972b). Benthic surveys, however, have been limited to rather circumscribed portions of LIS (e.g., Sanders 1956; Michael 1976; McCall 1977; Serafy et al. 1977; Rhoads et al. 1978). Due to their sessile nature and wide variety of life histories and tolerances, the benthic macrofauna are particularly suited for biological monitoring of change (Wilhm 1967; Reish 1972; Boesch 1974; Swartz 1978). Many are also important as contaminant vectors and as forage for resource species.

We therefore felt it would be useful to conduct a synoptic study of the water column chemistry and benthos throughout LIS. This information can serve as a "baseline" against which to measure future natural fluctuations and anthropogenic impacts.

Our surveys began in the summer of 1972. We sampled sediments, benthic macrofauna, and water column temperature, salinity, dissolved oxygen, and nutrients three times (July-August 1972, April and September 1973), and have since surveyed sediments, bottom waters, and macrofauna in September of 1975 and 1976 and July of 1977 and 1978. This report summarizes data from the 1972 and 1973 cruises.

METHODS

We established a total of 142 stations, the majority located every 3-5 km on north-south transects spaced 8.7 km apart (on consecutive 5′ longitude lines) for the length of LIS (Fig. 1). Latitude, longitude, and depth of each station are given in Table 1. Water column, sediment, and macrofauna samples were taken at all stations on the summer 1972 cruise. On subsequent surveys we have resampled bottom waters (+1 m), sediments, and macrofauna from 40 to 95 of these stations. Additional water column sampling was done on the two 1973 cruises. Station locating has been by loran A or C and fathometer, augmented by horizontal sextant, land, and buoy ranges when possible.

On Cruise 1, temperature and salinity were measured at 5 m depth intervals using a Beckman RS-5 induction salinometer. Temperatures were measured with reversing thermometers on Cruises 2 and 3, and a Beckman RS-7B salinometer was used for salinity determinations. Samples for water chemistry analysis were taken 1 m from surface and bottom, using Van Dorn water bottles on Cruise 1 and Niskin bottles on Cruises 2 and 3. Additional water samples were taken at 25 m depth intervals at 15 deepwater stations along the

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[1] Northeast Fisheries Center Sandy Hook Laboratory, National Marine Fisheries Service, NOAA, Highlands, NJ 07732.

Table 1. — Sampling locations and depths, Long Island Sound, 1972-73.

Stn	Latitude N	Longitude W	Depth (m)	Stn.	Latitude N	Longitude W	Depth (m)	Stn	Latitude N	Longitude W	Depth (m)	Stn.	Latitude N	Longitude W	Depth (m)
1	40°49.1'	73°47.6'	6.1	42	40°59.2'	73°10.0'	25.9	83	41°13.4'	72°45.0'	11.9	123	41°13.1'	72°20.0'	42.7
2	40°48.1'	73°41.1'	30.5	43	40°55.8'	73°10.0'	2.4	84	41°11.5'	72°45.0'	18.3	124	41°10.7'	72°20.0'	25.9
3	40°48.0'	73°46.3'	4.6	44	41°10.4'	73°05.0'	6.1	85	41°09.1'	72°45.0'	27.5	125	41°08.4'	72°20.0'	6.1
4	40°52.8'	73°46.1'	9.2	45	41°07.8'	73°05.0'	12.2	86	41°06.9'	72°45.0'	28.0	126	41°17.0'	72°15.0'	4.6
5	40°52.8'	73°45.0'	18.3	46	41°04.9'	73°05.2'	22.9	87	41°04.2'	72°45.0'	29.0	127	41°15.8'	72°15.0'	25.9
6	40°52.[illegible]	73°43.4'	4.6	47	41°02.8'	73°05.0'	30.5	88	41°02.0'	72°45.0'	33.6	128	41°13.4'	72°15.0'	38.7
7	40°5[illegible]	73°41.4'	6.1	48	41°00.2'	73°05.0'	36.6	89	41°00.2'	72°45.0'	25.9	129	41°11.2'	72°15.0'	39.7
8	40°55.2'	73°41.0'	15.3	49	40°59.1'	73°05.0'	2.4	90	41°58.4'	72°45.0'	5.5	130	41°09.7'	72°15.0'	9.2
9	40°53.4'	73°41.0'	10.7	50	41°11.0'	73°03.2'	7.6	91	40°14.9'	72°40.0'	4.6	131	41°18.2'	72°10.0'	9.2
10	40°51.8'	73°41.0'	7.6	51	41°11.3'	73°01.5'	9.2	92	41°1[illegible].6'	72°40.0'	21.4	132	41°16.2'	72°10.0'	24.4
11	40°59.8'	73°35.0'	5.5	52	41°13.1'	73°00.0'	7.6	93	41°11.5'	72°40.0'	27.7	133	41°14.0'	72°10.0'	54.9
12	40°58.7'	73°35.0'	18.0	53	41°11.3'	73°00.0'	10.4	94	41°09.1'	72°40.0'	27.7	134	41°11.5'	72°10.0'	6.1
13	40°56.4'	73°35.0'	17.7	54	41°09.0'	73°00.0'	15.2	95	41°07.2'	72°40.0'	27.4	135	41°18.2'	72°05.0'	9.2
14	40°55.0'	73°35.0'	4.6	55	41°06.2'	73°00.2'	22.9	96	41°04.2'	72°40.0'	24.4	136	41°15.7'	72°05.0'	21.4
15	41°00.9'	73°31.6'	6.1	56	41°04.6'	73°00.0'	29.0	97	41°02.1'	72°40.0'	22.9	138	41°18.4'	72°00.0'	4.6
16	40°59.8'	73°31.7'	30.5	57	41°01.4'	72°58.6'	30.5	98	41°00.2'	72°40.0'	13.7	139	41°17.5'	72°00.0'	21.4
17	40°57.3'	73°31.7'	19.8	58	41°00.1'	73°00.0'	21.9	99	40°59.0'	72°40.0'	4.6	140	41°16.7'	72°00.0'	4.6
18	40°55.8'	73°31.7'	5.8	59	40°58.6'	73°00.0'	6.1	100	41°15.8'	72°35.0'	4.6	141	41°19.5'	71°55.0'	4.6
19	41°02.6'	73°28.1'	6.1	60	41°14.4'	72°56.6'	4.6	101	41°13.8'	72°35.0'	13.7	142	41°18.6'	71°55.0'	15.3
20	41°00.8'	73°28.1'	21.4	61	41°12.6'	72°55.0'	9.2	102	41°10.2'	72°35.0'	27.5	143	41°17.8'	71°55.0'	6.1
21	40°58.4'	73°28.[illegible]	21.4	62	41°10.6'	72°55.0'	15.3	103	41°07.8'	72°35.0'	21.4	G1	41°05.6'	72°17.4'	3.7
22	40°56.9'	73°28.[illegible]	6.1	63	41°06.3'	72°55.0'	25.0	104	41°04.9'	72°35.0'	21.4	G2	41°08.0'	72°15.0'	4.6
23	40°03.[illegible]	73°24.0'	6.1	64	41°04.3'	72°55.0'	28.1	105	41°02.5'	72°35.0'	18.3	G3	41°06.8'	72°15.0'	8.8
24	41°02.5'	73°24.0'	15.3	65	41°02.2'	72°55.0'	36.6	106	41°01.4'	72°35.0'	15.3	G4	41°05.5'	72°15.0'	6.4
25	40°59.[illegible]	73°23.9'	13.7	66	41°00.3'	72°55.0'	24.4	107	41°00.4'	72°35.0'	4.6	G5	41°04.1'	72°15.0'	4.9
26	40°58.1'	73°23.9'	6.1	67	40°58.4'	72°55.0'	6.1	108	41°15.2'	72°30.0'	4.6	G6	41°02.9'	72°15.0'	4.6
27	41°0[illegible]	73°19.5'	7.6	68	41°13.9'	72°52.9'	5.5	109	41°13.3'	72°30.0'	21.4	G7	41°02.2'	72°16.3'	4.6
28	41°04.2'	73°19.5'	10.7	69	41°09.0'	72°52.8'	18.9	110	41°10.8'	72°30.0'	30.5	G8	41°01.2'	72°15.0'	3.1
29	41°01.0'	73°19.5'	30.5	70	41°08.0'	72°53.9'	21.3	111	41°08.2'	72°30.0'	29.0	G9	41°11.1'	72°10.0'	4.6
30	40°58.[illegible]	73°19.5'	16.8	71	40°58.3'	72°52.6'	6.1	112	41°05.6'	72°30.0'	29.0	G10	41°09.2'	72°10.0'	22.9
31	40°56.[illegible]	73°19.6'	3.0	72	41°13.6'	72°50.6'	8.5	113	41°0[illegible].4'	72°30.0'	[illegible]	G11	41°08.0'	72°10.0'	9.2
32	41°06.9'	73°15.0'	5.5	73	41°12.8'	72°50.0'	12.2	114	41°16.0'	72°25.0'	5.5	G12	41°06.5'	72°10.0'	7.6
33	41°05.1'	73°15.0'	17.7	74	41°10.6'	72°50.0'	16.8	115	41°14.9'	72°25.0'	15.3	G13	41°04.4'	72°10.0'	7.6
34	41°02.5'	73°15.0'	23.5	75	41°08.6'	72°50.0'	24.4	116	41°13.1'	72°25.0'	24.4	G14	41°03.3'	72°10.0'	4.6
35	40°59.8'	73°15.0'	25.9	76	41°06.4'	72°50.0'	29.0	117	41°10.8'	72°25.0'	39.7	G15	41°04.1'	72°07.2'	7.6
36	40°57.3'	73°15.0'	16.8	77	41°04.2'	72°50.0'	31.1	118	41°08.4'	72°25.0'	29.0	G16	41°02.7'	72°06.4'	3.7
37	40°55.3'	73°15.0'	2.4	78	41°02.2'	72°50.0'	38.1	119	41°06.1'	72°25.0'	16.8	C1	41°16.3'	72°20.4'	6.1
38	41°08.7'	73°10.0'	6.1	79	41°00.4'	72°50.0'	31.4	120	41°05.5'	72°25.0'	4.6	C2	41°18.2'	72°21.0'	4.6
39	41°06.2'	73°10.0'	12.2	80	40°59.5'	72°50.0'	6.1	121	41°15.7'	72°20.0'	3.7	C3	41°20.2'	72°21.5'	4.6
40	41°03.8'	73°10.0'	21.4	81	41°13.6'	72°46.4'	12.2	122	41°14.9'	72°20.0'	9.2				
41	41°01.5'	73°10.0'	29.9	82	41°14.6'	72°45.0'	6.1								

Sound's east-west axis. Dissolved oxygen was determined by the azide modification of the Winkler technique (American Public Health Association 1965), with standard 0.25N phenylarsine oxide substituted for the less stable sodium thiosulfate. Water samples were frozen for later colorimetric determination of nitrate, nitrite, ammonia, urea, iron, and orthophosphorus, using a Technicon Auto Analyser. Nitrate and nitrite were anlyzed using the naphthylenediamine-sulfanilamide system with cadmium reduction of nitrate after Wood et al (1967). The ammonium analyses, which were based on the phenolhypochlorite Bertelot reaction (Solorzano 1969), were run within 15 days of collection. In some cases this is longer than our tests show is permissible without measurable loss (10 days); however, because of the large area surveyed, shorter intervals were sometimes not possible. The values represent, therefore, a conservative estimate of ammonium concentration. The urea analysis is an adaptation to seawater of Marsh et al.'s (1965) blood urea method in which diacetylmonoxime reacts with urea in the presence of thiosemicarbizide and ferric ion intensifiers. Orthophosphorus was measured utilizing the molybdate-ascorbic acid procedure after Murphy and Riley (1962). Iron was determined using the essentials of the 2-2' bipyridal procedure of Lewis and Goldberg (1954) as adapted to the autoanalyzer by Henriken (1967).

Benthic samples were collected with a 0.1 m^2 Smith-McIntyre bottom grab. At each station, sediments from one (Cruises 1 and 2) or two (Cruise 3) grabs were sieved to 1 mm. Retained macrofauna were relaxed in a magnesium chloride-seawater solution, preserved in a 1:9 Formalin to seawater mixture and later trasfered to 70% ethanol with 5% glycerin.

Samples were sorted under dissecting microscopes. All organisms were identified to species when possible. Our macrofauna analysis will concentrate on polychaetes, molluscs, and arthropods, which together comprise the great majorityof species and individuals collected McCall (1977) reported that these three groups accounted for 95% of the infaunal macrobenthos of central LIS).

Species diversity was calculated using the Shannon-

Weaver (1963) index: $H' = -\sum_{1}^{s} p_i \ln p_i$, where p_i is the proportion of individuals in the *i*th species. H' has two components: number of species (S, hereafter termed species richness), and equitability ($J' = H'/H'_{\max} = H'/\ln S$) (Lloyd and Ghelardi 1964). Both S and J' were computed for each 0.1 m^2 samples, as was the number of individuals (N).

Q-mode or normal cluster analyses (clustering stations by species) were done by James Archie, State University of New York, Stony Brook. Czekanowski's coefficient, $Cz = 2w/a+b$ (Bray and Curtis 1957), was used to measure faunal similarity between each pair of stations. Here a is the sum of abundances of all species found at station A, b is the sum of species abundances for station B, and w is the sum of the lower of the abundance values for each species common to A and B. Abundances were log transformed ($\log_e x + 1$), and then single linkage clustering was performed via unweighted pair-group method using arithmetic averages (Sneath and Sokal 1973).

Subsamples were taken from the grabs for analyses of sediment grain sizes, organics, carbonates, heavy metals, microflora, and meiofauna. The latter three topics were subjects of discrete studies, and their methodologies are described elsewhere (respectively Greig et al. 1977; Dudley et al. 1977; Tietjen 1977). Sedimentology studies used a sediment sample collected from each grab with a 3.7 cm inner diameter coring tube and frozen. Analyses were performed by James Parks and Alex Rugh, Lehigh University, Bethlehem, Pa. For grain size analysis, a portion of each core sample was wet-sieved through a 62 μm screen, with retained materials then sieved through a series of 12 screens with meshes from 4 mm to 62 μm. Pipette analysis was used to determine the clay and fine- and coarse-silt fractions of the <62 μm portion. Organic content was determined by weight loss of dried samples upon treatment with 10% hydrogen peroxide.

RESULTS AND DISCUSSION

Temperature and Salinity

Temperature and salinity on Cruises 2 and 3 followed expected patterns, as described by Riley (1955), Riley et al. (1952, 1956), Hardy (1970, 1972a, b), and Hardy and Weyl (1970). Temperatures were quite uniform both vertically and horizontally in April 1973 (Figs. 2,3), with all values between 4° and 9°C. In late September 1973 temperatures ranged from 14° to 22°C (Figs. 4, 5), and generally increased from east to west, with the exception of colder water near the Connecticut River. Again, no pronounced vertical stratification was observed. The vertical uniformity of temperatures (and moderate bottom dissolved oxygen concentrations, as mentioned below) indicate that mixing of the water column was already well underway by late September.

Hardy (1972b) noted that a thermocline develops in midsummer, especially in the central basin; thermal layering is also seen in our measurements for July and August 1972 (Figs. 6, 7). These Cruise 1 data will not be used in examining horizontal patterns, since the sampling period covered 6 wk, and effects of Hurricane Agnes may have obscured the typical distributions. Reflecting the storm's freshwater input, salinity (Figs. 8, 9) was below 22‰ for most surface waters in central LIS, and down to 17.8‰ at station 28 (Fig. 1), a mile south of the Saugatuck River mouth.

Salinity on Cruises 2 (Figs. 10, 11) and 3 (Figs. 12, 13) increased gradually from west to east (from 23 to 29.6‰ in April and 25.0 to 30.6‰ in September). There were only small increases in salinity with depth during this sampling period.

Nutrients

Distributions of all nutrients measured in summer 1972 exhibit basically a single pattern: very large inputs from the East River at the western end of the Sound dominate nutrient distributions and water quality throughout western LIS. Surface ammonium, for instance, approaches 30 microgram-atoms/liter (μgat/liter) at Throgs Neck (Fig. 14). These high levels agree with those reported for August of the previous year by Hardy (1972b). His study showed that to the west ammonium concentrations increased in the East River, to the west of Throgs Neck; a tenfold decrease in surface ammonium is evident from Throgs Neck to just east of Hempstead Harbor (stations 7-10, Fig. 1). Open surface waters of the central basin (as defined by Hardy 1972b) had moderate ammonium levels (generally 0.5-1.0 μgat/liter). The Long Island coast east of long. 73°10′W (stations 38-43 in Fig. 1) showed similar concentrations. The eastern end of the Sound was characterized by ammonium values of <0.5 μgat/liter, again in agreement with Hardy (1972b). There appear to be ammonium additions in the areas off New Haven-West Haven, Oyster Bay-Northport, and the Nissequogue River (station 37), and perhaps off New London and Bridgeport. Ammonium is also presumably being added in the densely populated western end, but this cannot be distinguished from the East River input.

Bottom ammonium (Fig. 15) was also most elevated in the western end, with values higher than in surface waters except at Throgs Neck. According to the bottom ammonium values, the "plume" of East River water extended east to the Oyster Bay-Stamford transec.

Surface nitrate (Fig. 16) showed much the same pattern as ammonium, with most conspicuous inputs from the East River, Bridgeport, New Haven, and New London. Bottom concentrations (Fig. 17) were greatest from Hempstead Harbor to Throgs Neck, and off New Haven; other areas with high surface nitrates did not show comparable levels in bottom waters. Nitrite (Figs. 18, 19) and orthophosphorus (Figs. 20, 21) distributions also had as their most significant feature elevated values in western LIS. As a rule, noticeably elevated concentrations were confined to waters west of long. 73°25′ (Lloyd Neck). Values in microgram-atoms per liter for these three nutrients ranged from undetectable to: surface nitrate, 2.76; bottom nitrate, 2.64; surface nitrite, 3.53;

bottom nitrite, 3.55; surface orthophosphate, 6.90; bottom orthophosphate, 6.14.

In April 1973, ammonium concentrations (Figs. 22, 23) were much lower at Throgs Neck than during the previous summer, and the decrease moving eastward was much less marked, with values at the eastern end slightly higher than for Cruise 1. Nitrate levels (Figs. 24, 25) were somewhat above those measured on Cruise 1, with extremely high concentrations (to 41.6 μgat/liter) at the mouth of the Connecticut River during this period of high runoff. Orthophosphorus (Figs. 26, 27) was low and uniform, varying between 0.4 and 1.0 μgat/liter except for values of 1.0 to 2.7 from Hempstead Harbor west. Nitrite (Figs. 28, 29) was lower than the previous summer; large portions of central and eastern LIS contained <0.1 μgat/liter.

On Cruise 2 we added urea determinations to our nutrient measurements in an effort to better determine the effects of sewage additions on LIS's nutrient patterns. Urea concentrations in April 1973 (Figs. 30, 31) were found to be <1 μgat/liter for most of LIS. As expected, the higher values were found in the western end, again most noticeably from Stamford and Hempstead Harbor west. The maximum concentration was 3.24 μgat/liter at Throgs Neck. This was somewhat higher than that measured by Hardy (1972b) in this area in April 1971. Hardy found that urea concentrations continued to increase in the East River, with a maximum of >6 μgat/liter in the lower river.

The Connecticut River and its plume into LIS had elevated urea concentrations as did a large area roughly between Bridgeport, New Haven, and Port Jefferson.

Dissolved Oxygen

Dissolved oxygen (DO) levels showed a strong inverse relationship to nutrient concentrations in summer 1972. Surface DO's (Fig. 32) were depressed, and bottom concentrations (Fig. 33) markedly so, in extreme western LIS. Surface values were >7 mg/liter through most of eastern and central LIS. DO declined sharply from approximately Hempstead Harbor west, falling from 8 to <3 mg/liter within 7 n.mi. Lesser DO depressions were evident off the Saugatuck River and in the areas of Bridgeport, New Haven, New London, and Huntington Bay (stations 22, 26). A significant feature of surface DO distributions was the appearance of supersaturated areas off Hempstead Harbor, Stamford, and between Bridgeport and Port Jefferson. Hardy and Weyl (1971) reported similar findings for August 1970. They attributed the observed pattern to phytoplankton blooming in response to the high nutrient levels in this area. West of the DO maxima, phytoplankton standing crops may be reduced by inhibition from East River sewage effluents (Hardy 1972b), or perhaps by light limitation or a necessary incubation period prior to blooming.

Bottom DO's (Fig. 33) were above 5 mg/liter for most of the central basin, and >7 in the eastern sector. They fell below 5 mg/liter in deep waters west of New Haven, <4 mg/liter west of Stamford, and <3 mg/liter past Hempstead Harbor. There were scattered areas of still greater depletion, with 1.7 and 1.8 mg/liter at two stations (9 and 10) in the Hempstead Harbor area, and 1.7 near the mouth of the Saugatuck River (station 27). Low oxygen levels in western LIS bottom waters during summer have been reported previously (Hardy and Weyl 1971). An earlier survey of this area (National Marine Fisheries Service[2]) revealed the entire western end to have its lowest bottom DO's (1.0 mg/liter at Throgs Neck; 0.7 at Hempstead Harbor's mouth) coincident with highest summer temperatures. In the present survey, the Connecticut shoreline in the Bridgeport-New Haven region also showed somewhat depressed bottom DO.

The low DO's described above are of course a seasonal phenomenon. In April 1973, after a lengthy period of cold temperatures and wind-generated mixing, DO's had risen above 10 mg/liter for the entire Sound (Figs. 34, 35). Our September 1973 data (Figs. 36, 37) indicate the rapidity with which oxygen levels in the western Sound can change. Samples taken on 12 and 13 September 1973 again revealed the characteristically low values associated with western LIS during the warmer months. Two weeks later, however, bottom DO's had increased to >5 mg/liter at Throgs Neck and >6 everywhere else. This dramatic improvement was again probably related to wind-generated mixing. Hardy and Weyl (1971) agreed that winds can have a controlling effect on DO concentrations in western LIS.

Sediments

Figure 38 shows distribution of silts and clays (<62 μm diameter) in surface sediments for summer 1972, based on means of two cores analyzed per station. Sediments over large portions of central and western LIS, especially in deeper waters but also along portions of the Connecticut coast, consist predominantly of fine materials (50-95% silt/clay). These soft-bottom areas are interrupted by strips or patches of coarser sediments in several parts of LIS, generally corresponding to shoaler areas. Coarser materials (≤5% silt/clay) are also found in shallow areas for the entire length of the Long Island coast. The relatively coarse sediments extend into deeper waters (17-26 m) atop Mattituck Sill, a submarine ridge separating eastern LIS from the remaining two-thirds of the Sound (Hardy 1972b). The well-flushed eastern basin has mostly coarse sediments.

Sediment Heavy Metals, Microorganisms

As mentioned earlier, distributions of sediment heavy metals and fecal coliform bacteria have been described elsewhere. To summarize: heavy metal and coliform distributions were in general agreement with the distributions of nutrients and dissolved oxygen described above.

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[2] National Marine Fisheries Service. 1972. Davids Island Phase I: A short-term ecological survey of western Long Island Sound. Middle Atlantic Coastal Fisheries Center, Informal Rep. 7, 29 p.

Concentrations in the extreme western end of LIS were almost invariably orders of magnitude higher than levels in the eastern basin. Most of the northern Long Island shoreline was also low in sediment heavy metals and fecal coliforms. Deep waters in central LIS showed intermediate values, while several areas near population and industrial centers on the Connecticut coastline had levels almost as high as were found at the western end.

Sediment Organic Matter

Distribution of sediment organic matter for Cruise 1 (Table 2) showed a pattern similar to that for the above water and sediment constituents. Much of LIS, especially along the Long Island coast and in the eastern basin, had <1% organic matter in sediments. The highest values were found from the station 7-10 transect (long. 73°40'W) west. Stations 1, 5, and 7 in westernmost LIS had between 9 and 10% organics in sediment. Highly organic sediments were also found in a band between long. 73°10' and 73°20'W, and in several other patches of mostly deepwater, muddy sediments in the central basin. Table 2 also indicates substantial between-cruise variability in sediment organics at a number of stations. This is undoubtedly due in part to sediment patchiness and/or station relocation inaccuracies.

Benthic Macrofauna

A list of all annelids, molluscs, and arthropods collected during our most extensive (summer 1972) sampling is given in Table 3. We identified a total of 248 species within these taxa, with annelids accounting for 46% of the species, molluscs 21%, and arthropods 33%.

Shannon-Weaver species diversities (*H'*) were calculated for all 1972 samples. Distribution of *H'* values is shown in Figure 39. An obvious feature of the *H'* distributions is that lowest values (<1.0 bits/individual) were found amost exclusively at deepwater stations with high silt-clay content (compare with Fig. 38). Low diversities in these areas were due mostly to a high degree of dominance by several bivalve species, as will be discussed below. In the central and western basins there was no apparent reduction of *H'* values with the higher levels of pollution found toward the western end of LIS. Highest diversities, however, were found in the eastern basin, which also had lowest contaminant levels.

Table 2.—Organic matter in Long Island Sound sediments (weight percent).

	Cruise				Cruise				Cruise				Cruise		
Station	1	2	3	Station	1	2	3	Station	1	2	3	Station	1	2	3
1	9.54		4.67	37	0.03	0.02	0.56	73	0.51		0.57	109	0.50		
2	0.26	6.83	5.15	38	0.16			74	0.53			110	0.10		0.00
3	0.54		3.30	39	0.09			75	5.86			111	0.13		0.57
4	0.35		0.34	40	0.42			76	0.46			112	4.37		
5	9.05	1.23	1.10	41	0.01			77	0.25			113	0.12		
6	0.08	0.33	0.61	42	7.36			78	0.52			114	0.64	0.35	1.34
7	9.96	0.41	4.31	43	0.16			79	0.74			115	0.11		0.70
8	1.14	0.01	1.35	44	0.17	1.38	2.48	80	0.01			116	0.02	0.09	0.00
9	0.35	1.58	0.00	45	0.10		6.23	81	0.14	0.90	3.37	117	0.06	0.01	0.42
10	5.44	0.11	0.94	46	0.37	0.01	2.22	82	1.46	2.42	4.14	118	0.15	0.04	0.57
11	0.74	0.13	0.26	47	0.39	0.18	1.68	83	0.09			119	0.17		0.98
12	0.41	1.66	6.66	48	2.13			84		7.61	3.54	120	0.11	0.08	0.80
13	0.10	0.05	6.17	49	0.09	0.05	0.76	85	3.24			121	0.35		0.43
14	0.23	0.52		50	0.10	0.14	1.21	86	0.29	1.57	3.19	122	0.03		
15	0.00		0.47	51	0.16	0.19	0.80	87	1.68			123	0.05		0.37
16	1.39	0.39	0.55	52	0.54			88	3.62	1.08	3.96	124	0.15		
17	0.79	1.61	0.93	53	0.32			89	2.49			125	0.26		0.79
18	0.23	0.07	0.51	54	0.06			90	0.28	0.27	0.80	126	0.51	0.23	1.38
19	0.53	0.64	0.30	55	2.15	0.60	3.38	91	0.48			127	0.68	0.06	1.34
20	2.26		6.79	56	3.04			92	0.23			128	0.05	0.04	0.65
21	0.42			57	1.99	0.12	0.51	93	0.29			129	0.13		0.87
22	0.18		4.11	58	0.66			94	2.82			130	0.18	0.02	0.48
23	0.18	0.04	1.15	59	0.02			95	0.30			131	0.19		1.10
24	0.35		2.46	60	1.22	1.99	5.96	96	0.21			132	0.38		0.55
25	0.26	0.31	2.46	61	0.22	2.18	0.86	97	0.16			133	0.91		0.50
26	0.13	0.03	0.79	62	0.02	0.50	1.18	98	0.24			134	0.11		0.52
27	0.08		0.92	63	0.27	0.30	1.45	99	0.06			135	1.28	0.43	0.45
28	0.53		0.57	64	1.13			100	1.46	1.94	3.07	136	1.17	0.05	1.04
29	1.05	2.38		65	0.97	1.42	6.98	101	0.07		0.94	138	0.08		
30	1.12		3.90	66	1.07			102	0.06	0.09	0.39	139	0.08		1.15
31	0.03		0.62	67	0.11	0.03	0.39	103	0.06	0.02	1.06	140	0.20		1.73
32	0.10	0.01	2.15	68	0.69	0.01	0.52	104	0.07		0.83	141	0.44		0.73
33	8.18			69	0.44	1.03	0.62	105	0.40	0.16	1.40	142	0.21		
34	1.26	0.06	0.53	70	0.46	0.70	4.64	106	1.48			143	0.27		
35	4.96	1.00	0.35	71	0.12	0.23		107	0.12		0.78				
36	1.18	0.56	1.08	72	0.95	0.45	3.20	108	1.44						

Table 3.—Benthic macrofauna species collected in Long Island Sound, 1972-73.

- POLYCHAETA
  - POLYNOIDAE
    - *Harmothoe extenuata*
    - *Harmothoe imbricata*
    - *Lepidonotus squamatus*
    - *Lepidonotus sublevis*
  - SIGALIONIDAE
    - *Sthenelais boa*
    - *Sthenelais limicola*
    - *Sigalion arenicola*
    - *Pholoe minuta*
  - PHYLLODOCIDAE
    - *Eteone heteropoda*
    - *Eumida sanguinea*
    - *Paranaitis speciosa*
    - *Phyllodoce arenae*
    - *Phyllodoce mucosa*
    - *Phyllodoce maculata*
  - HESIONIDAE
    - *Podarke obscura*
  - PILARGIDAE
    - *Cabira incerta*
    - *Sigambra tentaculata*
  - SYLLIDAE
    - *Proceraea cornuta*
    - *Autolytus verrilli*
    - *Autolytus* #1
    - *Odontosyllis fulgurans*
    - *Brania clavata*
    - *Brania* #2
    - *Exogone dispar*
    - *Exogone naidina*
    - *Parapionosyllis longicirrata*
    - *Syllides* #1
    - *Syllides* #2
    - *Typosyllis* #1
    - *Syllis gracilis*
    - *Syllis spongiphila*
    - *Sphaerosyllis erinaceus*
  - NEREIDAE
    - *Nereis acuminata*
    - *Nereis grayi*
    - *Nereis succinea*
    - *Nereis zonata*
  - NEPHTYIDAE
    - *Nephtys bucera*
    - *Nephtys incisa*
    - *Nephtys picta*
  - GLYCERIDAE
    - *Glycera americana*
    - *Glycera dibranchiata*
  - GONIADIDAE
    - *Goniadella gracilis*
  - SCALIBREGMIDAE
    - *Scalibregma inflatum*
  - OPHELIIDAE
    - *Travisia carnea*
  - CAPITELLIDAE
    - *Capitella capitata*
    - *Heteromastus filiformis*
    - *Notomastus luridus*
    - *Mediomastus ambiseta*
  - MALDANIDAE
    - *Clymenella zonalis*
    - *Clymenella torquata*
    - *Asychis elongata*
    - *Nicomache lumbricalis*
  - PARAONIDAE
    - *Aricidea catherinae*
    - *Paraonis gracilis*
    - *Paraonis lyra*
  - SPIONIDAE
    - *Polydora ligni*
    - *Polydora websteri*
    - *Polydora socialis*
    - *Polydora colonia*
    - *Polydora quadrilobata*
    - *Prionospio steenstripi*
    - *Scolecolepides viridis*
    - *Scolelepis (Scolelepis) squamata*
    - *Scolelepis (Nerinides)* # 1
    - *Spio filicornis*
    - *Spiophanes bombyx*
    - *Streblospio benedicti*
    - *Pygospio elegans*
    - *Spiochaetopterus oculatus*
    - *Boccardia* #1
  - SABELLARIIDAE
    - *Sabellaria vulgaris*
  - ONUPHIDAE
    - *Diopatra cuprea*
  - EUNICIDAE
    - *Marphysa sanguinea*
    - *Marphysa belli*
  - LUMBRINERIDAE
    - *Lumbrineris tenuis*
    - *Lumbrineris fragilis*
    - *Ninoe nigripes*
  - ARABELLIDAE
    - *Arabella iricolor*
    - *Drilonereis longa*
    - *Notocirrus spiniferus*
  - DORVILLEIDAE
    - *Schistomeringos longicornis*
    - *Schistomeringos caeca*
    - *Protodorvillea gaspiensis*
  - ORBINIIDAE
    - *Orbinia ornata*
    - *Orbinia swani*
    - *Scoloplos armiger*
    - *Haploscoloplos fragilis*
    - *Haploscoloplos robustus*
  - CIRRATULIDAE
    - *Cirratulus grandis*
    - *Tharyx annulosus*
    - *Tharyx acutus*
    - *Dodecaceria coralii*
    - *Caulleriella cf killariensis*
  - OWENIIDAE
    - *Owenia fusiformis*
  - PECTINARIIDAE
    - *Pectinaria gouldii*
  - AMPHARETIDAE
    - *Asabellides oculata*
    - *Melinna cristata*
    - *Ampharete arctica*
    - *Amage auricula*
  - TEREBELLIDAE
    - *Loimia medusa*
    - *Pista cristata*
    - *Pista maculata*
    - *Polycirrus eximius*
    - *Polycirrus medusa*
    - *Polycirrus phosphoreus*
    - *Nicolea venustula*
  - FLABELLIGERIDAE
    - *Pherusa affinis*
    - *Brada granosa*
    - *Brada villosa*
  - SABELLIDAE
    - *Potamilla reniformis*
    - *Sabella microphthalma*
    - *Euchone elegans*
    - *Laonome kroyeri*
  - SERPULIDAE
    - *Hydroides dianthus*
- GASTROPODA
  - CALPTRAEIDAE
    - *Crepidula fornicata*
    - *Crepidula plana*
  - NATICIDAE
    - *Polinices duplicatus*
    - *Lunatia heros*
    - *Natica pusilla*
    - *Naticid* #1
  - MURICIDAE
    - *Eupleura caudata*
    - *Urosalpinx cinerea*
  - COLUMBELLIDAE
    - *Anachis translirata*
    - *Mitrella lunata*
  - MELONGENIDAE
    - *Busycon canaliculatum*
  - NASSARIIDAE
    - *Nassarius trivittatus*
  - ACTEONIDAE
    - *Acteon punctostriatus*
  - SCAPHANDRIDAE
    - *Cylichna oryza*
  - PHILINIDAE
    - *Philine sinuata*
  - ACTEOCINIDAE
    - *Acteocina canaliculata*
  - PYRAMIDELLIDAE
    - *Odostomia* #1
    - *Turbonilla elegantula*
    - *Turbonilla sumneri*
  - ONCHIDORIDAE
    - *Onchidoris aspersa*
- PELECYPODA
  - SOLEMYIDAE
    - *Solemya velum*
  - NUCULIDAE
    - *Nucula proxima*
    - *Nucula delphinodonta*
    - *Yoldia limatula*
  - ARCIDAE
    - *Anadara transversa*
  - MYTILIDAE
    - *Mytilus edulis*
    - *Modiolus modiolus*
    - *Musculus corrugatus*
    - *Crenella glandula*
  - ANOMIIDAE
    - *Anomia simplex*
  - OSTREIDAE
    - *Crassostrea virginica*
  - ASTARTIDAE
    - *Astarte castanea*
    - *Astarte undata*
    - *Astarte quadrans*
  - CARDITIDAE
    - *Cyclocardia borealis*
  - MONTACUTIDAE
    - *Mysella planulata*
  - CARDIIDAE
    - *Cerastoderma pinnulatum*
  - VENERIDAE
    - *Mercenaria mercenaria*
    - *Pitar morrhuana*
    - *Gemma gemma*
  - PETRICOLIDAE
    - *Petricola pholadiformis*
  - TELLINIDAE
    - *Tellina agilis*
  - PERIPLOMATIDAE
    - *Periploma papyratium*
  - SOLENIDAE
    - *Ensis directus*
  - MACTRIDAE
    - *Spisula solidissima*
    - *Mulinia lateralis*
  - HIATELLIDAE
    - *Hiatella arctica*
  - MYACIDAE
    - *Mya arenaria*
  - CORBULIDAE
    - *Corbula contracta*
  - LYONSIIDAE
    - *Lyonsia hyalina*
  - PANDORIDAE
    - *Pandora gouldiana*
- PYCNOGONIDA
  - PHOXICHILIDIIDAE
    - *Anoplodactylus lentus*
  - AMMOTHEIDAE
    - *Achelia spinosa*
  - NYMPHONIDAE
    - *Nymphon grossipes*
- CUMACEA
  - LEUCONIDAE
    - *Leucon americanus*
    - *Eudorella pusilla*
  - DIASTYLIDAE
    - *Oxyurostylis smithi*
    - *Diastylis sculpta*
- TANAIDACEA
  - PARATANAIDAE
    - *Leptognatha caeca*
- ISOPODA
  - IDOTEIDAE
    - *Chiridotea tuftsi*
    - *Erichsonella filiformis*
    - *Edotea triloba*
  - ANTHURIIDAE
    - *Cyathura polita*
    - *Ptilanthura tenuis*
    - *Ananthura* #1
  - CIROLANIDAE
    - *Cirolana polita*
    - *Cirolana burbancki*
- AMPHIPODA
  - AMPELISCIDAE
    - *Ampelisca abdita*
    - *Ampelisca vadorum*
    - *Ampelisca verrilli*
    - *Ampelisca macrocephala*
    - *Byblis serrata*
  - AMPITHOIDAE
    - *Ampithoe longimana*
  - AORIDAE
    - *Lembos websteri*

Table 3.—Continued.

Leptocheirus pinguis
Microdeutopus gryllotalpa
Microdeutopus anomalus
Pseudunciola obliquua
COROPHIIDAE
Cerapus tubularis
Corophium acherusicum
Corophium tuberculatum
Corophium crassicorne
Corophium bonelli
Erichthonius brasiliensis
Unciola inermis
Unciola irrorata
Unciola serrata
Unciola dissimilis
GAMMARIDAE
Elasmopus levis
Gammarus mucronatus
HAUSTORIIDAE
Acanthohaustorius millsi
Bathyporeia parkeri
Parahaustorius attenuatus
Parahaustorius holmesi
Protohaustorius deichmannae
Protohaustorius wigleyi
Acanthohaustorius n. sp. #1
Acanthohaustorius n. sp. #2
ISAEIDAE
Photis dentata
ISCHYROCERIDAE
Jassa falcata
LILJEBORGIIDAE
Listriella barnardi
Sextonia americana
LYSIANASSIDAE
Lysianassa alba
Psammonyx nobilis
Orchomenella pinguis
OEDICEROTIDAE
Synchelidium americanum
PHOXOCEPHALIDAE
Paraphoxus spinosus
Phoxocephalus holbolli
Trichophoxus epistomus
PLEUSTIDAE
Stenopleustes gracilis
Stenopleustes inermis
Pleusymtes glaber
CAPRELLIDAE
Aeginina longicornis
Caprella unica
Caprella penantis
Paracaprella tenuis
Luconacia incerta
DECAPODA
HIPPOLYTIDAE
Eualus pusiolus
CRANGONIDAE
Crangon septemspinosa
THALASSINIDEA
Callianassa atlantica
Axius #1
PAGURIDAE
Pagurus longicarpus
Pagurus pollicaris
PORTUNIDAE
Ovalipes ocellatus
CANCRIDAE
Cancer borealis
Cancer irroratus
XANTHIDAE
Neopanope texana sayi
Xanthid #1
PINNOTHERIDAE
Dissodactylus mellitae
Pinnotheres maculatus
Pinnixa #1
MAJIDAE
Libinia dubia
Libinia emarginata

The cluster analysis of 1972 faunal data revealed one large group of 43 stations (Fig. 40) with relatively homogeneous fauna (similarity ≥50%). This group occurred mostly in muddy, deepwater sediments throughout central and western LIS; 37 of the stations had ≥69% silt/clay, and 38 were ≥15 m deep. Table 4 lists the fauna typical of these fine sediments in 1972, giving mean densities per square meter as well as coefficient of variation (standard deviation ÷ mean density × 100) and frequency of station occurrences for each of the 17 species found at a majority of the 43 stations (an 18th species, the anthozoan *Ceriantheopsis americana*, was present in a majority of samples analyzed for April and September 1973 though not for 1972). The 1972 mud-bottom assemblage was dominated by small bivalves, including *Nucula proxima* and *Yoldia limatula* (burrowing deposit feeders), *Pitar morrhuana*, and especially *Mulinia lateralis* (suspension feeders). Other very frequently occurring constituent species were the polychaete *Nephtys incisa* (burrowing deposit feeder), and gastropods *Nassarius trivittatus* (surface deposit feeder) and *Acteocina canaliculata* (carnivore). Overall faunal density was extremely high ($\bar{x}$ = 10,400/m^2). Diversity was quite low, due to low species richness and dominance by *Mulinia*. As indicated by frequencies of occurrence and coefficients of variation, *Nephtys*, *Nassarius*, *Acteocina*, *Mulinia*, and *Pitar* had relatively even abundances in the mud-bottom areas; distributions of the remaining species were patchier.

Table 4 also lists mean densities, coefficients of variation, and frequencies of occurrence of these 18 species based on the more limited data available for April 1973 (one sample from each of 13 stations) and September 1973 (16 samples, 13 stations; these stations were fairly evenly distributed over the area in which the mud assemblage was present in 1972, as was also the case for 1973 sampling in the sand and transitional assemblages discussed below).

Numbers of individuals and species declined precipitously from summer 1972 to April 1973, and no recovery was apparent by September 1973. The decline affected almost all taxa; only the anthozoan *Ceriantheopsis*, polychaetes *Nephtys* and *Pherusa*, and bivalve *Nucula* showed September 1973 densities greater than or equal to two-thirds as high as their summer 1972 values. Species diversity and equitability increased, reflecting the reductions in populations of dominants such as *Mulinia* and *Pitar*. This "population crash" had been reported for portions of central LIS (McCall 1977), but its areal extent had not been delimited. Our evidence indicates that the decline extended over the entire area containing the mud assemblage (Fig. 40) with the following exceptions: the westernmost station (5) had slightly increased numbers of individuals and species in 1973, though *Mulinia* and *Pitar* were replaced as dominant species by several polychaetes and *Ceriantheopsis;* station 72, in relatively shallow water near New Haven, also had a shift in species composition toward polychaetes with little change in overall faunal density or species richness; while station 86, the easternmost mud bottom area for which we have 1973 data, contained a typical *Mulinia* assemblage in April 1973, but *Mulinia* had disappeared and overall numbers of species and individuals were greatly reduced by September 1973.

A somewhat less widespread, more variable faunal assemblage, found at 12 stations with faunal similarity ≥37%, occurred primarily along the Long Island coast, in sandy sediments at shallow depths (Fig. 40). All stations in this group contained ≤3.7% silt/clay, and all were in water ≤6.1 m deep. This group of stations thus represents the other extreme of soft-bottom habitat types among our LIS samples. Only 15 species were present at ≥50% of the 12 stations in 1972 (Table 5) though overall species richness (and diversity) were considerably greater than in mud bottoms. The assemblage was dominated by three suspension-feeding bivalves, *Tellina agilis*, *Ensis directus*, and *Spisula solidissima*. Other prominent members were *Nephtys picta* and *Nassarius trivittatus* as well as a suspension-feeding gastropod, *Crepidula fornicata*, and the omnivorous hermit crab, *Pagurus longicarpus*.

Based on the few samples processed from September 1973 (Table 5), this habitat did not experience a faunal decline comparable with that described above for the

Table 4.—Average densities/m² ($\bar{x}$), coefficients of variation (CV), and frequencies of occurrence (F) of species commonly found in muddy, deep-water sediments in Long Island Sound, 1972-73.

	Summer 1972 n = 43 stations			April 1973 n = 13			September 1973 n = 13 (16 samples)		
	$\bar{x}$	CV,%	F,%	$\bar{x}$	CV,%	F,%	$\bar{x}$	CV,%	F,%
ANTHOZOANS									
Ceriantheopsis americana	14	151	44	14	128	62	58	237	56
POLYCHAETES									
Nephtys incisa	60	68	98	90	72	100	100	92	88
Pherusa affinis	50	122	77	14	105	62	45	290	50
Polydora ligni	157	291	74	1	350	8	2	211	19
Asychis elongata	18	212	56	12	120	54	7	181	31
GASTROPODS									
Nassarius trivittatus	101	77	98	61	104	85	55	99	94
Cylichna oryza	31	139	58	0	—	0	0	—	0
Acteocina canaliculata	179	82	93	12	288	23	0	—	0
PELECYPODS									
Nucula proxima	483	222	70	402	241	62	324	216	81
Yoldia limatula	191	155	93	4	134	38	51	267	56
Pitar morrhuana	357	72	95	29	170	62	4	143	38
Mulinia lateralis	8,217	61	100	710	325	54	11	276	19
Lyonsia hyalina	29	196	61	0	—	0	2	395	6
Pandora gouldiana	47	169	61	4	295	20	0	—	0
CRUSTACEANS									
Oxyurostylis smithi	17	139	63	0	—	0	0	—	0
Ampelisca abdita	53	132	70	0	—	0	26	275	25
Crangon septemspinosa	12	123	63	1	350	8	5	126	44
Cancer irroratus	7	115	54	1	350	8	1	417	6
[1]Total individuals/m²	10,400	56		1,469	181		1,263	136	
[1]Total species	21.2	31		9.6	42		10.1	65	
[1]Species diversity, H'	1.07	52		1.47	45		1.46	36	
Equitability, J'	0.35	51		0.67	37		0.69	33	

[1] Means for entire samples, including rarer species.

finer-sediment assemblage. Mean species richness, diversity, and equitability were almost identical between the two samplings. Mean faunal density did show a large drop in 1973; however, the high 1972 mean density had been due mostly to a large population of a small bivalve, *Gemma gemma*, at a single station (37). If this population is excluded from the calculations, faunal density is actually greater in 1973 ($\bar{x}$ = 3,703 vs. 3,041 individuals/m²). Major changes in densities of individual species included decreases in *Ensis* and *Spisula* and increases in *Tellina* and the polychaete *Spiophanes bombyx*

A third faunal group (Table 6), occurring at 21 stations (Fig. 40) with faunal similarity ≥41%, was transitional between the extremes of shallow sandy and deep muddy habitats. This group contained *Ensis directus, Tellina agilis, Ampharete arctica, Ampelisca vadorum,* and *Unciola irrorata* from the sand assemblage. Also common were *Polydora ligni, Pherusa affinis,* and *Ampelisca abdita* from the mud group, and the ubiquitous *Nassarius trivittatus* and *Oxyurostylis smithi.* The overlap between the three assemblages indicates that distributions of LIS macrofauna represent a faunal continuum rather than discrete, well-defined communities.

Populations in transitional sediments underwent faunal decline between 1972 and 1973 (Table 6) which was nearly as severe as that seen in the mud assemblage. Mean number of individuals dropped from 14,037 to 2,362/m²; much of the decrease was due to a large reduction in densities of four polychaetes, *Polydora, Ampharete, Streblospio benedicti,* and *Tharyx acutus,* and to a lesser extent the bivalves *Ensis* and *Tellina.* Mean number of species was also substantially reduced, falling from 34.3 to 23.8 per sample. Diversity and equitability increased due to the lowered polychaete dominance. Only one species, the amphipod *Ampelisca abdita,* showed a major population increase.

While the "population crash" between 1972 and 1973 has also been reported elsewhere for portions of LIS (McCall, 1977; Rhoads and Michael[1]), no obvious causes of the decline have been uncovered. Rhoads and Michael theorized that a major erosion event in the spring of 1973 may have led to widespread recruitment failure. We are continuing to explore possible causes of the decline, and longer term fluctuations in the mud-bottom assemblage. Frequency, severity, and causes of these fluctuations in the benthic macrofauna must be better understood if the fauna are to be of value in environmental monitoring and impact assessment. Moreover, future management of resource finfish and crustaceans requires a thorough understanding of changes in benthic populations which serve as forage for these species.

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[1] Rhoads, D. C., and A. Michael. 1974. Summary of benthic biologic sampling in central Long Island Sound and New Haven Harbor prior to dredging and dumping, July 1972-August 1973. Unpubl. manuscr., 15 p. Report to U.S. Corps of Engineers, by Yale University.

Table 5.—Average densities/m² (x), coefficients of variation (CV), and frequencies of occurrence (F) of species commonly found in shallow sandy sediments in Long Island Sound, 1972-73.

	Summer 1972 $n = 12$ stations			September 1973 $n = 9$		
	$\bar{x}$	CV,%	F,%	$\bar{x}$	CV,%	F,%
POLYCHAETES						
Nephtys picta	75	98	83	48	92	67
Aricidea catherinae	45	194	50	6	180	33
Spiophanes bombyx	25	133	67	207	113	78
Ampharete arctica	28	159	50	33	178	44
Owenia fusiformis	6	200	33	22	125	56
GASTROPODS						
Crepidula fornicata	214	253	67	96	195	44
Nassarius trivittatus	72	81	92	88	58	100
PELECYPODS						
Tellina agilis	445	170	100	1,910	206	100
Ensis directus	122	130	100	74	155	78
Spisula solidissima	795	194	75	29	167	44
Pandora gouldiana	92	150	58	32	105	67
CRUSTACEANS						
Oxyurostylis smithi	38	136	58	32	93	67
Ampelisca vadorum	92	188	67	49	212	56
Unicola irrorata	34	178	67	18	156	33
Paraphoxus epistomus	52	159	75	89	172	44
Pagurus longicarpus	37	108	83	20	90	78
Crangon septemspinosa	5	200	25	16	107	67
[1]Total individuals/m²	6,938	189		3,703	135	
Total species	23.1	48		22.9	40	
[1]Species diversity, H'	1.92	39		1.93	29	
Equitability, J'	0.62	35		0.64	25	

[1] Means for entire samples, including rarer species.

Table 6.—Average densities/m² (x), coefficients of variation (CV), and frequencies of occurrence (F) of species commonly found in "transitional" sediments in Long Island Sound, 1972-73.

	Summer 1972 $n = 21$ stations			September 1973 n 13		
	$\bar{x}$	CV,%	F,%	$\bar{x}$	CV,%	F,%
POLYCHAETES						
Pectinaria gouldii	9	215	33	24	173	54
Eumida sanguinea	26	144	67	40	168	39
Glycera americana	21	115	71	45	121	69
Mediomastus ambiseta	175	159	71	143	257	46
Polydora ligni	7,131	187	95	1	360	8
Streblospio benedicti	1,549	138	86	14	160	54
Tharyx acutus	533	204	86	4	169	31
Ampharete arctica	415	185	90	43	178	62
Pherusa affinis	16	157	57	2	360	8
Nereis succinea	33	201	38	19	135	62
Spiophanes bombyx	9	244	24	38	118	54
GASTROPODS						
Nassarius trivittatus	91	81	95	109	89	92
PELECYPODS						
Tellina agilis	418	109	86	222	110	69
Ensis directus	281	96	100	104	119	62
CRUSTACEANS						
Oxyurostylis smithi	52	185	62	3	205	23
Ampelisca abdita	96	194	76	44	278	31
Ampelisca vadorum	81	222	57	508	260	85
Unicola irrorata	48	120	81	15	230	31
Crangon septemspinosa	18	150	48	22	93	85
Pagurus longicarpus	16	253	43	19	139	54
ASTEROIDS						
Asterias forbesi	46	273	48	32	163	69
[1]Total individuals/m²	14,037	118		2,362	62	
[1]Total species	34.3	27		23.8	52	
[1]Species diversity, H'	1.83	27		2.03	12	
[1]Equitability, J'	0.53	28		0.64	10	

[1] Means for entire samples, including rarer species.

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Ruth Turner and Austin Williams aided in identification of molluscs and decapods, respectively. Errors in identification or nomenclature, however, remain our responsibility. Illustration work was done by Michele Cox and typing by Diane McDonnell. John Pearce reviewed the report and made helpful suggestions. We also wish to thank the many persons who served as crew and scientists on field surveys and who carried out the bulk of the sorting, identifying, and enumerating of benthic macrofauna.

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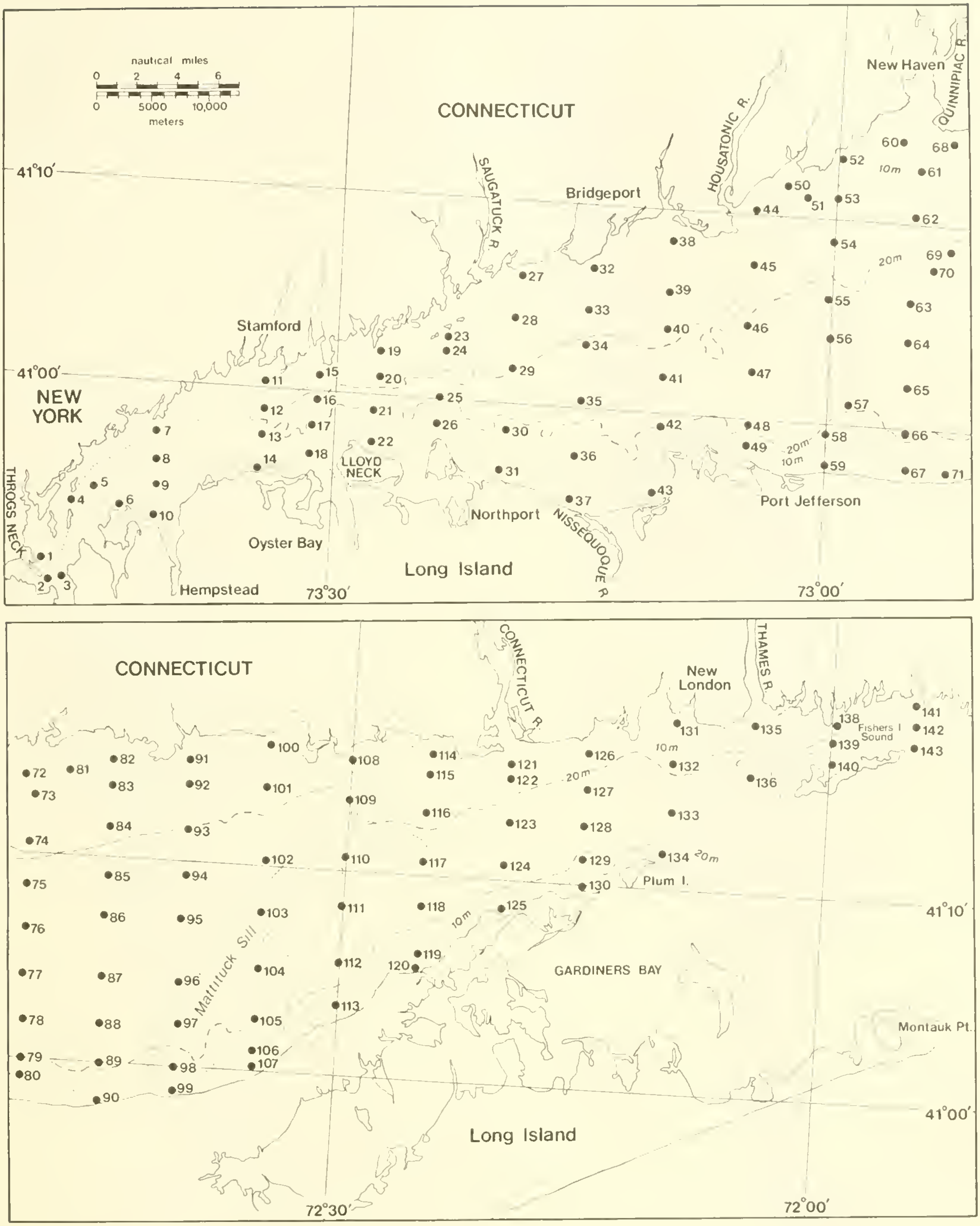


Figure 1.—Sampling pattern in Long Island Sound.

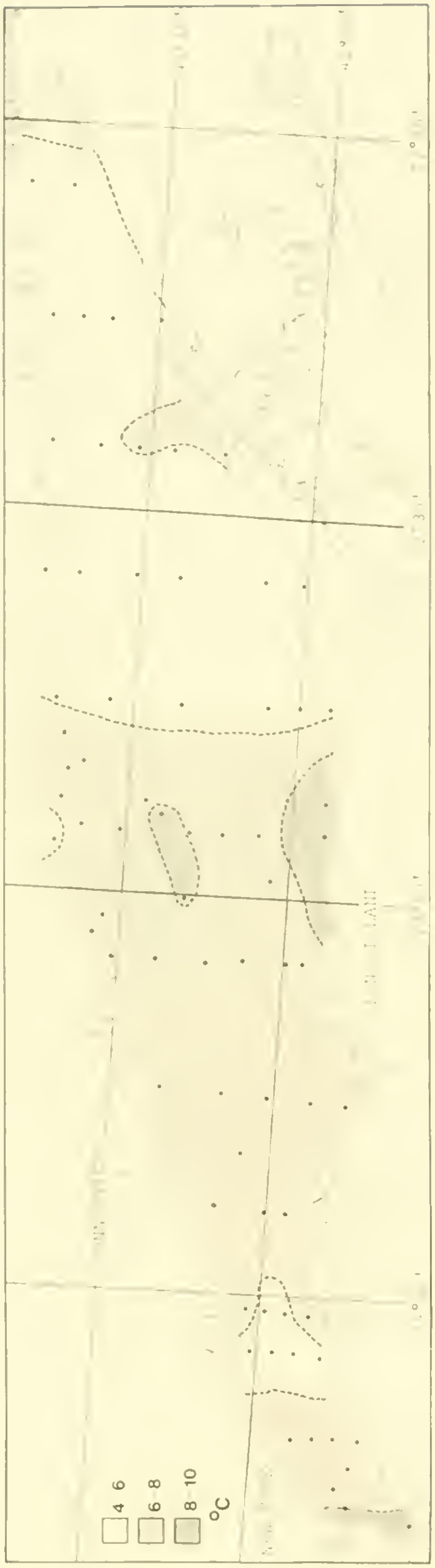


Figure 2. Surface temperature, Long Island Sound, April 1973.

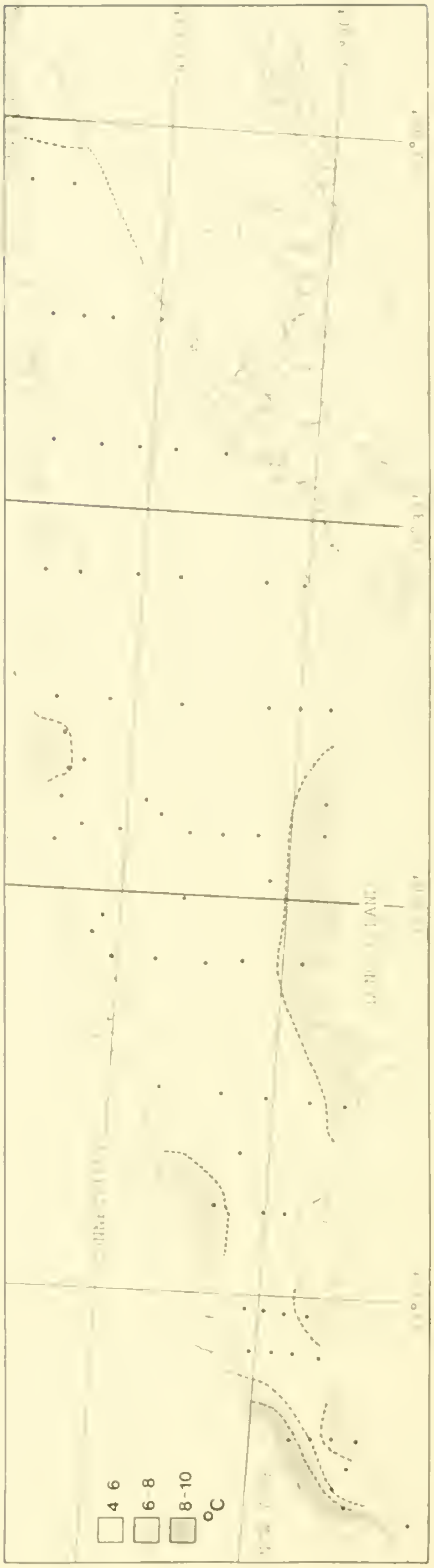


Figure 3. Bottom temperature, Long Island Sound, April 1973.

Figure 1.—Surface temperature, Long Island Sound, September 1973.

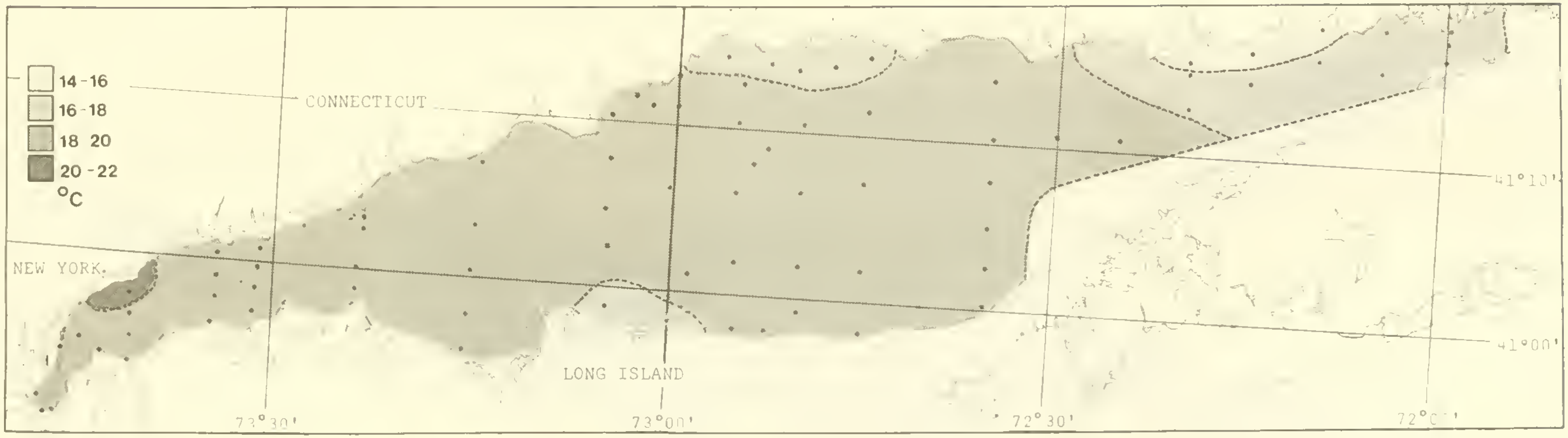


Figure 5.—Bottom temperature, Long Island Sound, September 1973.

Figure 6. Surface temperature, Long Island Sound, summer 1972.

Figure 7. Bottom temperature, Long Island Sound, summer 1972.

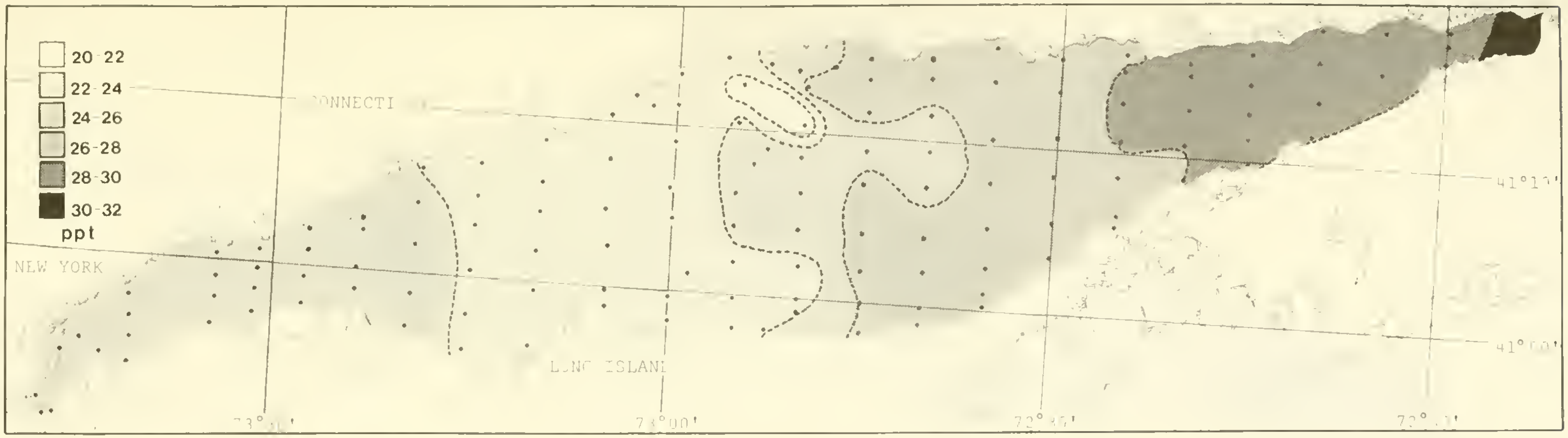


Figure 8.—Surface salinity, Long Island Sound, summer 1972.

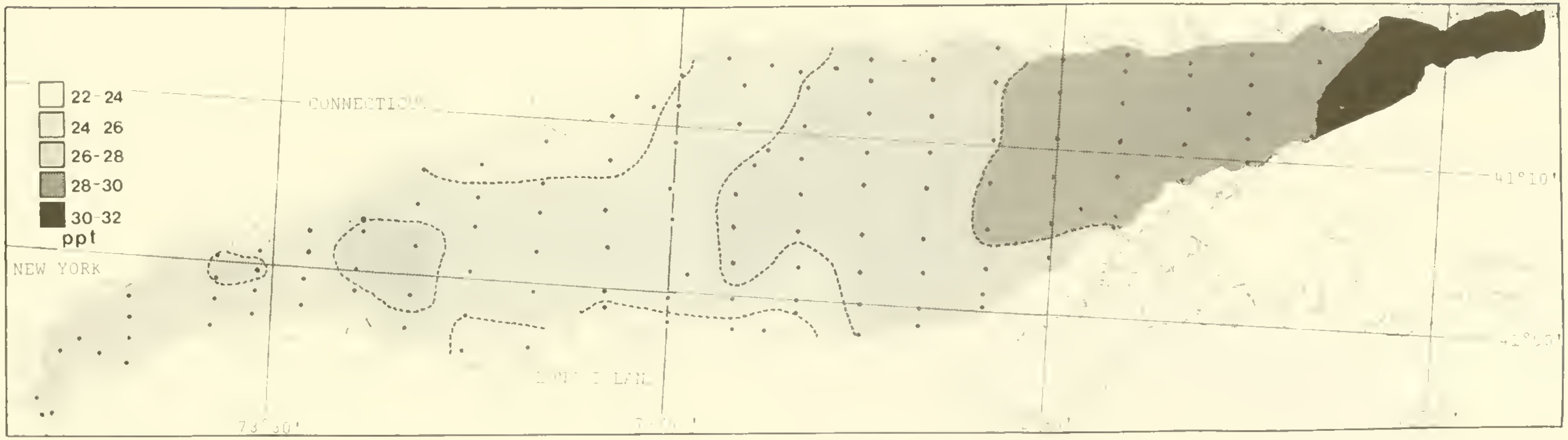


Figure 9.—Bottom salinity, Long Island Sound, summer 1972.

Figure 10.—Surface salinity, Long Island Sound, April 1973.

Figure 11.—Bottom salinity, Long Island Sound, April 1973.

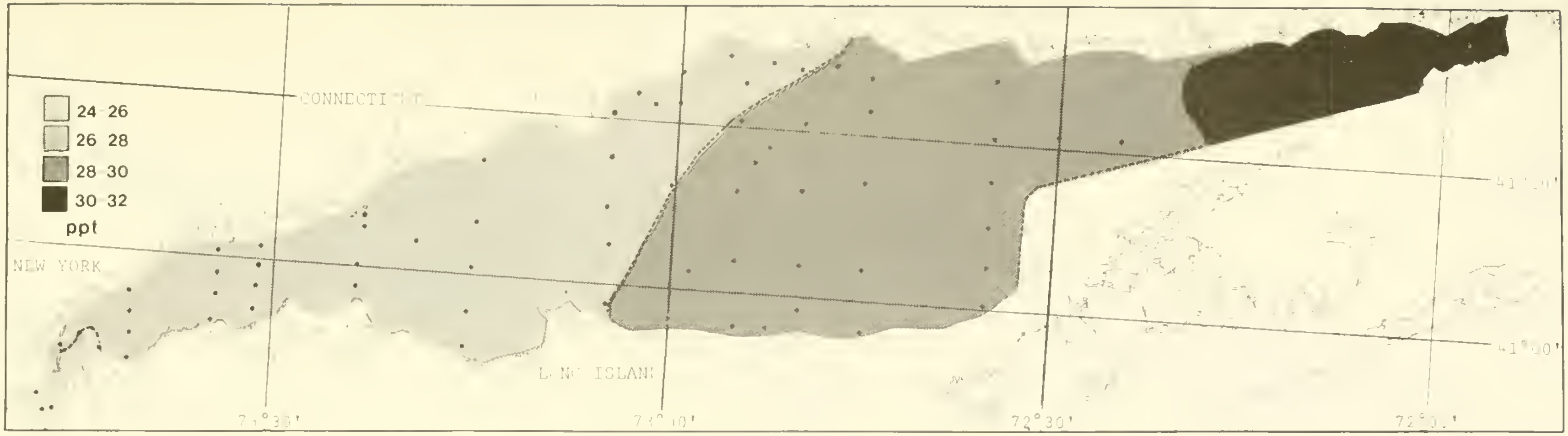


Figure 12.--Surface salinity, Long Island Sound, September 1973.

Figure 13.--Bottom salinity, Long Island Sound, September 1973.

Figure 11.—Surface ammonium, Long Island Sound, summer 1972.

Figure 15.—Bottom ammonium, Long Island Sound, summer 1972.

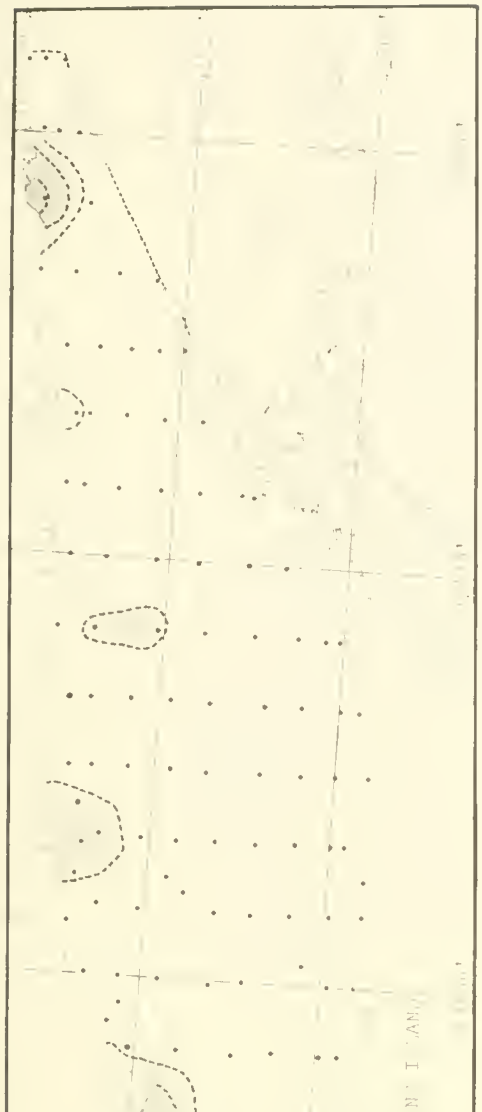


Figure 16.—Surface nitrate, Long Island Sound, summer 1972.

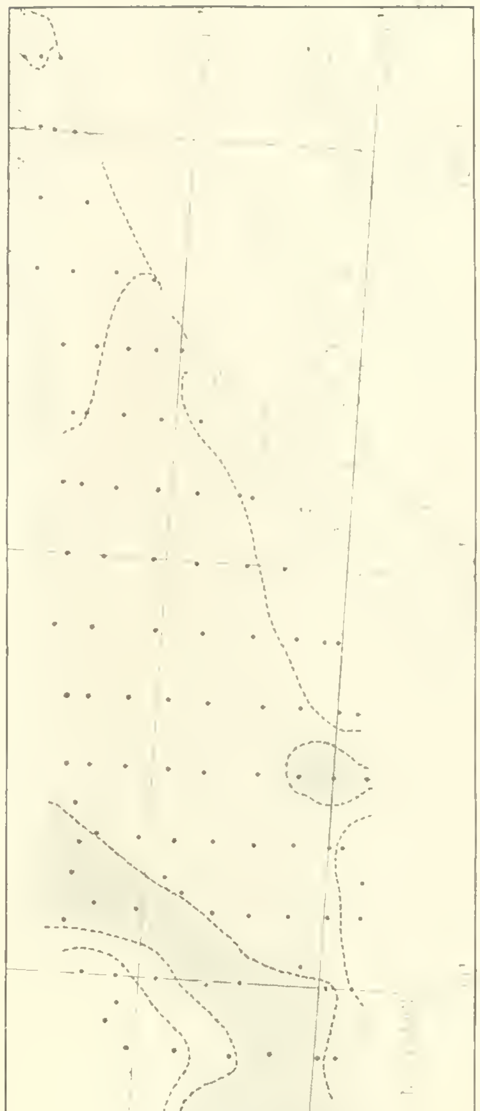


Figure 17.—Bottom nitrate, Long Island Sound, summer 1972.

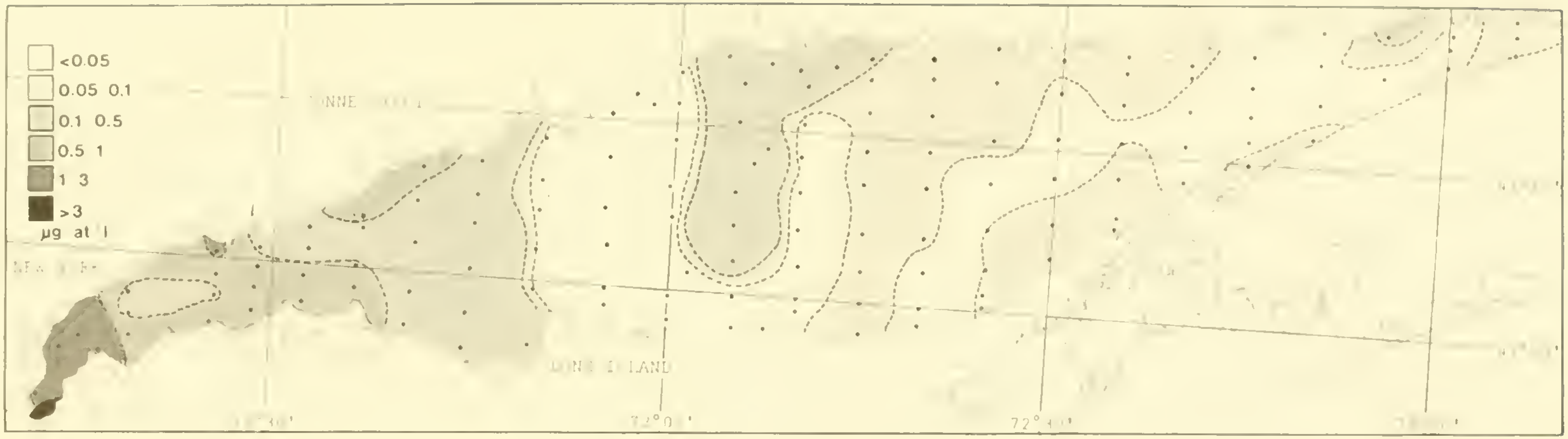


Figure 18.—Surface nitrite, Long Island Sound, summer 1972.

Figure 19.—Bottom nitrite, Long Island Sound, summer 1972.

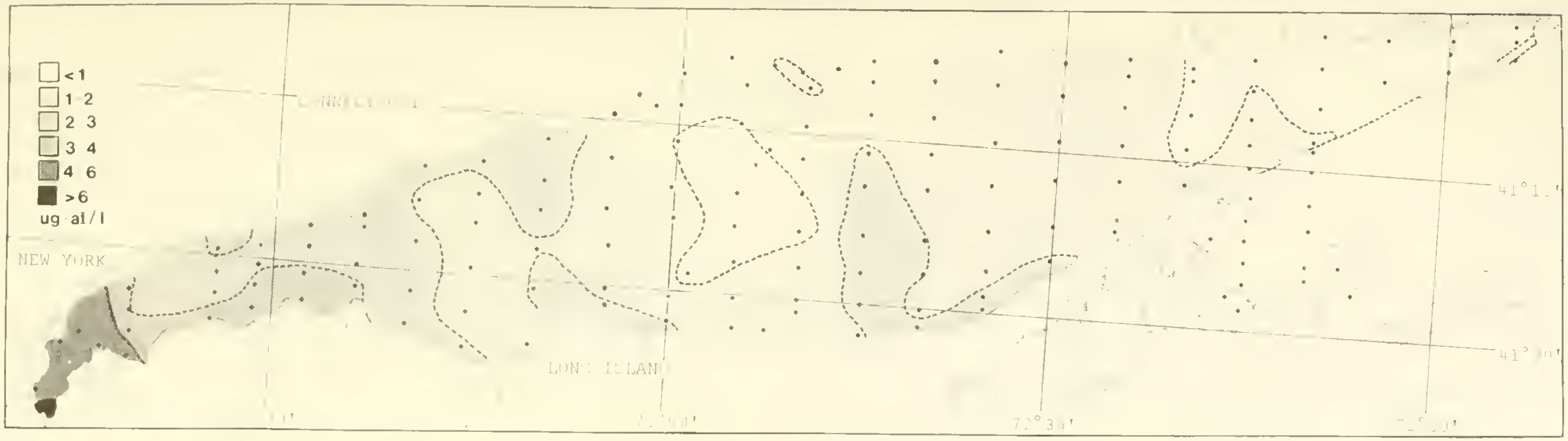


Figure 20.—Surface orthophosphorus, Long Island Sound, summer 1972.

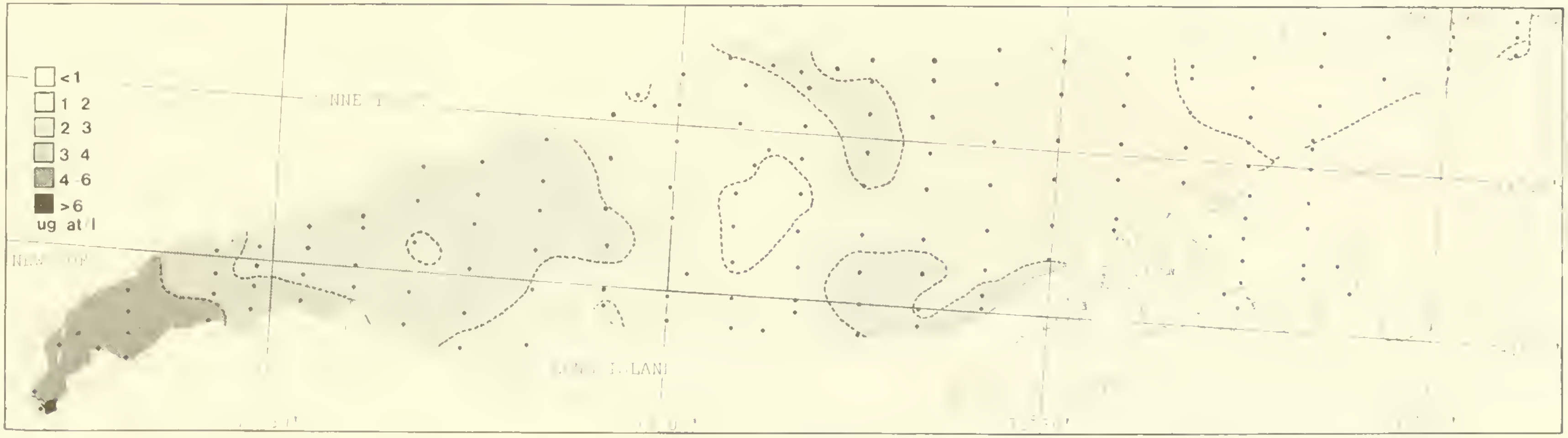


Figure 21. Bottom orthophosphorus, Long Island Sound, summer 1972.

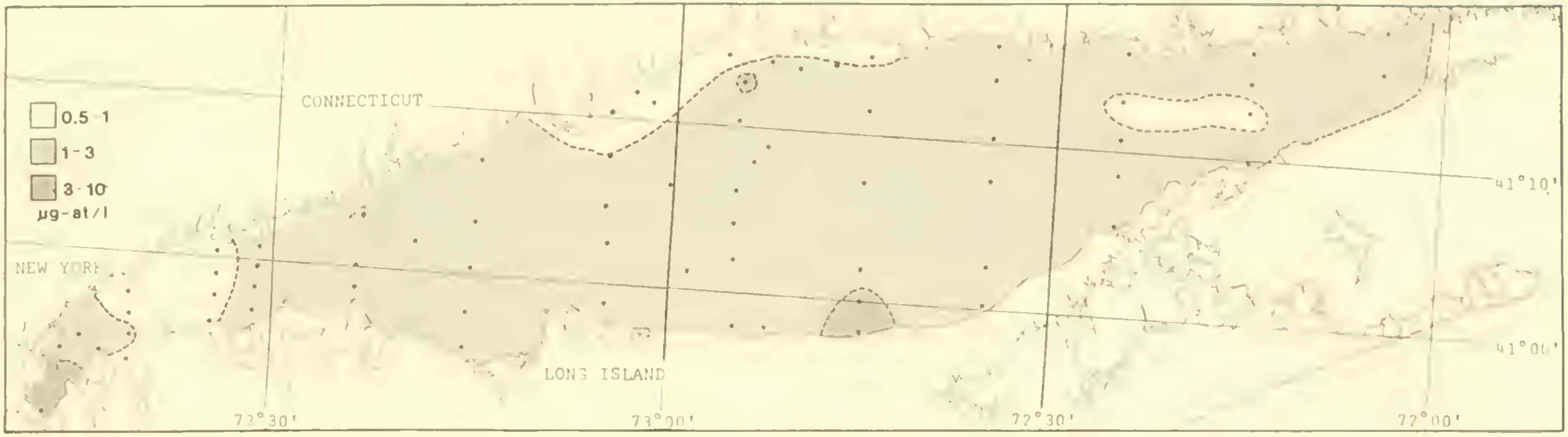


Figure 22.—Surface ammonium, Long Island Sound, April 1973.

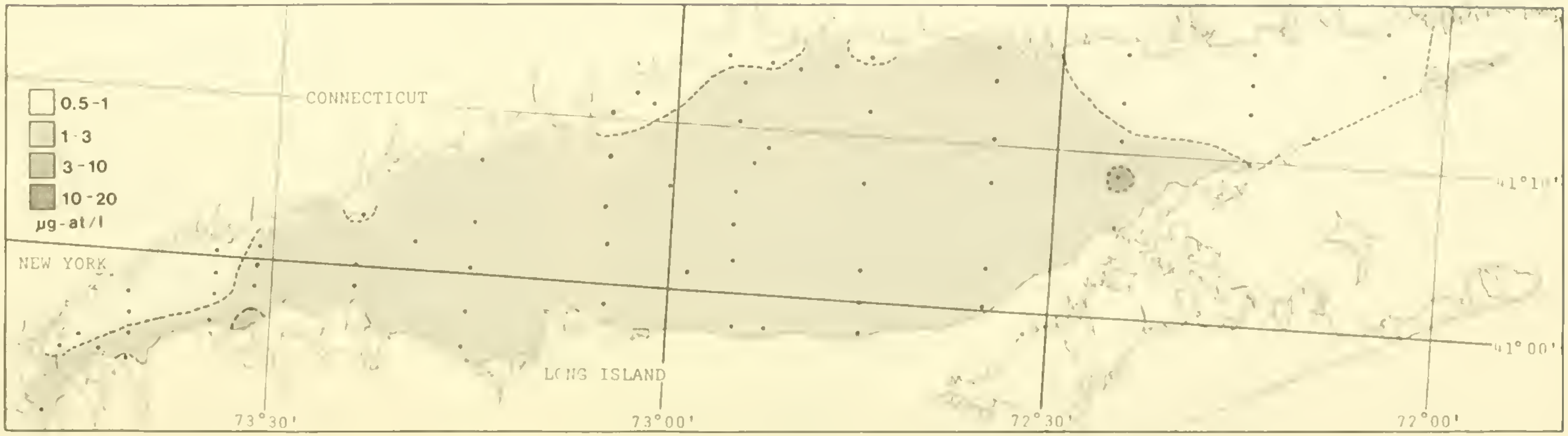


Figure 23.—Bottom ammonium, Long Island Sound, April 1973.

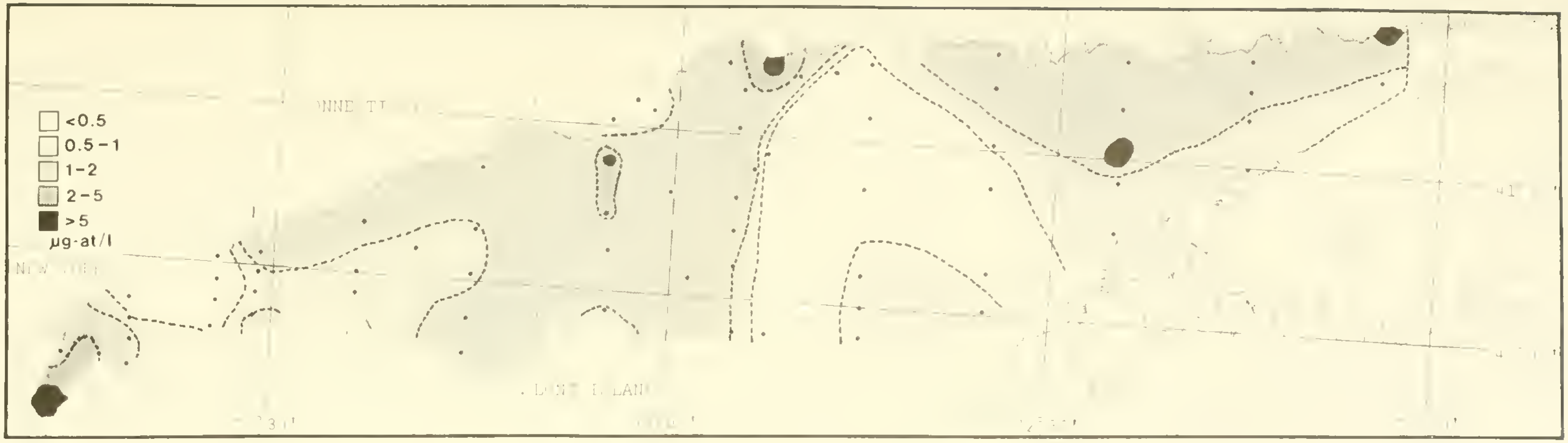


Figure 24.—Surface nitrate, Long Island Sound, April 1973.

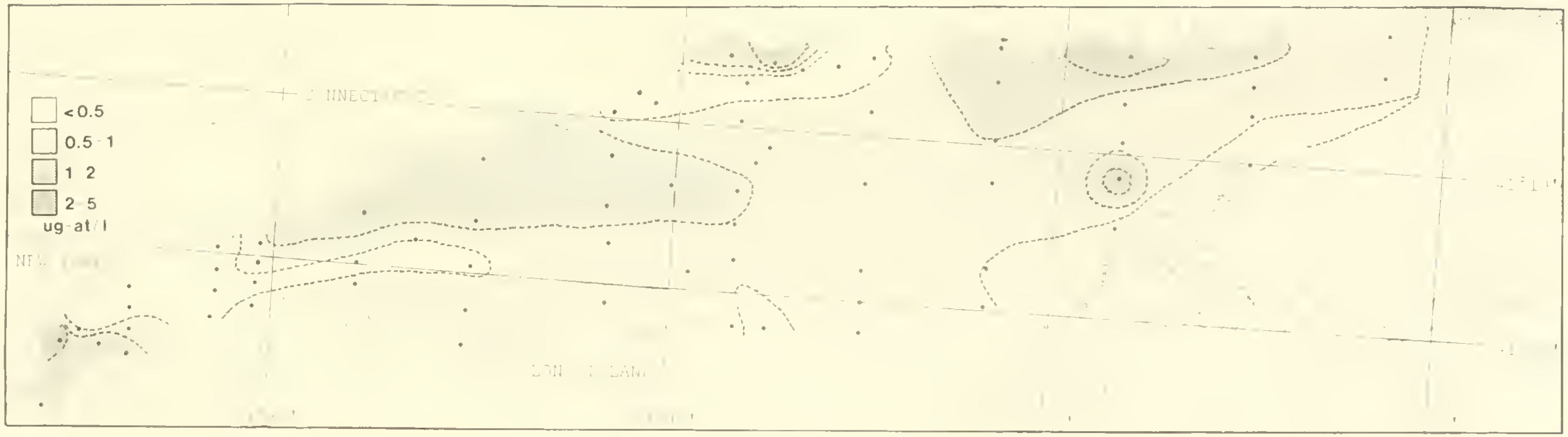


Figure 25.—Bottom nitrate, Long Island Sound, April 1973.

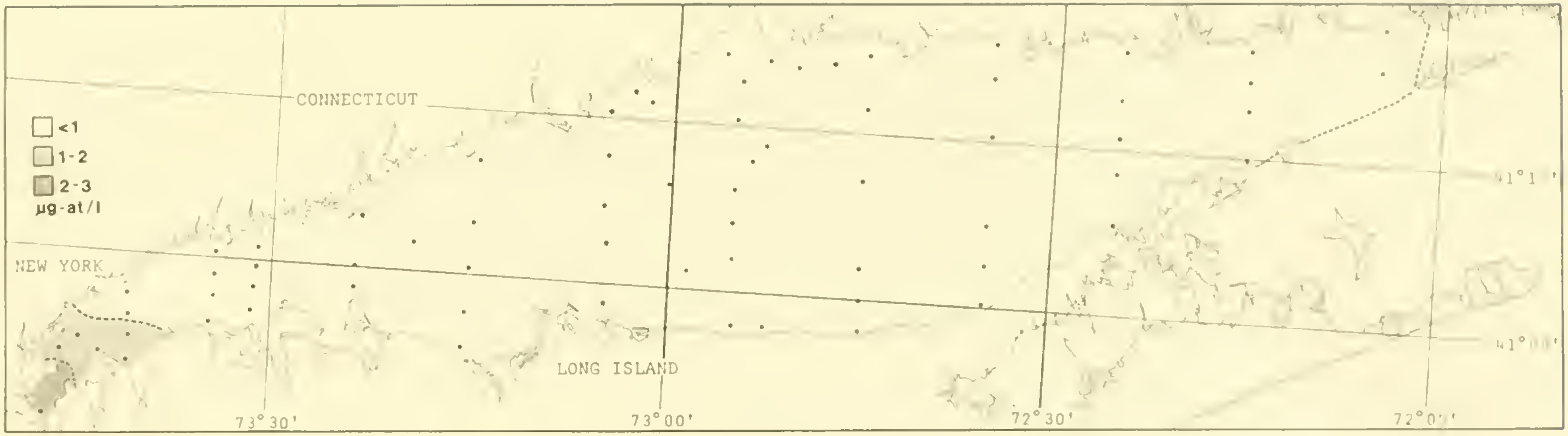


Figure 26.—Surface orthophosphorus, Long Island Sound, April 1973.

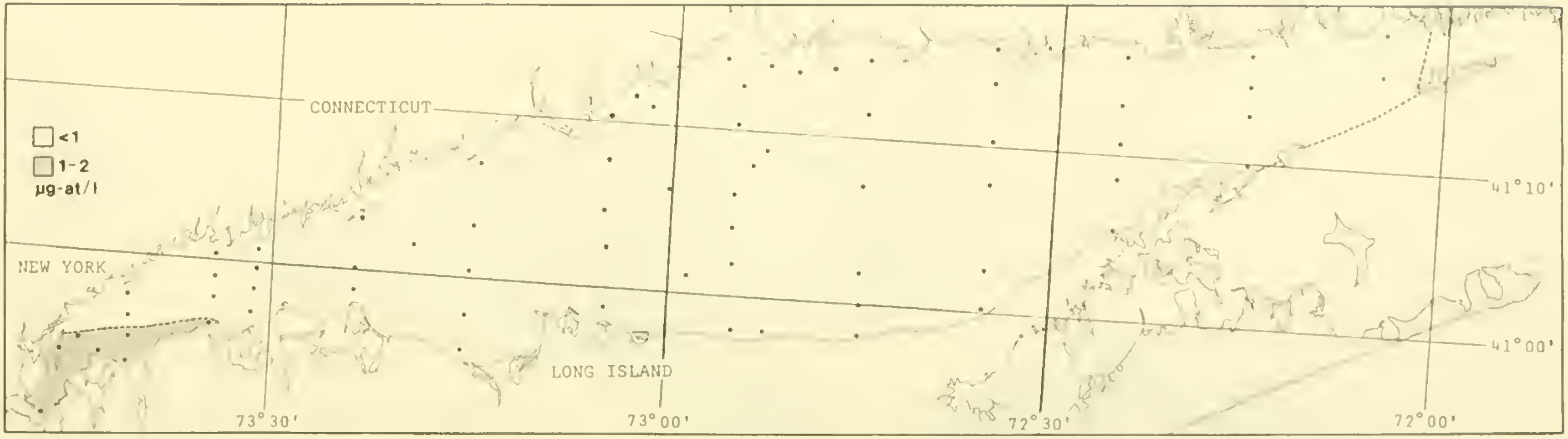
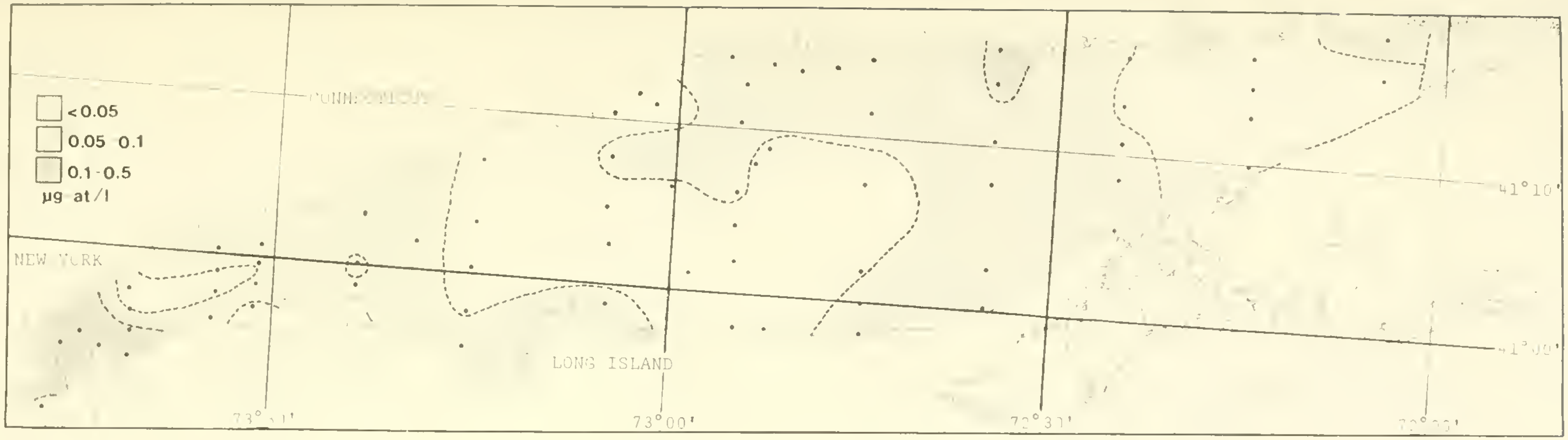


Figure 27.—Bottom orthophosphorus, Long Island Sound, April 1973.



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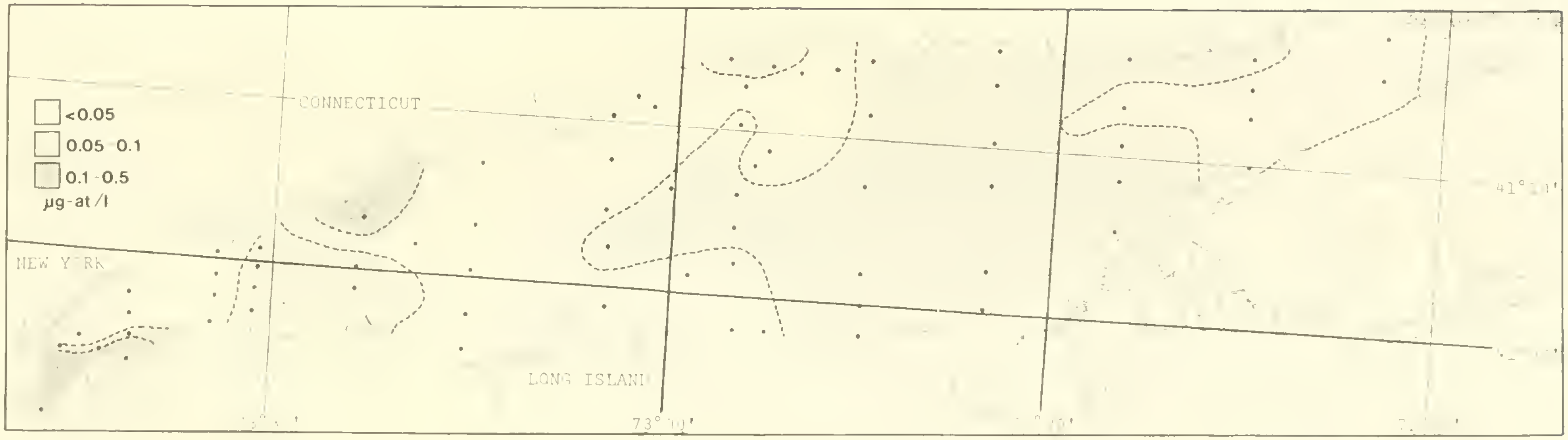


Figure 29.—Bottom nitrite, Long Island Sound, April 1973.

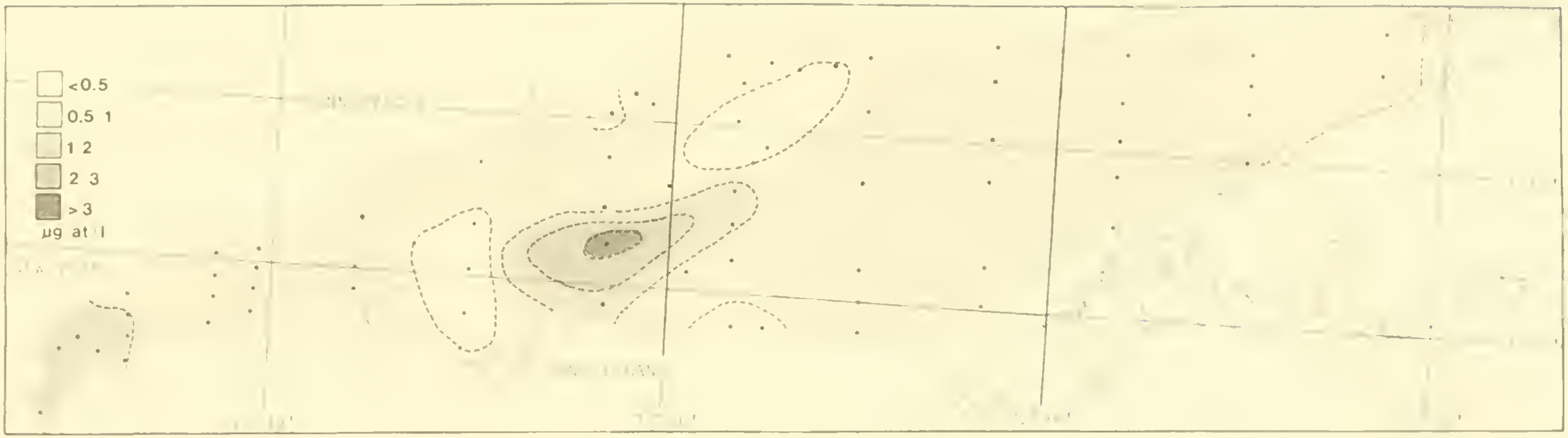


Figure 30. Surface urea, Long Island Sound, April 1973.

Figure 31. Bottom urea, Long Island Sound, April 1973.

Figure 32.—Surface dissolved oxygen, Long Island Sound, summer 1972.

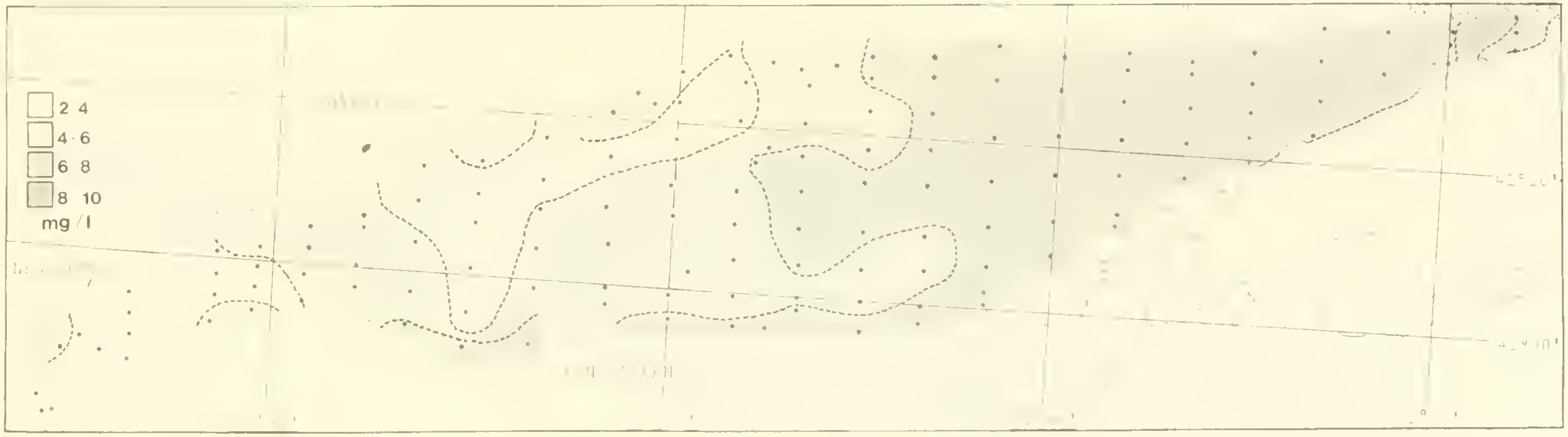
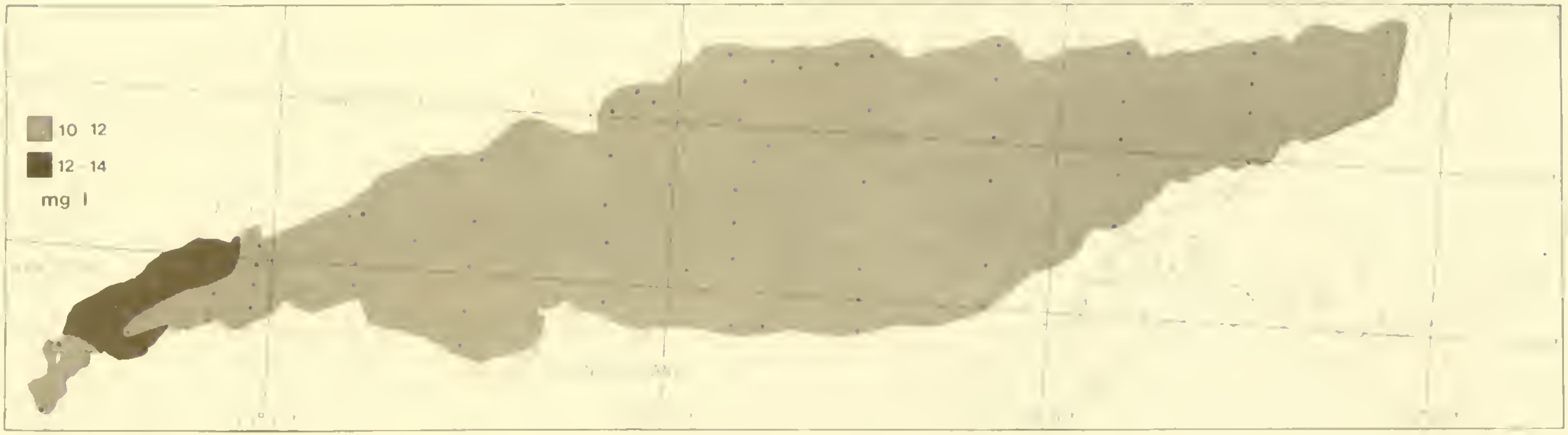


Figure 33. Bottom dissolved oxygen, Long Island Sound, summer 1972.



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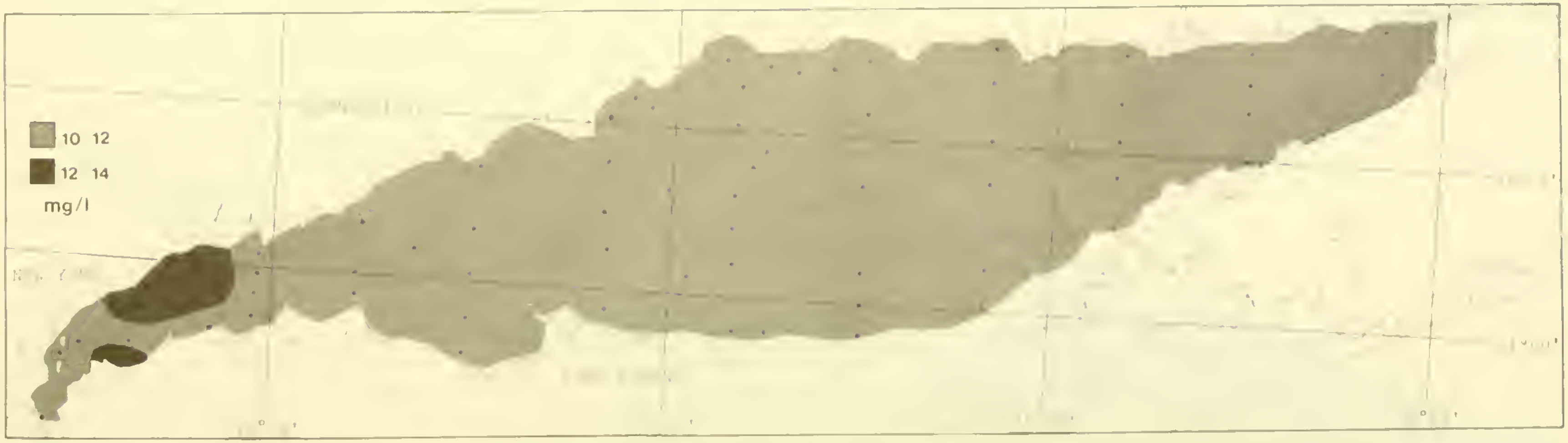

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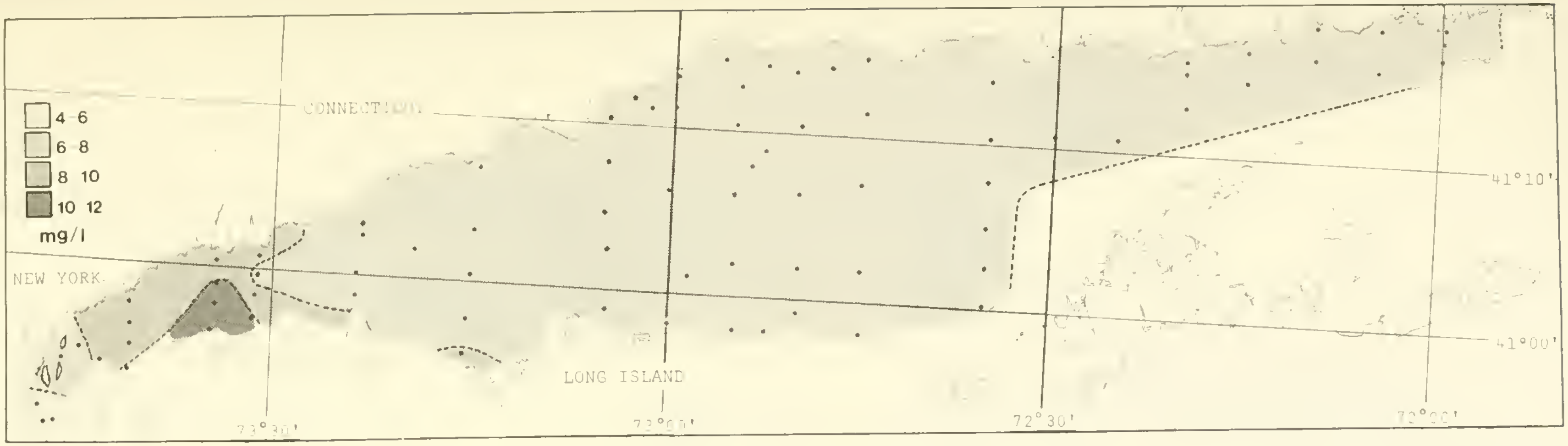

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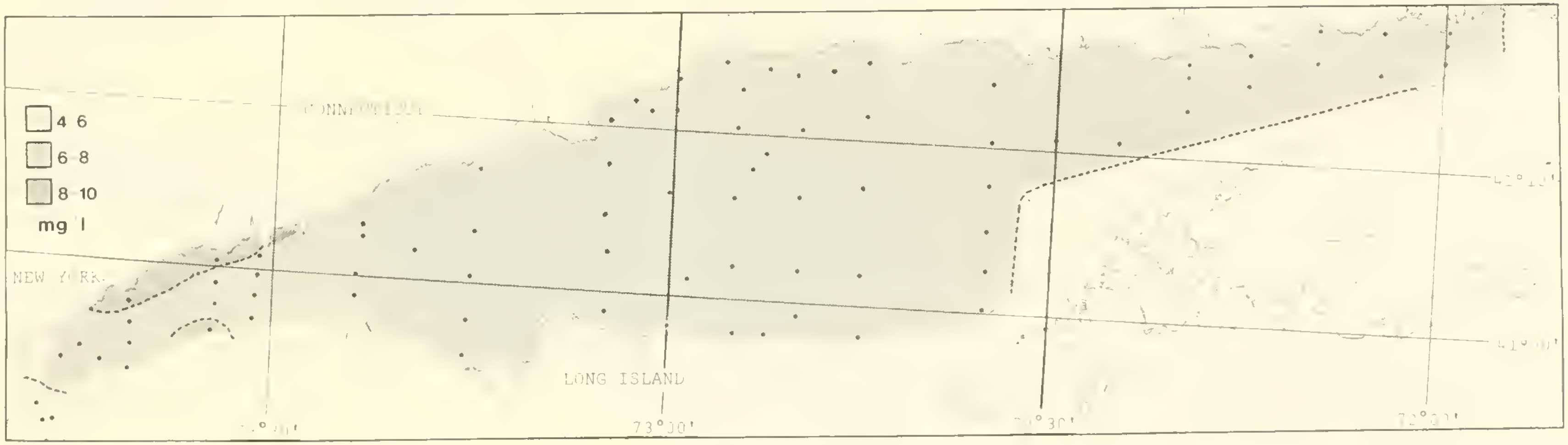

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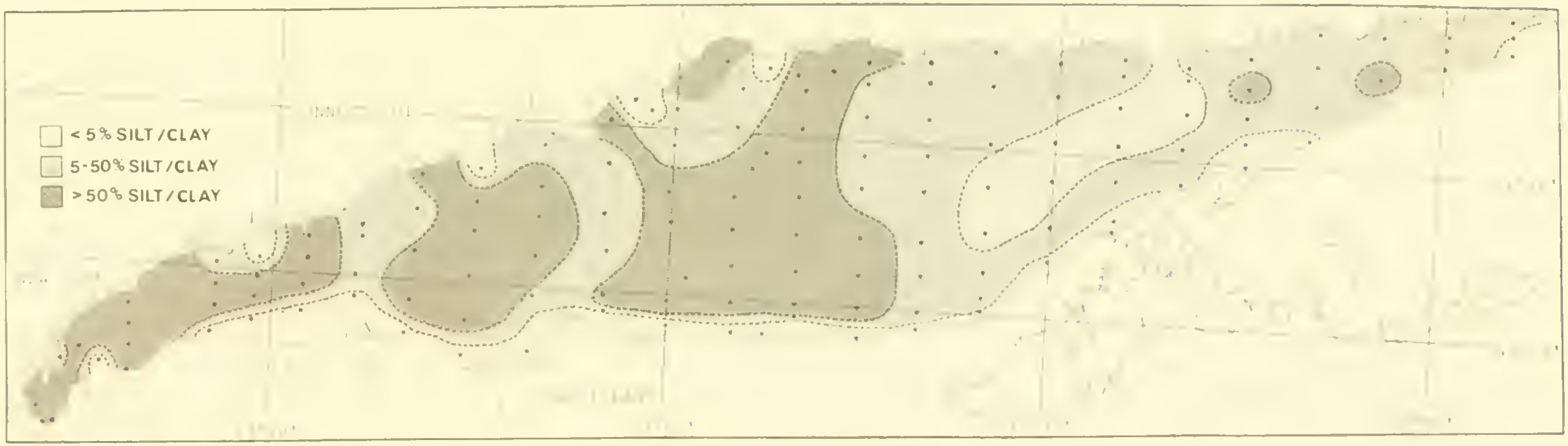
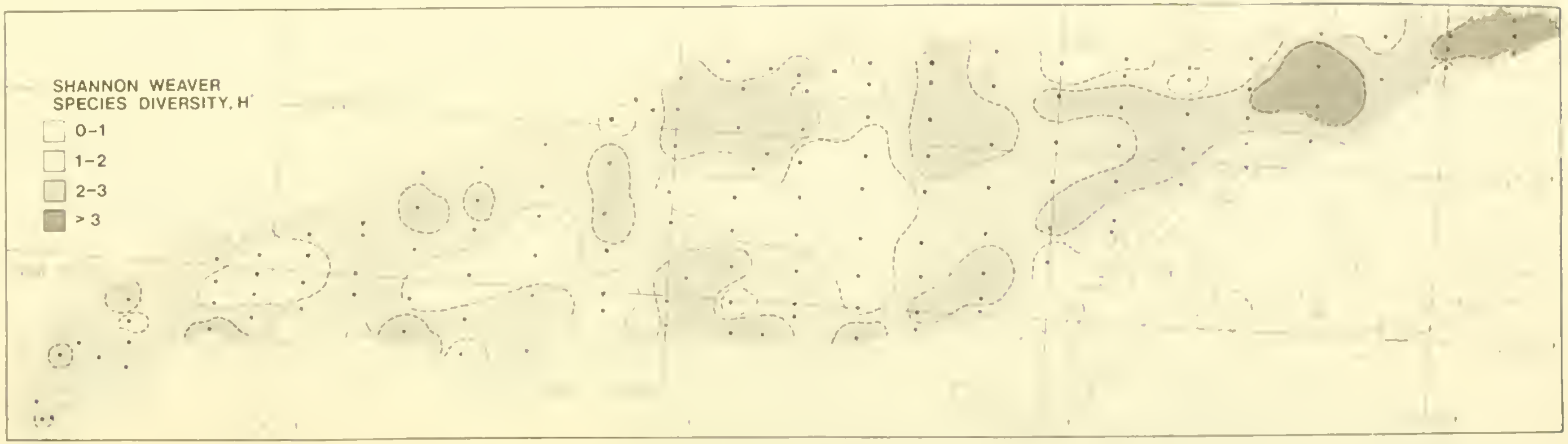


Figure 38.—Distribution of silts and clays (< 62μm) in surface sediments, Long Island Sound, summer 1972.



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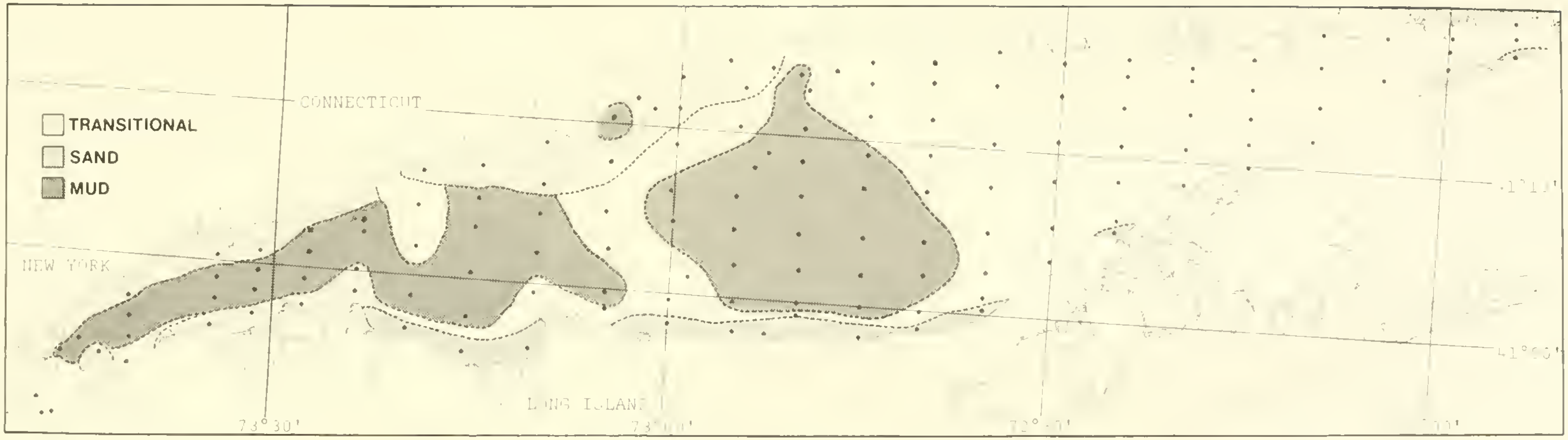

Figure 10.—Distribution of mud, sand, and transitional faunal assemblages, Long Island Sound, summer 1972.

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