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Environmental Baselines in
Long Island Sound, 1972-73

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

December 1979

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National Oceanic and Atmospheric Administration
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National Oceanic and Atmospheric Administration

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R. N. REID, A. B. FRAME, and A. F. DRAXLER¹

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 tem-

perature, 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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Table 1. Sampling locations and depths, Long Island Sound, 1952-73.

Stn	Latitude-Longitude-Depth			Stn	Latitude-Longitude-Depth			Stn	Latitude-Longitude-Depth			Stn	Latitude-Longitude-Depth		
	N	W	(m)		N	W	(m)		N	W	(m)		N	W	(m)
1	40°40.1	73°47.0	0.1	42	40°59.2	73°19.0	25.9	8	41°11.4	72°45.0	11.9	12	41°18.1	72°20.0	42.7
2	40°45.0	73°41.1	0.5	43	41°55.8	73°16.0	2.4	84	41°11.7	72°45.0	18.3	124	41°10.7	72°29.0	25.9
	40°45.0	73°39.0	4.0	44	41°10.4	73°05.0	6.1	85	41°09.1	72°45.0	27.5	125	41°08.4	72°29.0	6.1
3	41°52.8	73°46.1	9.2	47	41°07.8	73°05.0	12.2	86	41°06.0	72°45.0	28.0	126	41°17.0	72°15.0	4.6
4	41°52.8	73°40.0	18.0	46	41°04.9	73°05.2	21.9	87	41°04.2	72°47.0	29.0	127	41°15.8	72°15.0	25.9
5	41°52.8	73°43.4	4.0	47	41°02.8	73°05.0	30.5	88	41°02.0	72°45.0	33.0	128	41°13.4	72°15.0	37.7
	41°52.8	73°42.4	6.1	48	41°00.2	73°05.0	36.6	89	41°00.2	72°45.0	25.0	129	41°11.2	72°15.0	39.7
8	40°57.2	73°41.0	17.0	49	40°59.1	73°05.0	2.4	90	41°58.4	72°45.0	17.5	130	41°09.7	72°15.0	9.2
9	40°57.4	73°41.0	10.7	50	41°11.0	73°03.2	7.0	91	40°44.9	72°40.0	4.0	131	41°18.2	72°19.0	9.2
	40°57.8	73°41.0	7.0	51	41°11.0	73°01.8	9.2	92	41°11.0	72°40.0	21.4	132	41°16.2	72°19.0	24.4
11	40°57.8	73°37.0	17.1	52	41°11.1	73°00.0	7.6	93	41°11.5	72°40.0	27.7	133	41°14.0	72°19.0	54.9
12	40°58.7	73°36.0	18.0	53	41°11.0	73°00.0	10.4	94	41°09.1	72°40.0	27.7	134	41°11.5	72°19.0	6.1
	40°59.0	73°34.0	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°33.0	14.6	55	41°06.2	73°00.2	22.0	96	41°04.2	72°40.0	24.4	136	41°15.7	72°05.0	21.4
17	41°00.0	73°30.0	6.1	56	41°04.6	73°00.0	23.0	97	41°02.1	72°40.0	22.0	138	41°18.4	72°00.0	4.6
19	40°59.8	73°27.0	30.7	57	41°01.4	72°58.6	30.5	98	41°00.2	72°40.0	11.7	139	41°17.5	72°00.0	21.4
20	40°57.7	73°27.0	19.8	58	41°00.1	73°00.0	21.9	99	40°59.0	72°40.0	4.0	140	41°16.7	72°00.0	4.6
25	40°55.8	73°21.7	15.8	59	40°58.6	73°00.0	6.1	100	41°15.8	72°35.0	4.0	141	41°15.5	71°55.0	4.6
26	41°02.0	73°28.1	6.1	60	41°14.4	72°56.6	4.6	101	41°11.8	72°35.0	11.7	142	41°18.0	71°55.0	15.4
29	41°08.8	73°28.1	21.4	61	41°12.6	72°55.0	1.2	102	41°10.2	72°35.0	21.7	143	41°17.8	71°55.0	6.1
31	41°58.4	73°28.0	21.4	62	41°10.0	72°55.0	10.0	103	41°07.8	72°35.0	21.4	144	41°07.0	72°17.4	3.7
32	41°59.0	73°28.0	6.1	63	41°06.4	72°55.0	25.0	104	41°04.9	72°35.0	21.4	145	41°08.0	72°17.0	4.6
33	41°59.0	73°24.0	6.1	64	41°04.0	72°55.0	28.1	105	41°02.7	72°35.0	18.0	146	41°06.8	72°15.0	8.8
34	41°02.7	73°24.0	11.0	65	41°02.2	72°55.0	6.0	106	41°01.4	72°35.0	15.0	147	41°05.5	72°15.0	6.4
	41°03.0	73°22.0	17.7	66	41°00.0	72°55.0	21.4	107	41°00.4	72°35.0	4.0	148	41°04.1	72°15.0	4.9
36	40°58.7	73°22.0	6.1	67	40°58.4	72°55.0	9.1	108	41°01.2	72°35.0	4.0	149	41°02.9	72°15.0	4.6
37	40°58.0	73°19.5	17.0	68	40°57.0	72°52.9	10.0	109	41°01.0	72°35.0	21.4	150	41°02.2	72°16.3	4.6
38	41°03.2	73°16.5	10.7	69	41°00.0	72°52.8	18.0	110	41°00.8	72°35.0	10.7	158	41°01.2	72°15.0	3.1
39	41°03.0	73°19.5	10.7	70	41°08.0	72°51.8	21.3	111	41°08.2	72°35.0	20.0	159	41°11.1	72°10.0	4.6
40	40°58.0	73°16.0	16.8	71	40°57.8	72°52.6	6.1	112	41°07.0	72°35.0	20.0	160	41°06.2	72°10.0	22.9
41	40°59.0	73°16.0	11.0	72	41°10.6	72°53.6	8.7	113	41°05.4	72°35.0	18.0	161	41°08.0	72°10.0	9.2
42	41°06.9	73°15.0	15.5	73	41°12.8	72°50.0	12.2	114	41°04.0	72°35.0	15.5	162	41°06.7	72°10.0	7.6
	41°06.7	73°15.0	17.7	74	41°10.6	72°50.0	16.8	115	41°14.0	72°35.0	17.0	163	41°04.4	72°10.0	7.6
44	41°02.7	73°17.0	21.3	75	41°08.6	72°50.0	24.4	116	41°13.1	72°35.0	24.4	164	41°03.3	72°10.0	4.6
	40°57.8	73°15.0	21.9	76	41°06.4	72°50.0	29.0	117	41°10.8	72°35.0	10.7	165	41°04.1	72°07.2	7.6
46	41°05.0	73°17.0	18.8	77	41°04.2	72°50.0	31.1	118	41°08.4	72°35.0	20.0	166	41°02.7	72°08.4	3.7
47	41°05.0	73°15.0	21.4	78	41°02.2	72°50.0	8.1	119	41°06.1	72°35.0	16.8	167	41°16.3	72°20.4	6.1
48	41°08.7	73°16.0	6.1	79	41°00.4	72°50.6	31.4	120	41°05.5	72°35.0	4.0	168	41°18.2	72°21.0	4.6
49	41°06.2	73°16.0	12.2	80	40°59.3	72°51.0	6.1	121	41°15.7	72°29.0	10.7	169	41°20.2	72°21.5	4.6
50	41°03.8	73°15.0	21.4	81	41°13.0	72°46.4	12.2	122	41°14.9	72°29.0	10.2				
51	41°01.5	73°16.0	29.0	82	41°14.0	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 analyzed using the naphthylendiamine-sulfanilamide system with cadmium reduction of nitrate after Wood et al. (1965). The ammonium analyses, which were based on the phenylhypochlorite 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 thio-

micarbide 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 m² 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 transferred 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 majority of species and individuals collected. McColl (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 m² 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 μ m screen, with retained materials then sieved through a series of 12 screens with meshes from 4 mm to 62 μ m. Pipette analysis was used to determine the clay and fine-and coarse-silt fractions of the <62 μ m 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 (μ gat/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 μ gat/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 μ gat/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 $\mu\text{g}/\text{liter}$) 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 $\mu\text{g}/\text{liter}$ 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 $\mu\text{g}/\text{liter}$.

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 $\mu\text{g}/\text{liter}$ 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 $\mu\text{g}/\text{liter}$ 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 $\mu\text{g}/\text{liter}$ 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 Service¹) 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 ($\leq 5\%$ 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.

¹National 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 almost 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).

Station	Cruise			Station	Cruise			Station	Cruise			Station	Cruise		
	1	2	3		1	2	3		1	2	3		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	PARAONIDAE	FLABELLIGERIDAE	MONTACUTIDAE
POLYNOIDAE	<i>Aricidea catherinae</i>	<i>Pherusa affinis</i>	<i>Mysella planulata</i>
<i>Harmothoe extenuata</i>	<i>Paraonis gracilis</i>	<i>Brada granosa</i>	CARDIIDAE
<i>Harmothoe imbricata</i>	<i>Paraonis lyra</i>	<i>Brada villosa</i>	<i>Cerastoderma pinnulatum</i>
<i>Lepidonotus squamatus</i>	SPIONIDAE	SABELLIDAE	VENERIDAE
<i>Lepidonotus sublevis</i>	<i>Polydora ligni</i>	<i>Potamilla reniformis</i>	<i>Mercenaria mercenaria</i>
SIGALIONIDAE	<i>Polydora u ebsteri</i>	<i>Sabella microphthalmia</i>	<i>Pitar morrhuaana</i>
<i>Sthenelais boa</i>	<i>Polydora socialis</i>	<i>Euchone elegans</i>	<i>Gemma gemma</i>
<i>Sthenelais limicola</i>	<i>Polydora colania</i>	<i>Laonome kroeyeri</i>	PETRICOLIDAE
<i>Sigalon arenicola</i>	<i>Polydora quadrilobata</i>	SERPULIDAE	<i>Petricola pholadiformis</i>
<i>Pholoe minuta</i>	<i>Prionospio steenstripi</i>	<i>Hydroides dianthus</i>	TELLINIDAE
PHYLLODOCIDAE	<i>Scolecopides viridis</i>	GASTROPODA	<i>Tellina agilis</i>
<i>Eteone heteropoda</i>	<i>Scolelepis (Scolelepis) squamata</i>	CALPTRAEIDAE	PERIPLOMATIDAE
<i>Eumida sanguinea</i>	<i>Scolelepis (Nerinides) # 1</i>	<i>Crepidula fornicata</i>	<i>Periploma papyratium</i>
<i>Paranaitis speciosa</i>	<i>Spio filicornis</i>	<i>Crepidula plana</i>	SOLENIDAE
<i>Phyllodoce arenae</i>	<i>Spiophanes bombyx</i>	NATICIDAE	<i>Ensis directus</i>
<i>Phyllodoce mucosa</i>	<i>Streblospio benedicti</i>	<i>Polinices duplicatus</i>	MACTRIDAE
<i>Phyllodoce maculata</i>	<i>Pygospio elegans</i>	<i>Lunatia heros</i>	<i>Spisula solidissima</i>
HESIONIDAE	<i>Spiochaetopterus oculatus</i>	<i>Natica pusilla</i>	<i>Mulinia lateralis</i>
<i>Podarke obscura</i>	<i>Boccardia #1</i>	NATICID #1	HIAPELLIDAE
PILARGIDAE	SABELLARIIDAE	MURICIDAE	<i>Hiatella arctica</i>
<i>Cabira incerta</i>	<i>Sabellaria vulgaris</i>	<i>Eupleura caudata</i>	MYACIDAE
<i>Sigambra tentaculata</i>	ONUPHIDAE	<i>Urosalpinx cinerea</i>	<i>Mya arenaria</i>
SYLLIDAE	<i>Diopatra cuprea</i>	COLUMBELLIDAE	CORBULIDAE
<i>Proceraea cornuta</i>	EUNICIDAE	<i>Anachis translirata</i>	<i>Corbula contracta</i>
<i>Autolytus verriilli</i>	<i>Morphysa sanguinea</i>	<i>Mitrella lunata</i>	LYONSIIDAE
<i>Autolytus #1</i>	<i>Morphysa belli</i>	MELONGENIDAE	<i>Lyonsia hyalina</i>
<i>Odontosyllis fulgurans</i>	LUMBRINERIDAE	<i>Busycon canaliculatum</i>	PANDORIDAE
<i>Brania clavata</i>	<i>Lumbrineris tenuis</i>	NASSARIIDAE	<i>Pandora gouldiana</i>
<i>Brania #2</i>	<i>Lumbrineris fragilis</i>	ACTEONIDAE	PYCNOGONIDA
<i>Exogone dispar</i>	<i>Ninoe nigripes</i>	<i>Acteon punctostriatus</i>	PHOXICHLIDIIDAE
<i>Exogone naidina</i>	ARABELLIDAE	SCAPHANDRIDAE	<i>Anaplodactylus lentus</i>
<i>Parapionosyllis longicirrata</i>	<i>Arabella tricolor</i>	<i>Cylichna oryza</i>	AMMOTHEIDAE
<i>Syllides #1</i>	<i>Drilonereis longa</i>	PHILINIDAE	<i>Achelia spinosa</i>
<i>Syllides #2</i>	<i>Notocirrus spiniferus</i>	<i>Philine sinuata</i>	NYMPHONIDAE
<i>Typosyllis #1</i>	DORVILLEIDAE	ACTEOCINIDAE	<i>Nymphon grossipes</i>
<i>Syllis gracilis</i>	<i>Schistomeringos longicornis</i>	<i>Acteocina canaliculata</i>	CUMACEA
<i>Syllis spongiphila</i>	<i>Schistomeringos caeca</i>	PYRAMIDELLIDAE	LEUCONIDAE
<i>Sphaerosyllis erinaceus</i>	<i>Protodorvillea gaspiensis</i>	<i>Odotomia #1</i>	<i>Leucon americanus</i>
NEREIDAE	ORBINIIDAE	<i>Turbonilla elegantula</i>	<i>Eudorella pusilla</i>
<i>Nereis acuminata</i>	<i>Orbinia ornata</i>	<i>Turbonilla sumneri</i>	DIASTYLIDAE
<i>Nereis grayi</i>	<i>Orbinia suoni</i>	ONCHIDORIDAE	<i>Oxyurostylis smithi</i>
<i>Nereis succinea</i>	<i>Scoloplos armiger</i>	<i>Onchidoris aspersa</i>	<i>Diastylis sculpta</i>
<i>Nereis zonata</i>	<i>Haploscoloplos fragilis</i>	PELECYPODA	TANAIDACEA
NEPHTYIDAE	<i>Haploscoloplos robustus</i>	SOLEMYIDAE	PARATANAIDAE
<i>Nephtys buccera</i>	CIRRATULIDAE	<i>Solemya velum</i>	<i>Leptognatha caeca</i>
<i>Nephtys incisa</i>	<i>Cirratulus grandis</i>	NUCULIDAE	ISOPODA
<i>Nephtys picta</i>	<i>Tharyx annulosus</i>	<i>Nucula proxima</i>	IDOTEIDAE
GLYCERIDAE	<i>Tharyx acutus</i>	<i>Nucula delphinodonta</i>	<i>Chiridotea tuftsi</i>
<i>Glycera americana</i>	<i>Dodecaceria coralii</i>	<i>Yoldia limatula</i>	<i>Erichsonella filiformis</i>
<i>Glycera dibranchiata</i>	<i>Caulieriella cf killariensis</i>	ARCIDAE	<i>Edotea triloba</i>
GONIADIDAE	OWENIIDAE	<i>Anadara transversa</i>	ANTHURIIDAE
<i>Goniadella gracilis</i>	<i>Owenia fusiformis</i>	MYTILIDAE	<i>Cyathura polita</i>
SCALIBREGMIDAE	PECTINARIIDAE	<i>Mytilus edulis</i>	<i>Ptilanthura tenuis</i>
<i>Scalibregma inflatum</i>	<i>Pectinaria gouldii</i>	<i>Modiolus modiolus</i>	<i>Ananthura #1</i>
OPHELIDAE	AMPHARETIDAE	<i>Musculus corrugatus</i>	CIROLANIDAE
<i>Travitia carnea</i>	<i>Asabellides oculata</i>	<i>Crenella glandula</i>	<i>Cirolana polita</i>
CAPITELLIDAE	<i>Melinna cristata</i>	ANOMIIDAE	<i>Cirolana burbancki</i>
<i>Capitella capitata</i>	<i>Ampharete arctica</i>	<i>Anomia simplex</i>	AMPHIPODA
<i>Heteromastus filiformis</i>	<i>Amage auricula</i>	OSTREIDAE	AMPELISCIDAE
<i>Notomastus luridus</i>	TEREBELLIDAE	<i>Crassostrea virginica</i>	<i>Ampelisca abdita</i>
<i>Mediomastus ambiseta</i>	<i>Loimia medusa</i>	ASTARTIDAE	<i>Ampelisca vadorum</i>
MALDANIDAE	<i>Pista cristata</i>	<i>Astarte castanea</i>	<i>Ampelisca verriilli</i>
<i>Clymenella zonalis</i>	<i>Pista maculata</i>	<i>Astarte undata</i>	<i>Ampelisca macrocephala</i>
<i>Clymenello torquata</i>	<i>Polycirrus eximius</i>	<i>Astarte quadrans</i>	AMPITHOIDAE
<i>Asychis elongata</i>	<i>Polycirrus medusa</i>	CARDITIDAE	<i>Ampithoe longimana</i>
<i>Nicomache lumbricalis</i>	<i>Polycirrus phosphoreus</i>	<i>Cyclocardia borealis</i>	AORIDAE
	<i>Nicolea venustula</i>		<i>Lembos websteri</i>

Table 3.—Continued.

<i>Leptocherius pinguis</i>	PHOXOCEPHALIDAE
<i>Microdeutopus gryllotalpa</i>	<i>Paraphoxus spinosus</i>
<i>Microdeutopus anomalis</i>	<i>Phoxocephalus holbolli</i>
<i>Pseudunciola obliquua</i>	<i>Trichophoxus epistomus</i>
COROPHIIDAE	PLEUSTIDAE
<i>Cerapus tubularis</i>	<i>Stenopleustes gracilis</i>
<i>Corophium acherusicum</i>	<i>Stenopleustes inermis</i>
<i>Corophium tuberculatum</i>	<i>Pleusymtes glaber</i>
<i>Corophium crassicoxae</i>	CAPRELLIDAE
<i>Corophium bonelli</i>	<i>Aegnina longicornis</i>
<i>Erichthonius brasiliensis</i>	<i>Caprella unica</i>
<i>Unciola inermis</i>	<i>Caprella penantis</i>
<i>Unciola irrorata</i>	<i>Paracaprella tenuis</i>
<i>Unciola serrata</i>	<i>Luconacia incerta</i>
<i>Unciola dissimilis</i>	DECAPODA
GAMMARIDAE	HIPPOLYTIDAE
<i>Elasmopus levii</i>	<i>Eualus pustolus</i>
<i>Gammarus mucronatus</i>	CRANGONIDAE
HAUSTORIIDAE	<i>Crangon septemspinosa</i>
<i>Acanthohaustorius millsi</i>	THALASSINIDEA
<i>Bathyporeia parkeri</i>	<i>Callinassa atlantica</i>
<i>Parahaustorius attenuatus</i>	<i>Axius</i> #1
<i>Parahaustorius holmesi</i>	PAGURIDAE
<i>Protohaustorius aetchmannae</i>	<i>Pagurus longicarpus</i>
<i>Protohaustorius wigleyi</i>	<i>Pagurus pollicaris</i>
<i>Acanthohaustorius</i> n. sp. #1	PORTUNIDAE
<i>Acanthohaustorius</i> n. sp. #2	<i>Orhalipes ocellatus</i>
ISAEIDAE	CANCRIDAE
<i>Photis dentata</i>	<i>Cancer borealis</i>
ISCHYRO CERIDAE	<i>Cancer irroratus</i>
<i>Jassa falcata</i>	XANTHIDAE
LILJEBORGIDAE	<i>Neopanope texana sayi</i>
<i>Listriella barnardi</i>	<i>Xanthid</i> #1
<i>Sextonia americana</i>	PINNOTHERIDAE
LYSIANASSIDAE	<i>Dissodactylus mellitae</i>
<i>Lysianassa alba</i>	<i>Pinnotheres maculatus</i>
<i>Psammoxys nobilis</i>	<i>Pinnixa</i> #1
<i>Orchomenella pinguis</i>	MAJIDAE
OEDICEROTIDAE	<i>Libinia dubia</i>
<i>Synchlidium americanum</i>	<i>Libinia emarginata</i>

The cluster analysis of 1972 faunal data revealed one large group of 43 stations (Fig. 40) with relatively homogeneous fauna (similarity $\geq 50\%$). This group occurred mostly in muddy, deepwater sediments throughout central and western LIS; 37 of the stations had $\geq 69\%$ 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 \div mean density $\times 100$) 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 indi-

cated 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 $\geq 37\%$, occurred primarily along the Long Island coast, in sandy sediments at shallow depths (Fig. 40). All stations in this group contained $\leq 3.7\%$ 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 $\geq 50\%$ 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 (m⁻²), 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			April 1973			September 1973		
	n = 3 stations			n = 13			n = 1300 samples		
	\bar{x}	CV _s	F	\bar{x}	CV	F	\bar{x}	CV _s	F
ANILHOZOANS									
<i>Coronothoassis americana</i>	14	151	44	14	128	62	78	247	56
POLYCHAETES									
<i>Nephtys incisa</i>	60	68	98	96	72	100	100	92	88
<i>Pherusa affinis</i>	50	122	77	14	105	62	45	290	50
<i>Polydora ligni</i>	157	291	74	1	350	8	2	211	19
<i>Asychis elongata</i>	18	212	56	12	120	54	7	181	31
GASTROPODS									
<i>Nassarius trivittatus</i>	101	77	98	61	104	85	55	360	94
<i>Cyathina oriza</i>	31	139	78	0		0	0		0
<i>Acteocina canaliculata</i>	170	82	93	12	288	23	0		0
PELECYPODS									
<i>Nacella proxima</i>	48	222	70	402	241	62	24	210	81
<i>Yoldia smutaria</i>	191	155	93	4	134	38	51	267	56
<i>Pitar orbicula</i>	67	72	95	29	170	62	4	143	38
<i>Macoma lateralis</i>	8,217	61	100	710	325	54	11	250	19
<i>Lionis rhombana</i>	29	136	61	0		0	2	395	6
<i>Pandora gouldiana</i>	47	169	61	4	295	20	0		0
CRUSTACEANS									
<i>Oxyurostylis smithi</i>	17	139	63	0		0	0		0
<i>Ampelisca abdita</i>	53	132	70	0		0	26	275	25
<i>Crangon septemspinosa</i>	12	123	63	1	350	8	5	126	44
<i>Cancer irroratus</i>	7	115	54	1	350	8	1	417	6
Total individuals m ⁻²	10,400	56		1,469	181		1,263	136	
Total species	21.2	31		9.6	42		10.1	65	
Species diversity, <i>H'</i>	1.07	52		1.47	45		1.46	36	
Equitability, <i>J'</i>	0.35	51		0.67	37		0.69	33	

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 m⁻²). 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 $\geq 41\%$, 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 m⁻²; much of the decrease was due to a large reduc-

tion 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), 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.

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. manuscript, 15 p. Report to U.S. Corps of Engineers, by Yale University.

Table 5.—Average densities/m² (\bar{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 <i>n</i> = 12 stations			September 1973 <i>n</i> = 9		
	\bar{x}	CV _s ¹	F _s ¹	\bar{x}	CV _s ¹	F _s ¹
POLYCHAETES						
<i>Nephtys picta</i>	75	98	83	48	92	67
<i>Aricidea</i>						
<i>catherinae</i>	45	194	50	6	180	33
<i>Spiophanes</i>						
<i>bombyx</i>	25	133	67	207	113	78
<i>Ampharete</i>						
<i>arctica</i>	28	159	50	33	178	44
<i>Ouenia</i>						
<i>justiformis</i>	6	200	33	22	125	56
GASTROPODS						
<i>Crepidula</i>						
<i>formicata</i>	214	253	67	96	195	44
<i>Nassarius</i>						
<i>trivittatus</i>	72	81	92	88	58	100
PELECYPODS						
<i>Tellina agilis</i>	415	170	100	1,910	206	100
<i>Ensis directus</i>	122	130	100	74	155	78
<i>Spisula</i>						
<i>solidissima</i>	795	194	75	29	167	44
<i>Pandora</i>						
<i>gouldiana</i>	92	150	58	32	105	67
CRUSTACEANS						
<i>Oxyurostylis</i>						
<i>smithi</i>	38	136	58	32	93	67
<i>Ampelisca</i>						
<i>vadorum</i>	92	188	67	49	212	56
<i>Unicola irrorata</i>	34	178	67	18	156	33
<i>Paraphoxus</i>						
<i>epistomus</i>	52	159	75	89	172	44
<i>Pagurus</i>						
<i>longicarpus</i>	37	108	83	20	90	78
<i>Crangon</i>						
<i>septemspinosa</i>	5	200	25	16	107	67
Total individuals/ m ²	6,938	189		3,703	135	
Total species	23.1	48		22.9	40	
Species diversity, <i>H'</i>	1.92	39		1.93	29	
Equitability, <i>J'</i>	0.62	35		0.64	25	

¹Means for entire samples, including rarer species.

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Table 6.—Average densities/m² (\bar{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 <i>n</i> = 21 stations			September 1973 <i>n</i> = 13		
	\bar{x}	CV _s ¹	F _s ¹	\bar{x}	CV _s ¹	F _s ¹
POLYCHAETES						
<i>Pectinaria</i>						
<i>gouldi</i>	9	215	33	24	173	54
<i>Eumida</i>						
<i>sanguinea</i>	26	144	67	40	168	39
<i>Glycera</i>						
<i>americana</i>	21	115	71	45	121	69
<i>Melidomastus</i>						
<i>ambiseta</i>	175	159	71	143	257	46
<i>Polydora</i>						
<i>lignm</i>	7,131	187	95	1	360	8
<i>Streblospio</i>						
<i>benedicti</i>	1,549	138	86	14	160	54
<i>Tharyx</i>						
<i>acutus</i>	533	204	86	4	169	31
<i>Ampharete</i>						
<i>arctica</i>	415	185	90	43	178	62
<i>Phorus affinis</i>	16	157	57	2	360	8
<i>Nereis succinea</i>	33	201	38	19	135	62
<i>Spiophanes</i>						
<i>bombyx</i>	9	244	24	38	118	54
GASTROPODS						
<i>Nassarius</i>						
<i>trivittatus</i>	91	81	95	109	89	92
PELECYPODS						
<i>Tellina agilis</i>	418	109	86	222	110	69
<i>Ensis directus</i>	281	96	100	104	119	62
CRUSTACEANS						
<i>Oxyurostylis</i>						
<i>smithi</i>	52	185	62	3	205	23
<i>Ampelisca</i>						
<i>abdit</i>	96	194	76	44	278	31
<i>Ampelisca</i>						
<i>vadorum</i>	81	222	57	508	260	85
<i>Unicola irrorata</i>	48	120	81	15	230	31
<i>Crangon</i>						
<i>septemspinosa</i>	18	150	48	22	93	85
<i>Pagurus</i>						
<i>longicarpus</i>	16	253	43	19	139	54
ASTEROIDS						
<i>Asterias forbesi</i>	46	273	48	32	163	69
Total individuals/ m ²	14,037	118		2,362	62	
Total species	34.3	27		23.8	52	
Species diversity, <i>H'</i>	1.83	27		2.03	12	
Equitability, <i>J'</i>	0.53	28		0.64	10	

¹Means for entire samples, including rarer species.

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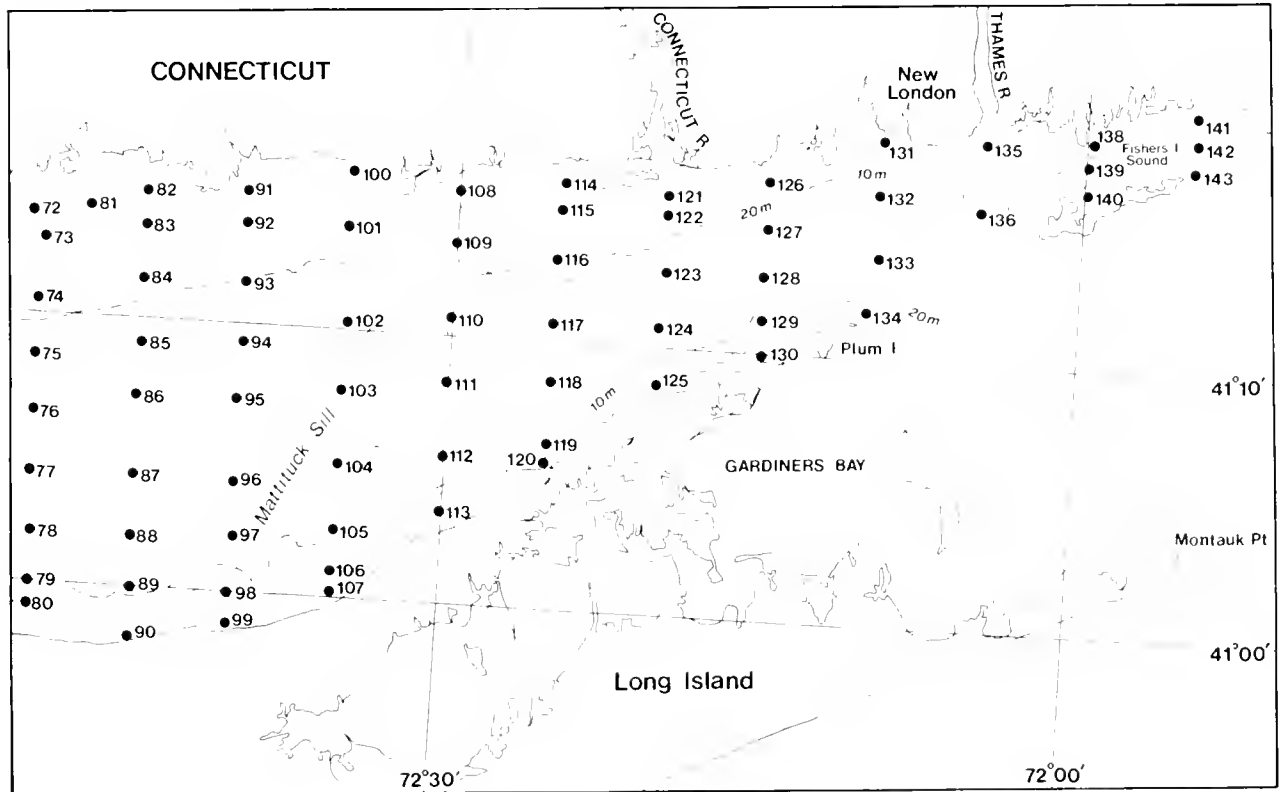
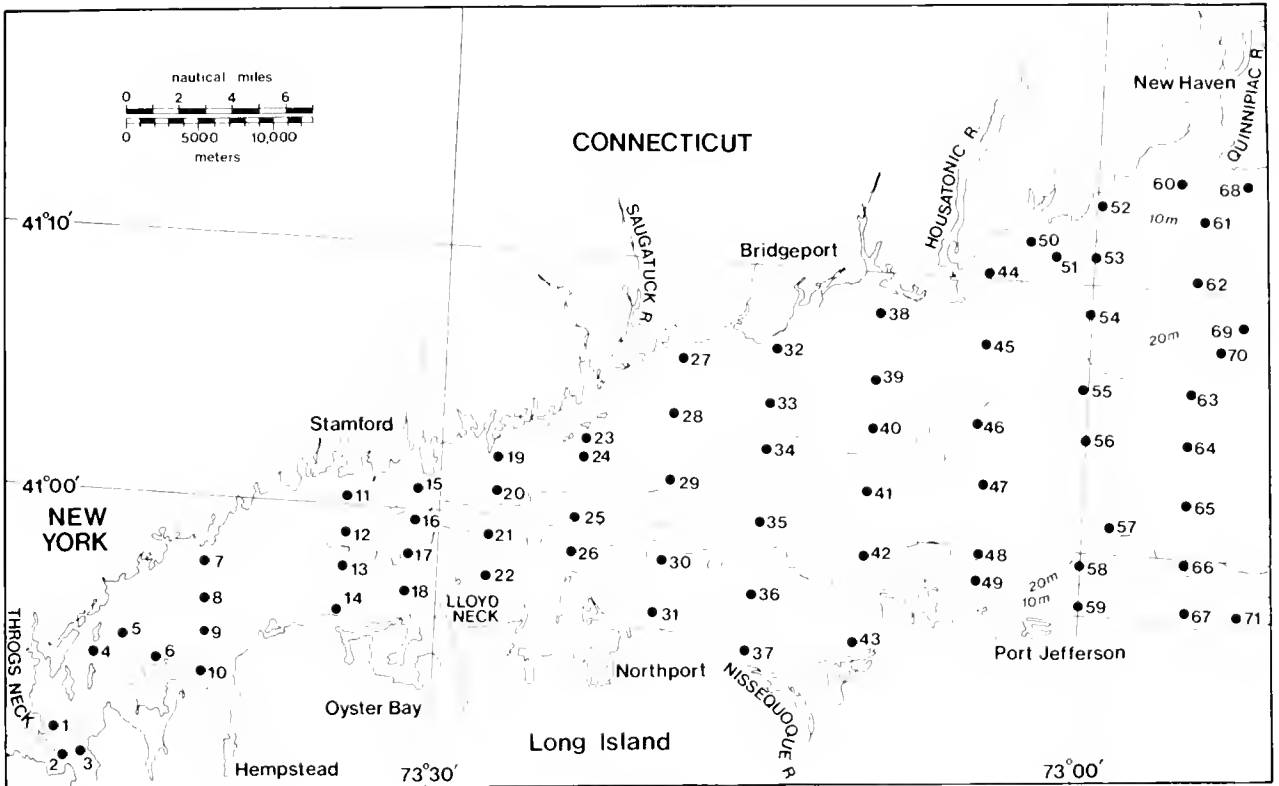


Figure 1.—Sampling pattern in Long Island Sound.

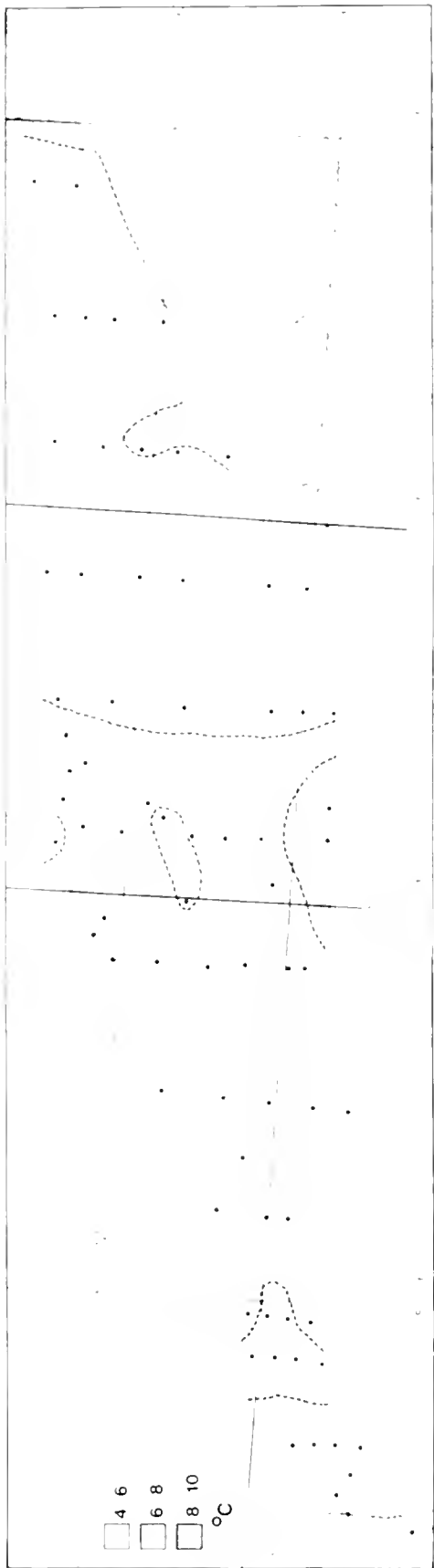


Figure 2. Surface temperature, Long Island Sound, April 1973.

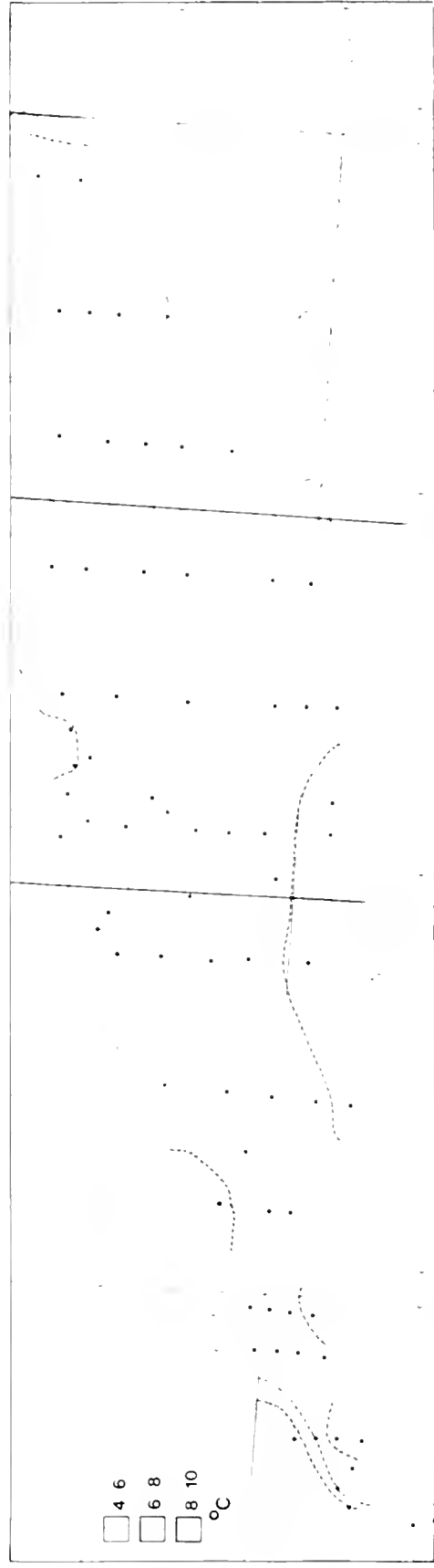


Figure 3. Bottom temperature, Long Island Sound, April 1973.

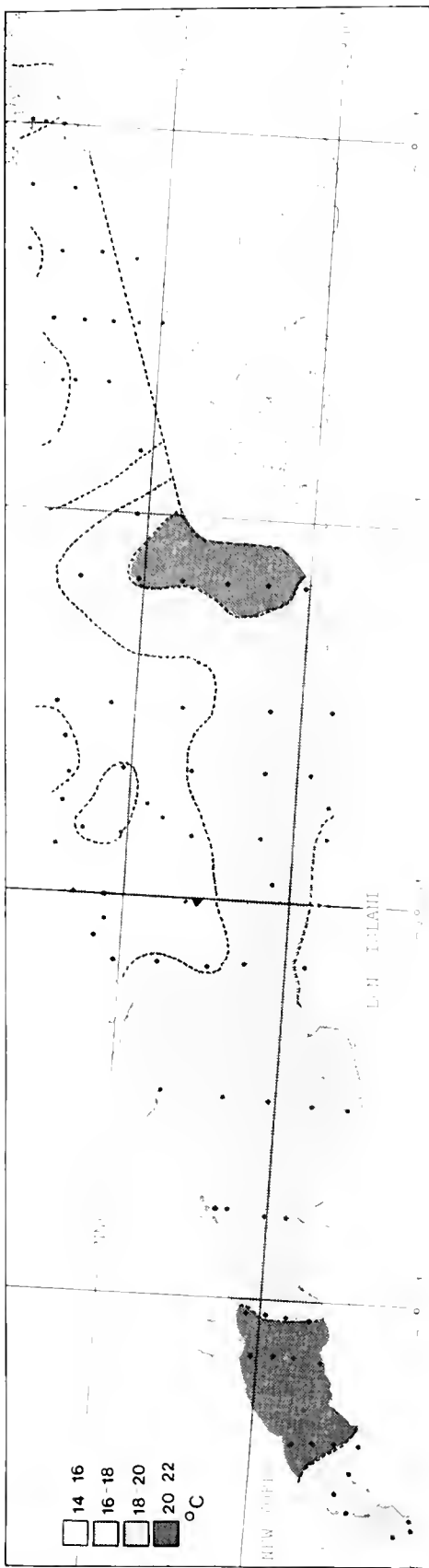


Figure 4. Surface temperature, Long Island Sound, September 1973.

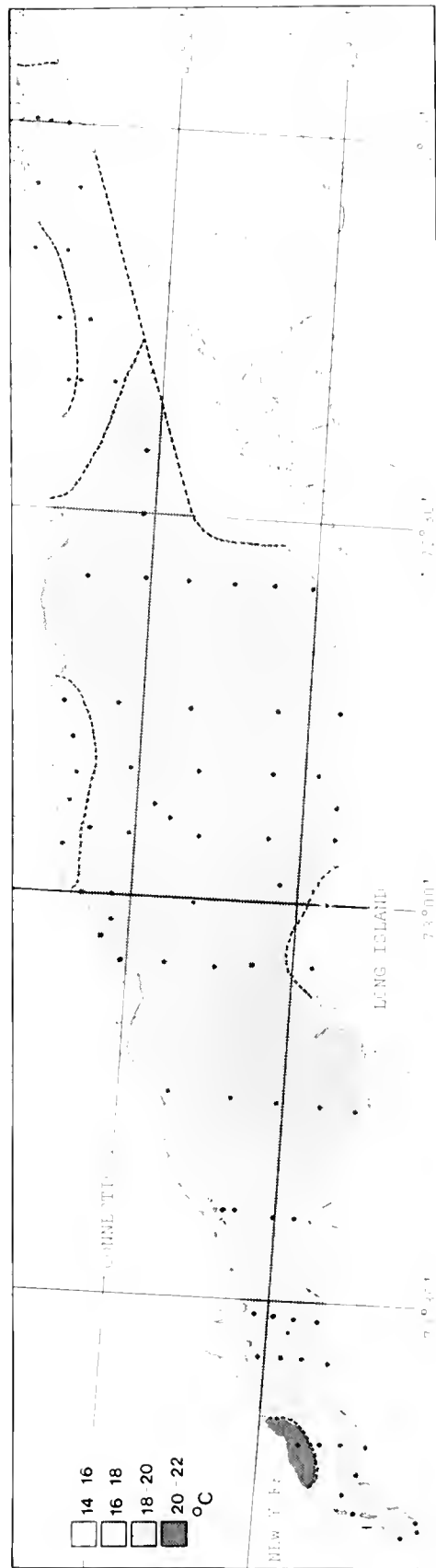


Figure 5. Bottom temperature, Long Island Sound, September 1973.



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



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

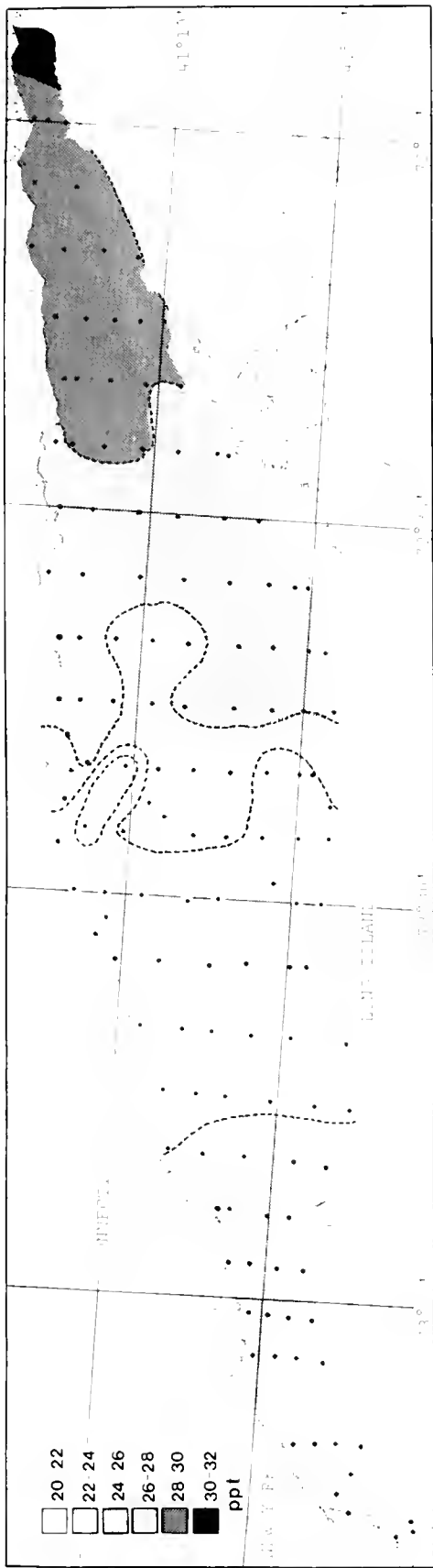


Figure 8.—Surface salinity, Long Island Sound, summer 1972.

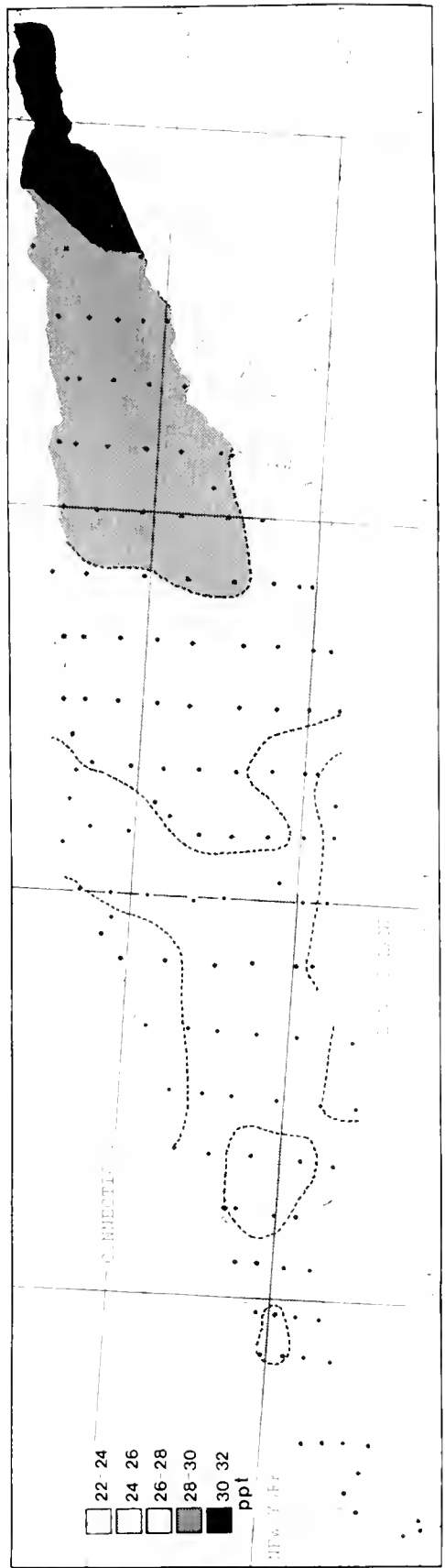


Figure 9.—Bottom salinity, Long Island Sound, summer 1972.

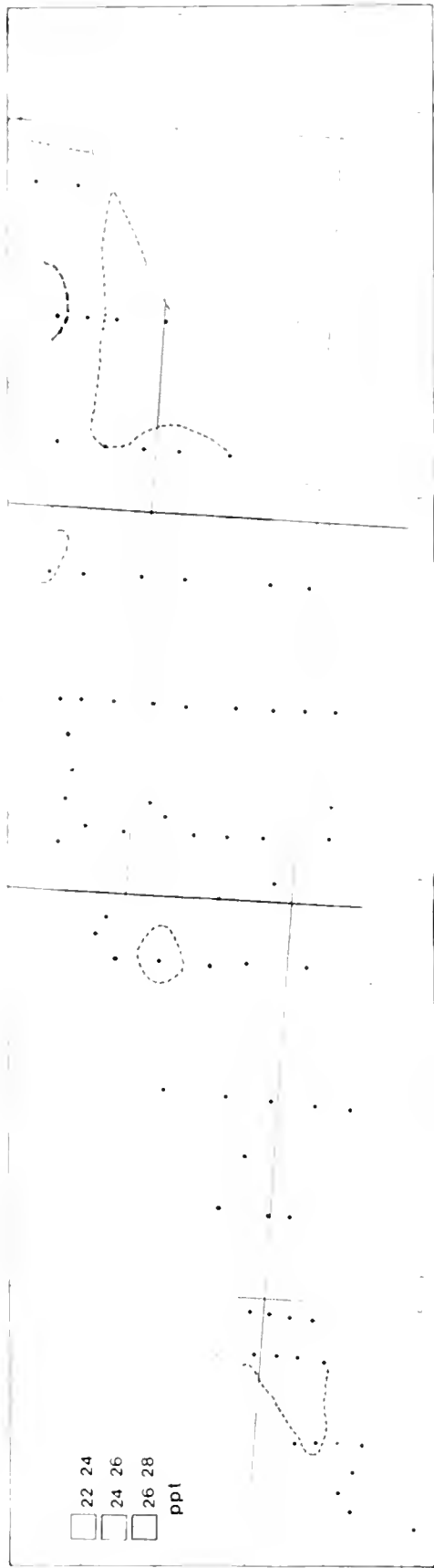


Figure 10. Surface salinity, Long Island Sound, April 1973.

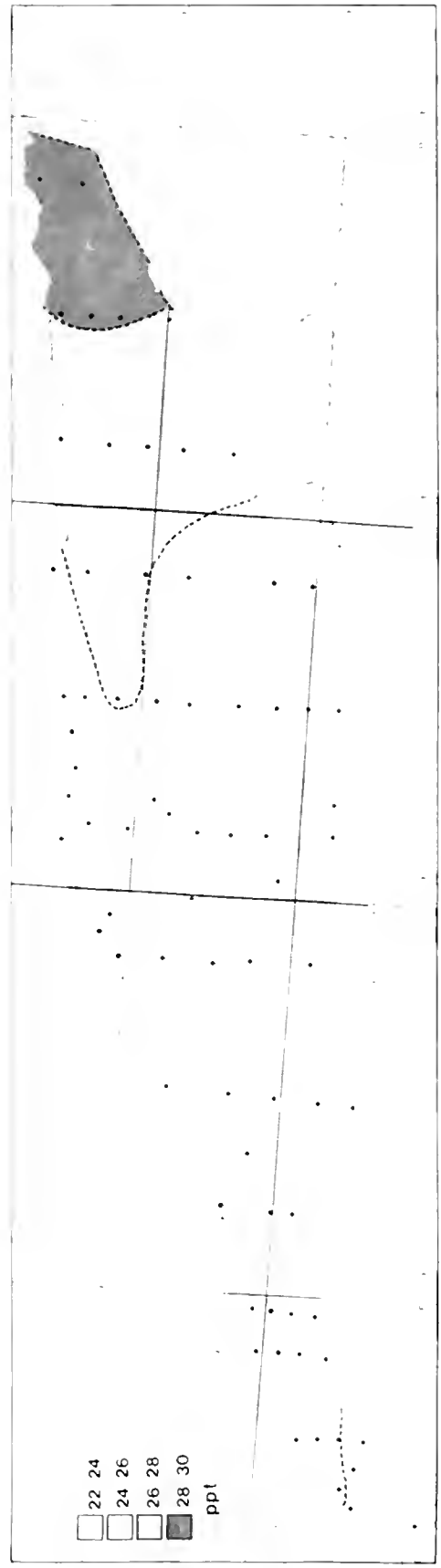


Figure 11. Bottom salinity, Long Island Sound, April 1973.

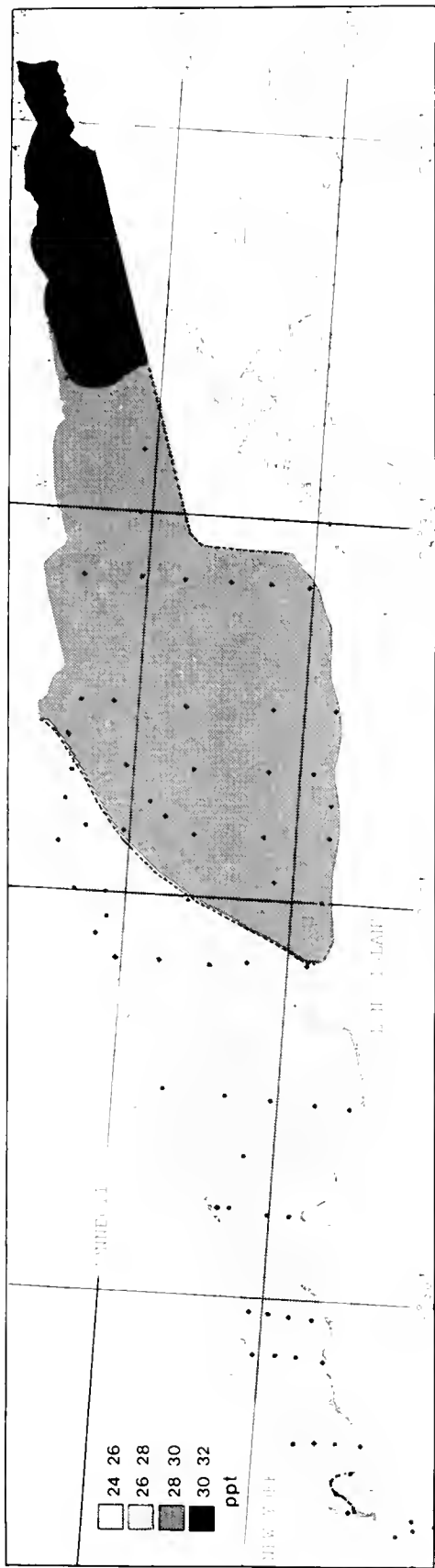


Figure 12.—Surface salinity, Long Island Sound, September 1973.

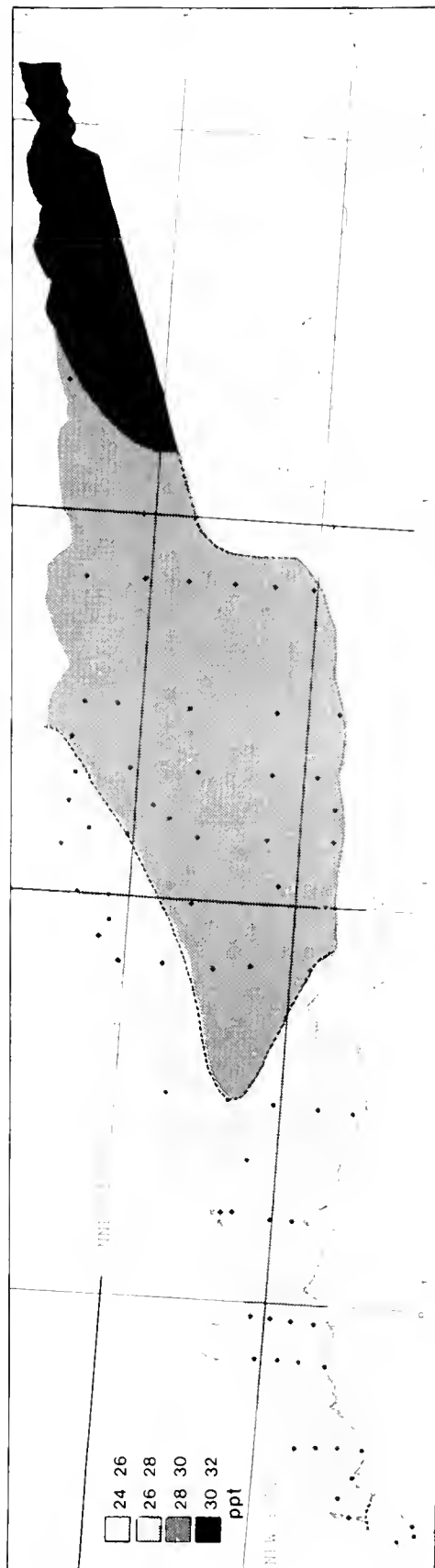


Figure 13.—Bottom salinity, Long Island Sound, September 1973.

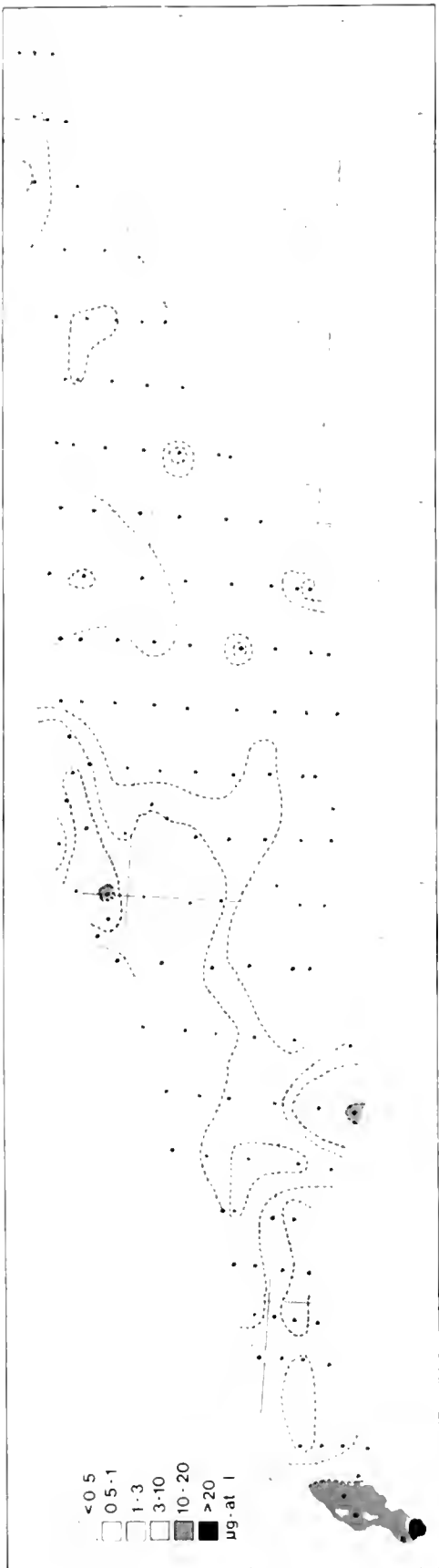


Figure 14. Surface ammonium, Long Island Sound, summer 1972.

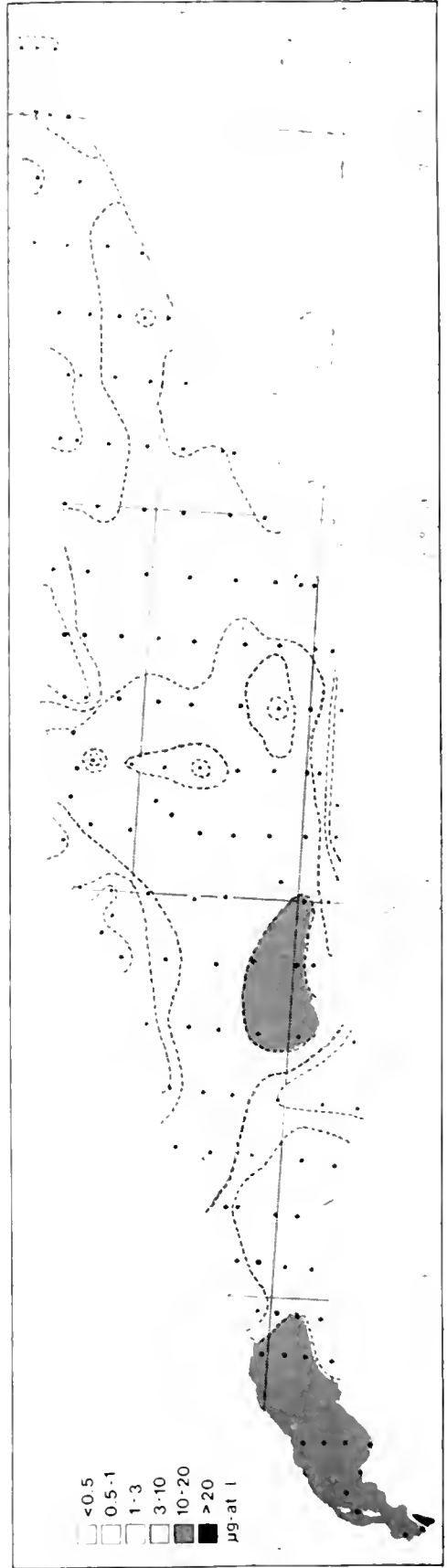


Figure 15. Bottom ammonium, Long Island Sound, summer 1972.

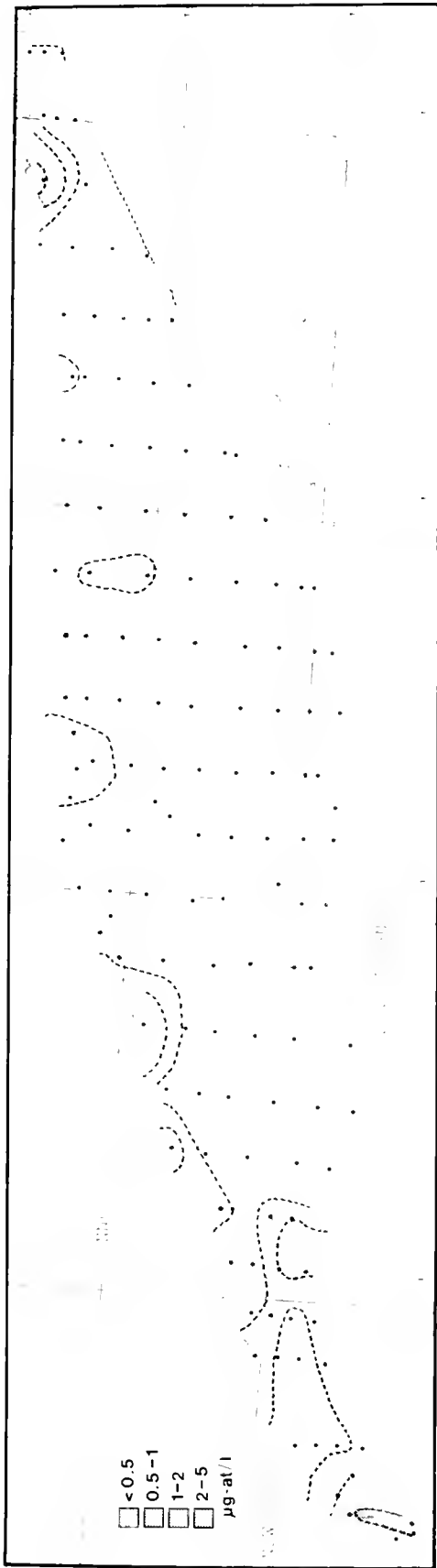


Figure 16.—Surface nitrate, Long Island Sound, summer 1972.

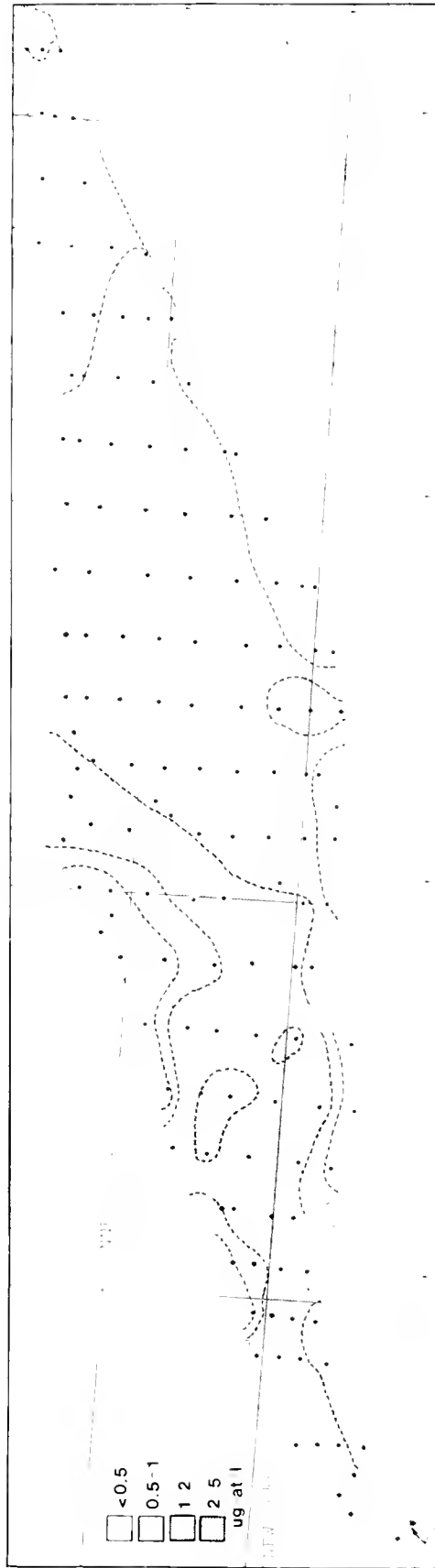


Figure 17. Bottom nitrate, Long Island Sound, summer 1972.

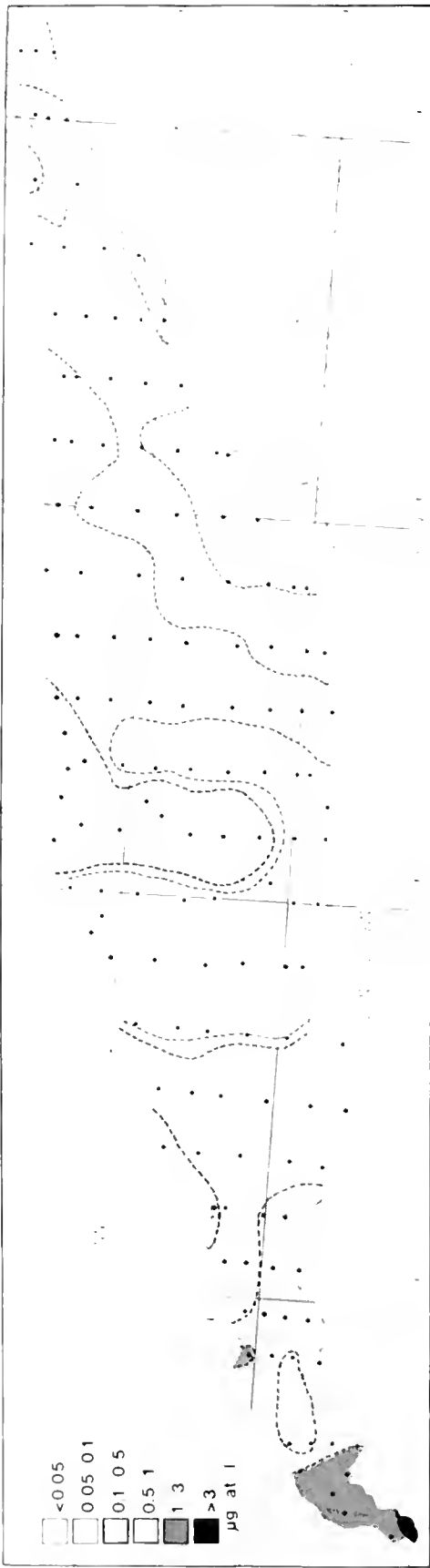


Figure 18. Surface nitrite, Long Island Sound, summer 1972.

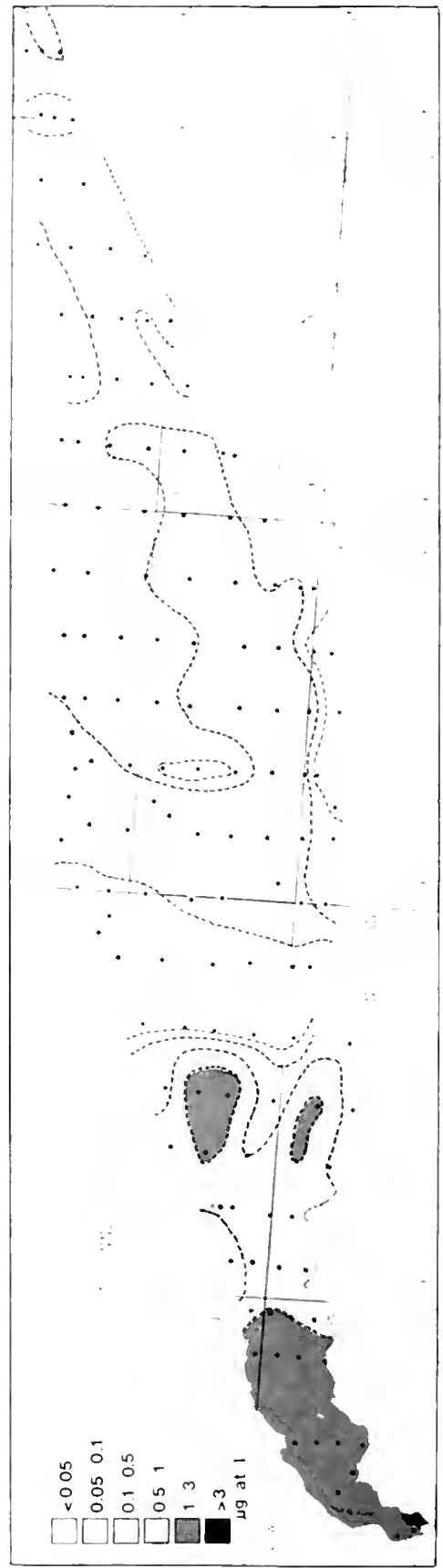


Figure 19. Bottom nitrite, Long Island Sound, summer 1972.

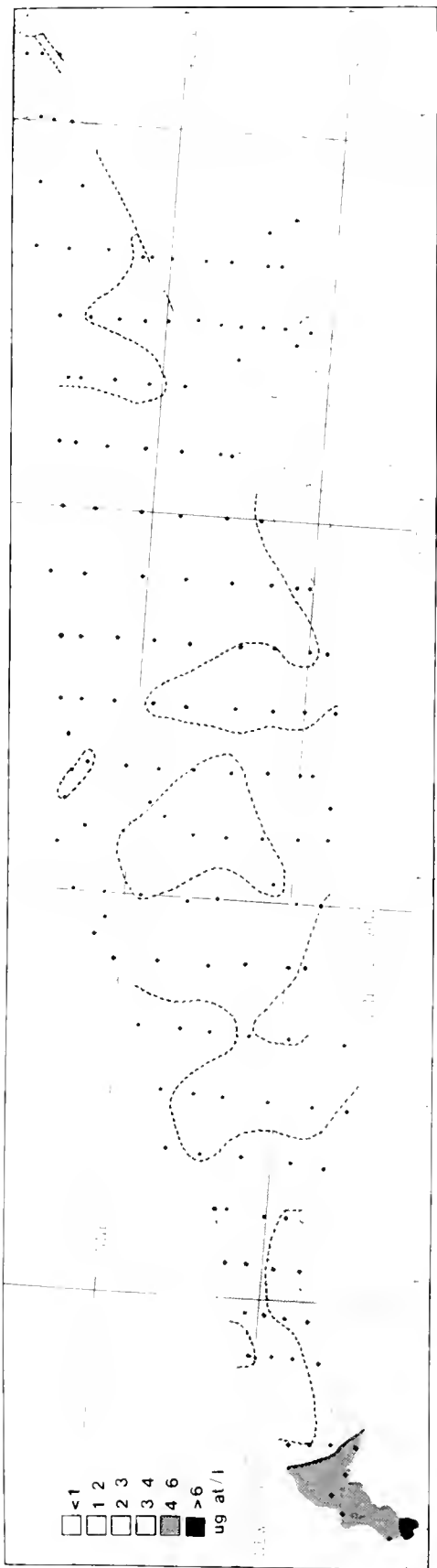


Figure 20. — Surface orthophosphorus, Long Island Sound, summer 1972.

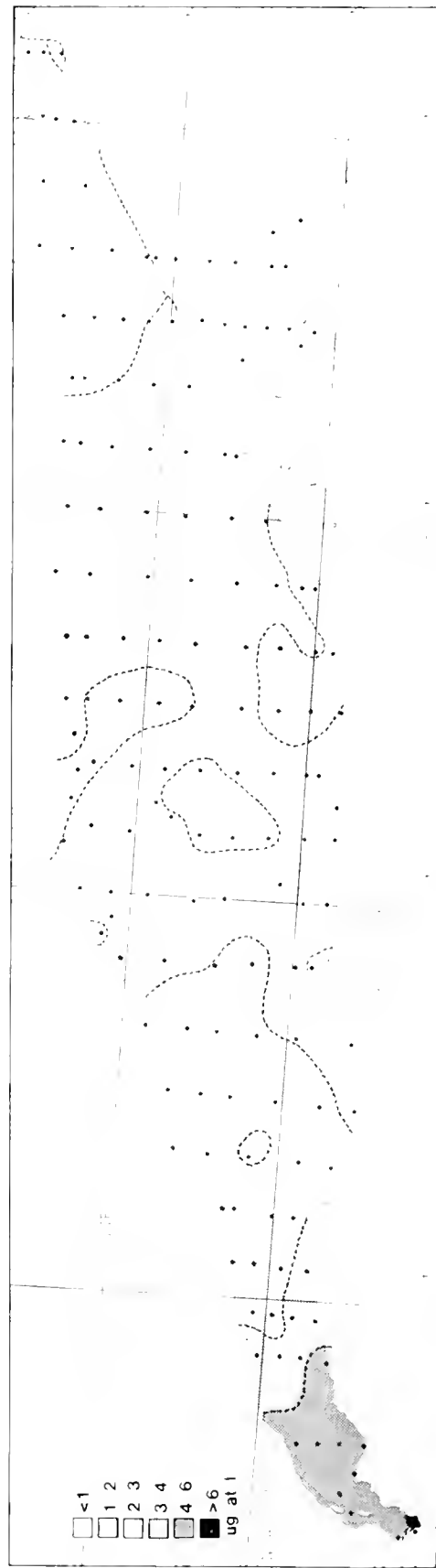


Figure 21. — Bottom orthophosphorus, Long Island Sound, summer 1972.

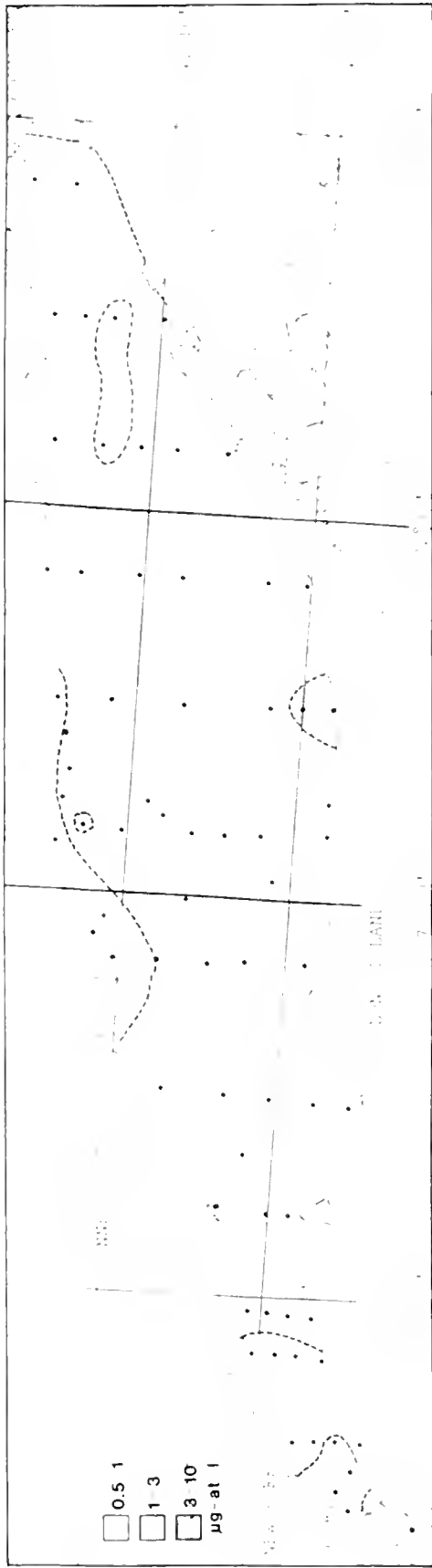


Figure 22. Surface ammonium, Long Island Sound, April 1973.

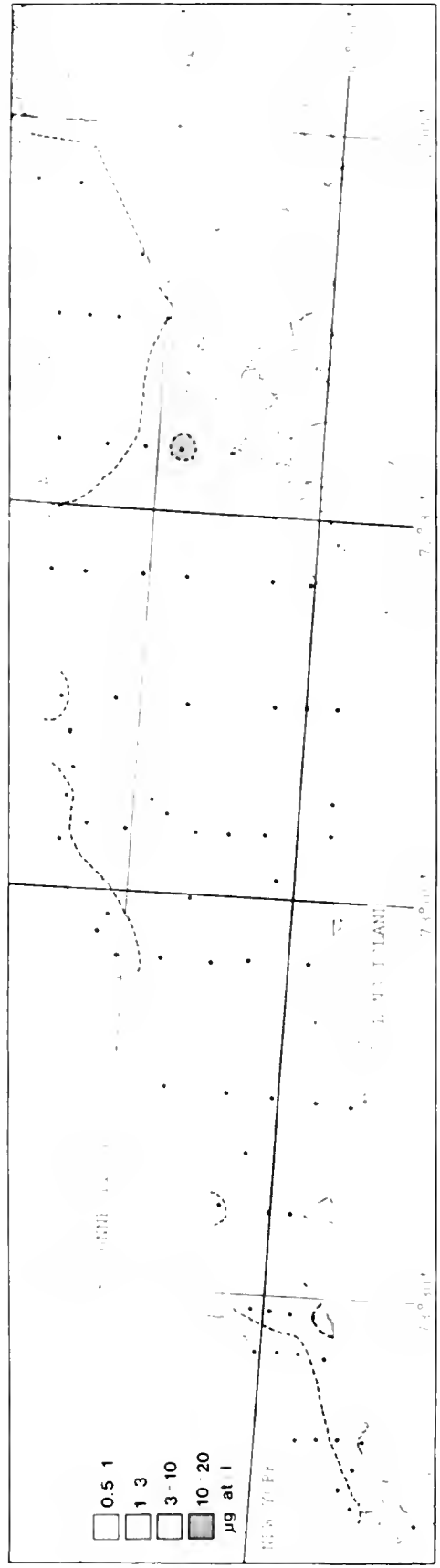


Figure 23. Bottom ammonium, Long Island Sound, April 1973.

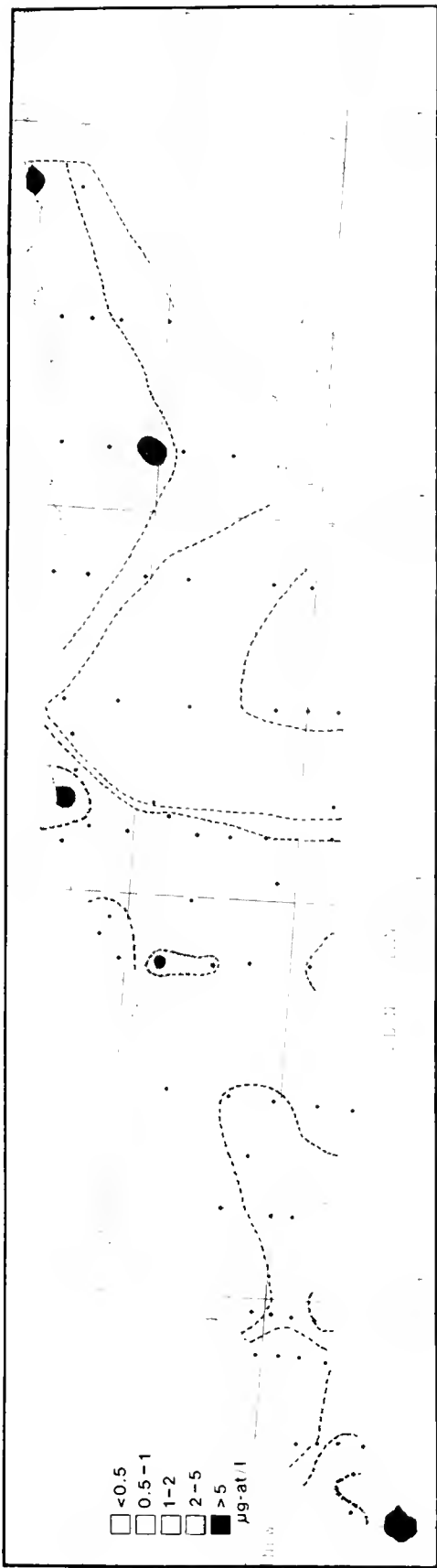


Figure 24.—Surface nitrate, Long Island Sound, April 1973.

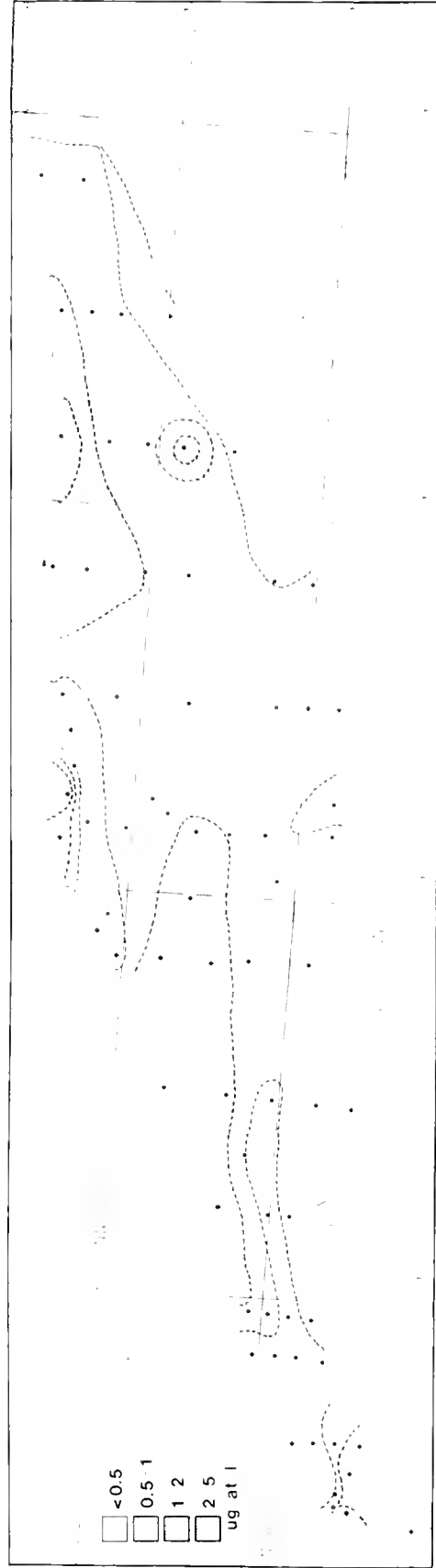


Figure 25.—Bottom nitrate, Long Island Sound, April 1973.

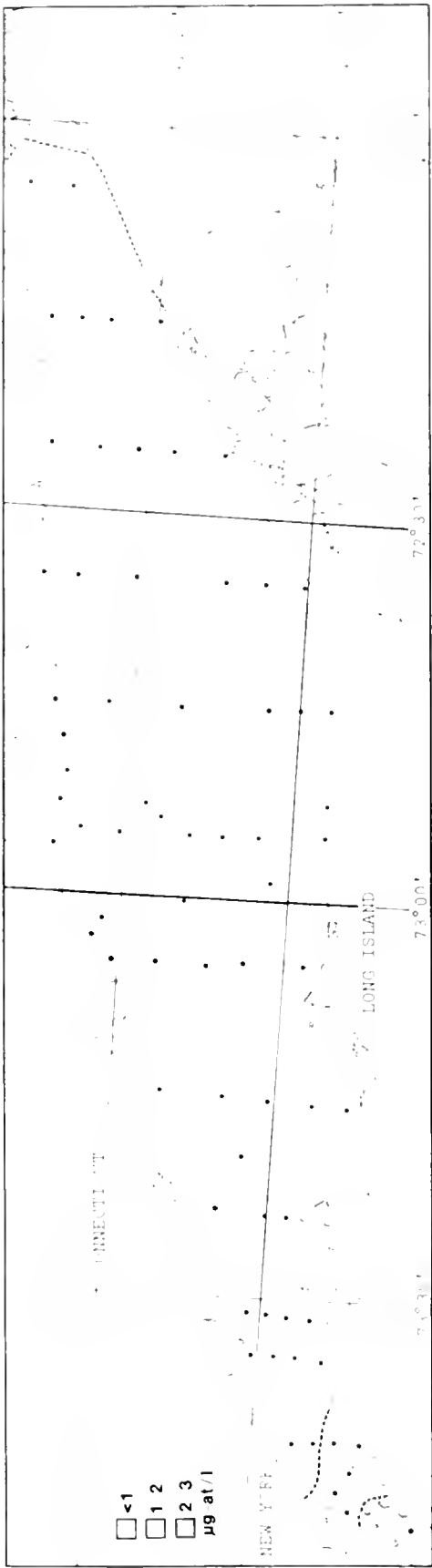


Figure 26. Surface orthophosphorus, Long Island Sound, April 1973.

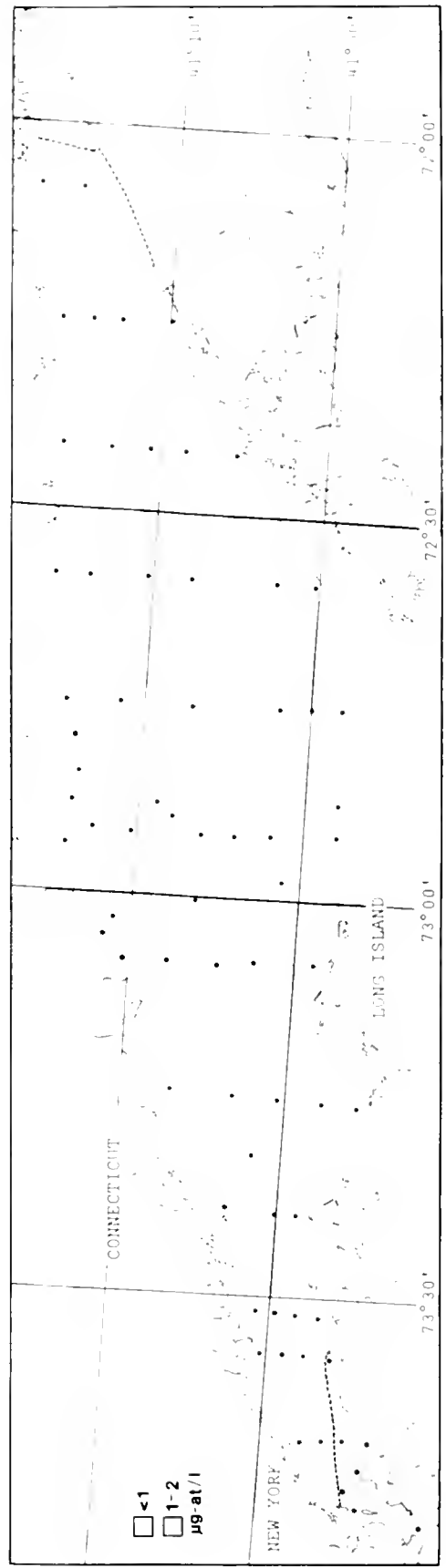


Figure 27. Bottom orthophosphorus, Long Island Sound, April 1973.

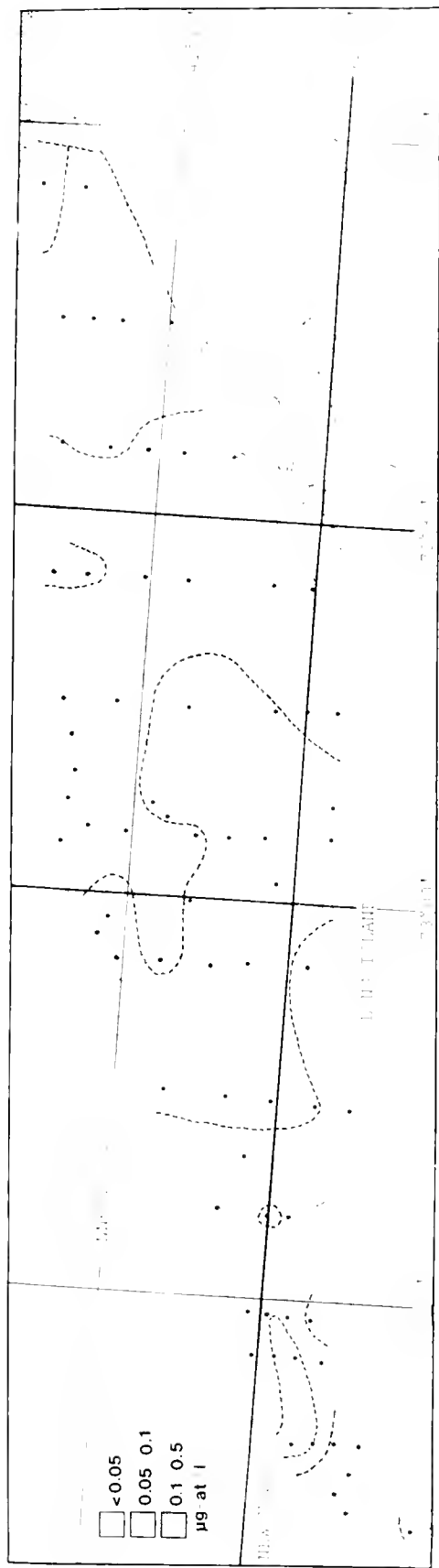


Figure 28.—Surface nitrite, Long Island Sound, April 1973.

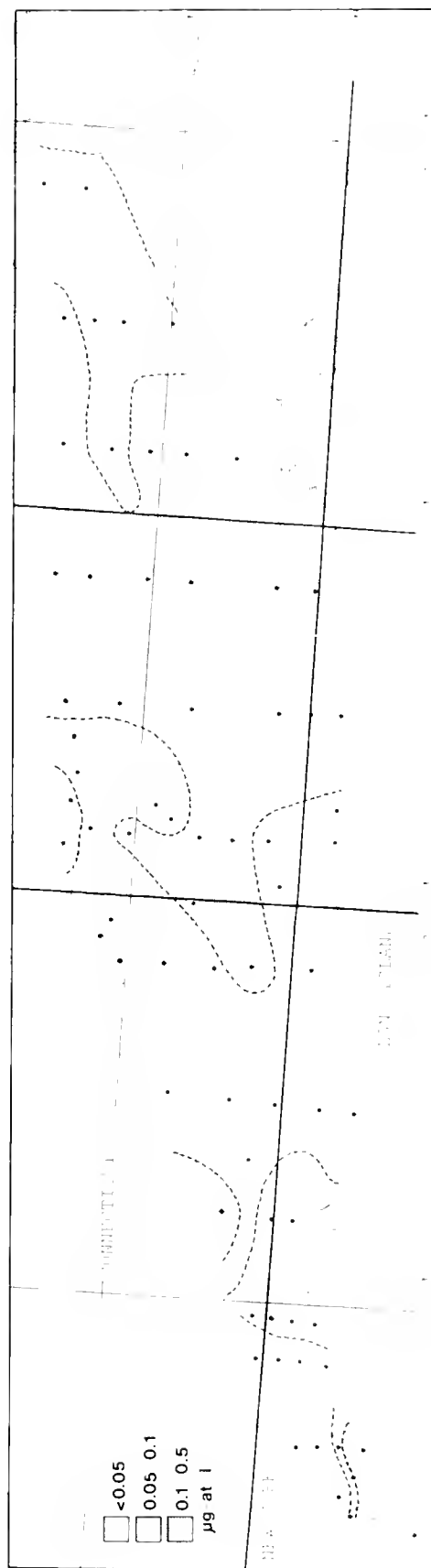


Figure 29.—Bottom nitrite, Long Island Sound, April 1973.

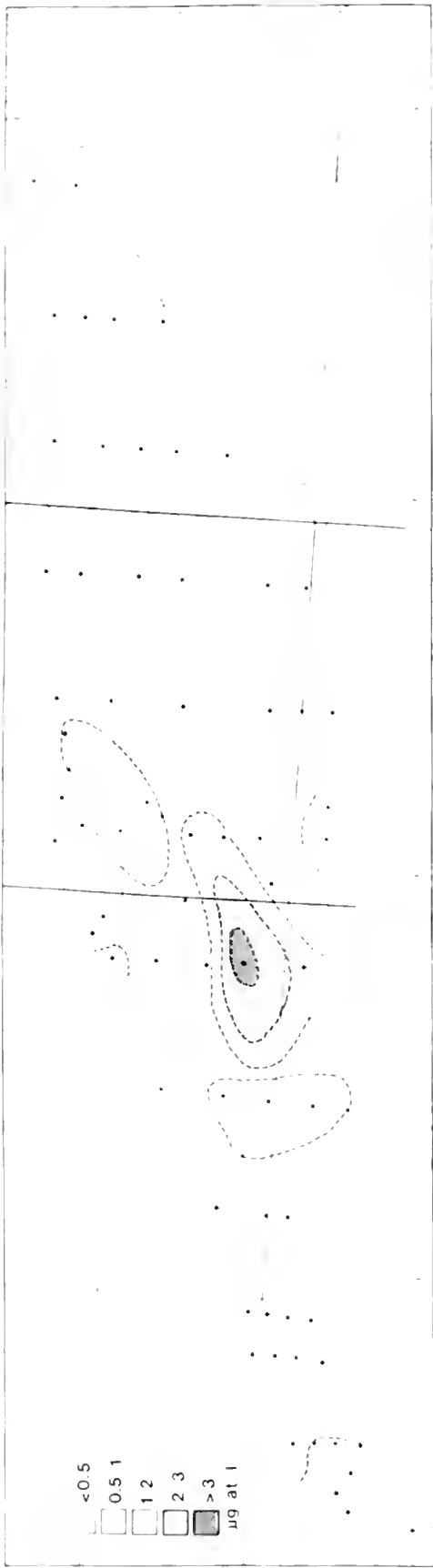


Figure 30. Surface area, Long Island Sound, April 1973.

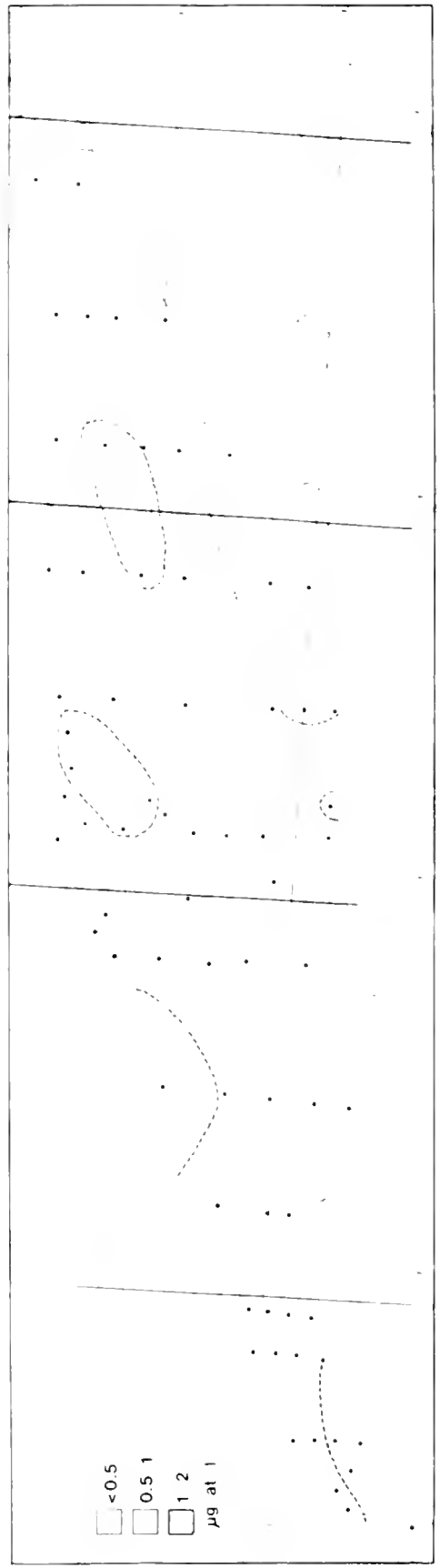


Figure 31. Bottom area, Long Island Sound, April 1973.

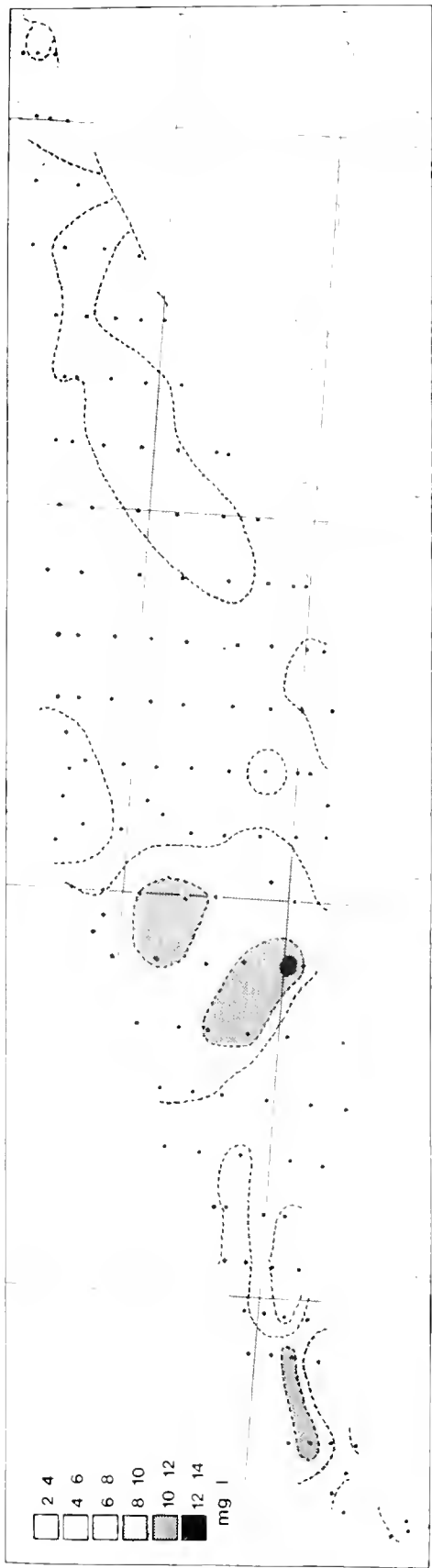


Figure 32. Surface dissolved oxygen, Long Island Sound, summer 1972.

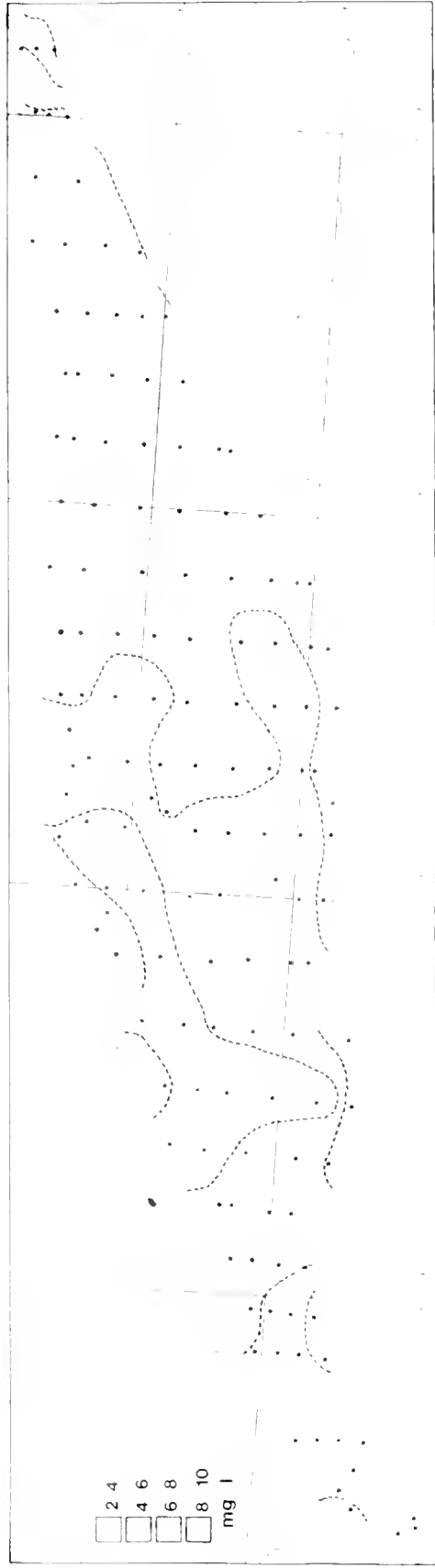


Figure 33. Bottom dissolved oxygen, Long Island Sound, summer 1972.

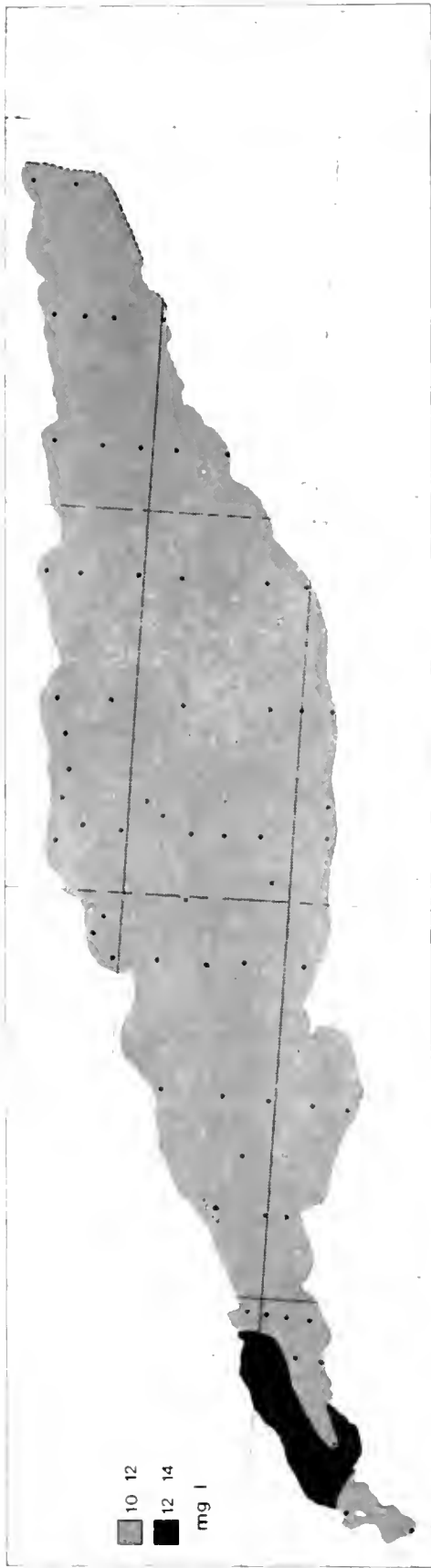


Figure 34. Surface dissolved oxygen, Long Island Sound, April 1973.

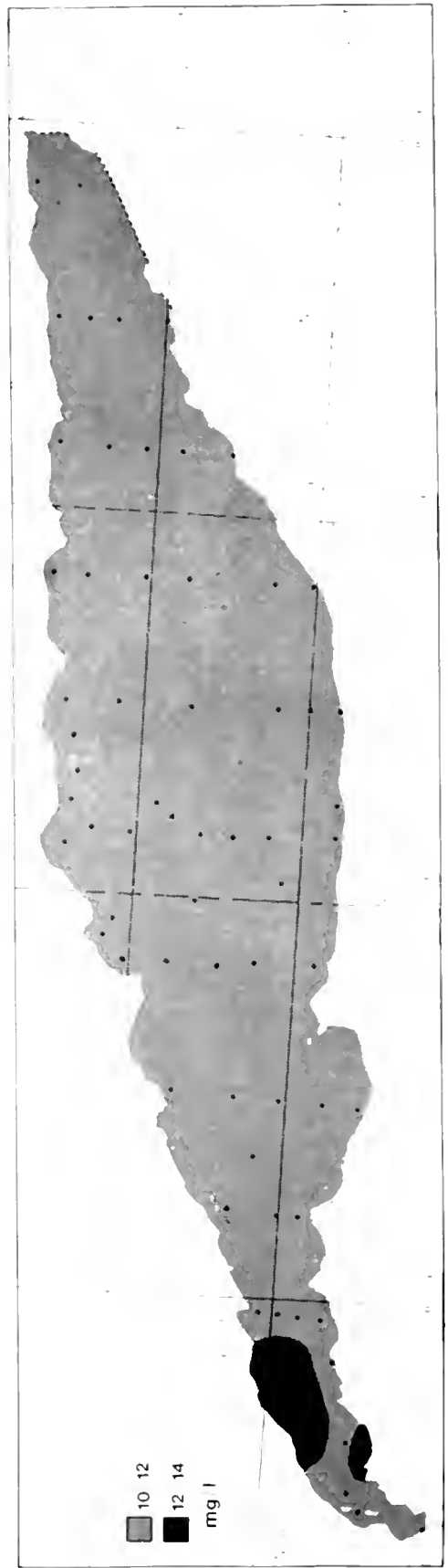


Figure 35. Bottom dissolved oxygen, Long Island Sound, April 1973.

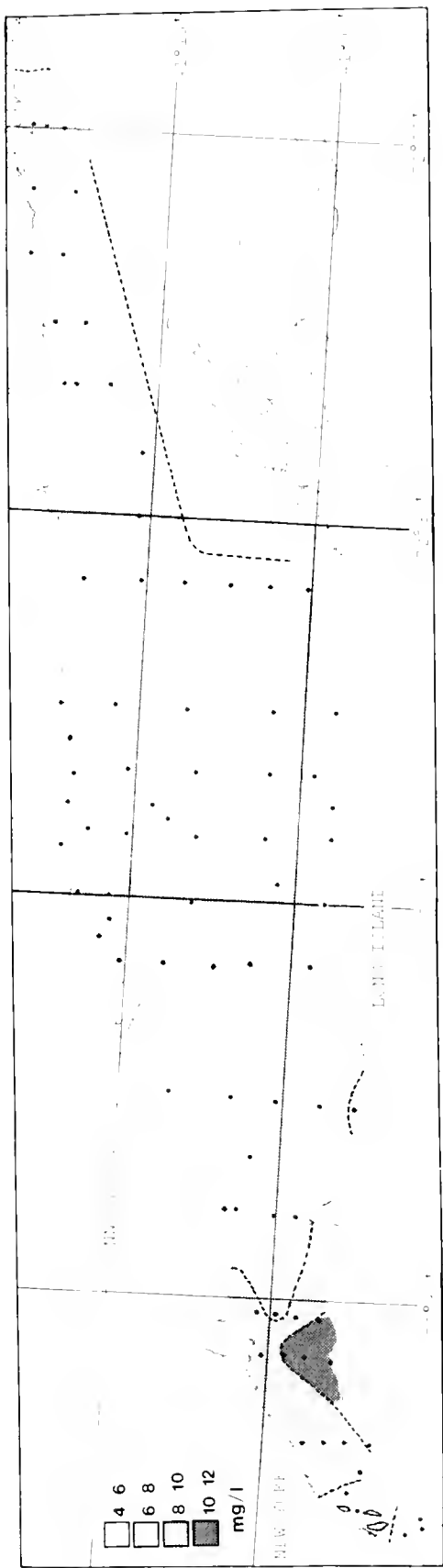


Figure 36. — Surface dissolved oxygen, Long Island Sound, September 1973.

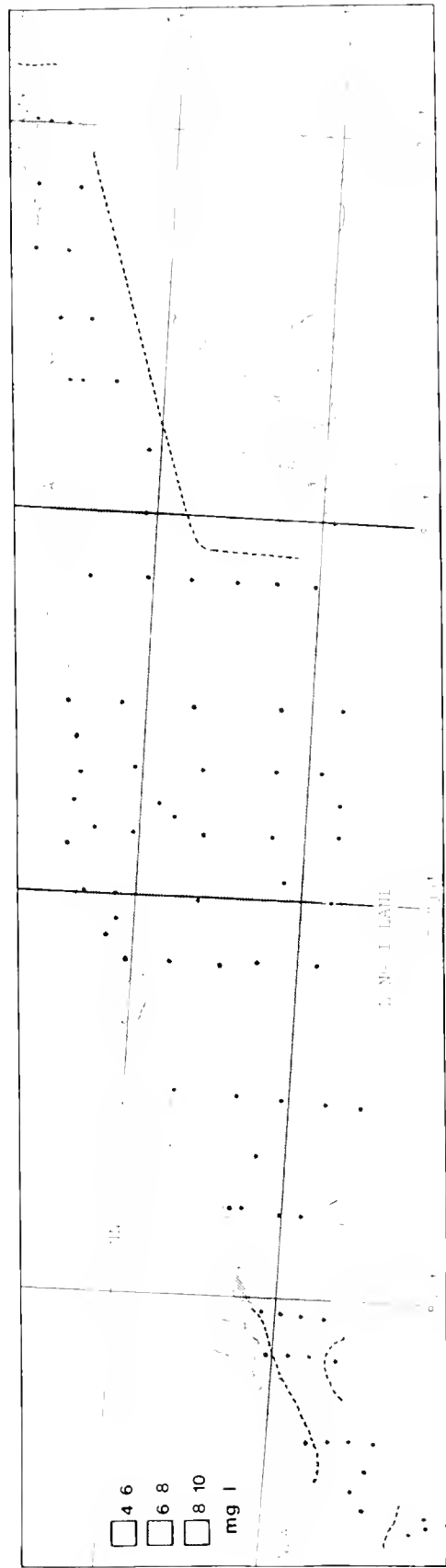


Figure 37. — Bottom dissolved oxygen, Long Island Sound, September 1973.

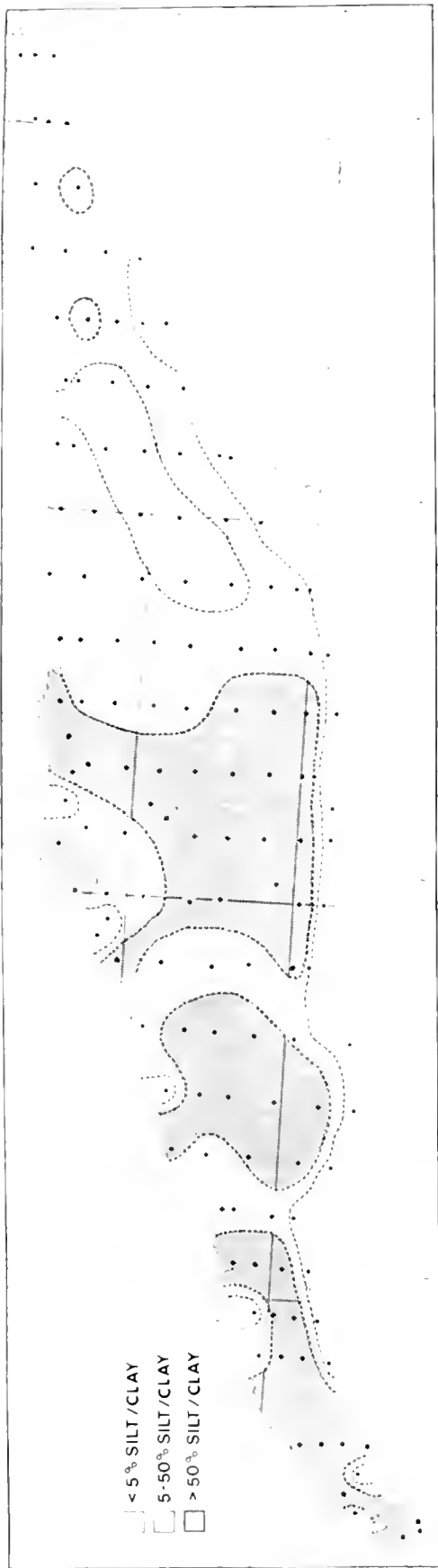


Figure 38. Distribution of silts and clays (62cm) in surface sediments, Long Island Sound, summer 1972.

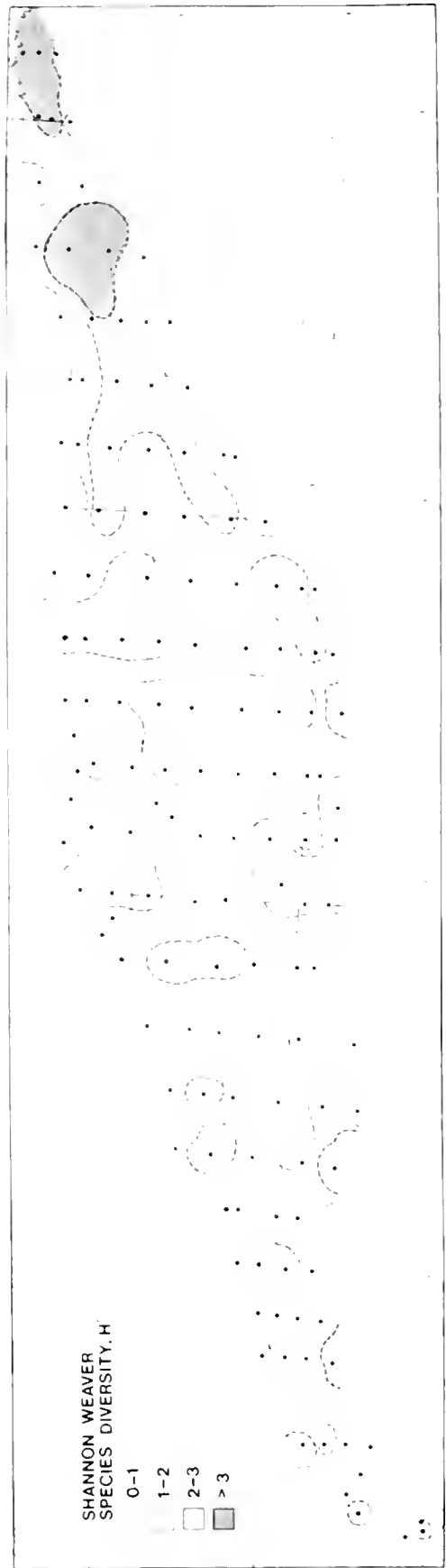


Figure 39. Distribution of Shannon-Weaver species diversity values, Long Island Sound, summer 1972.

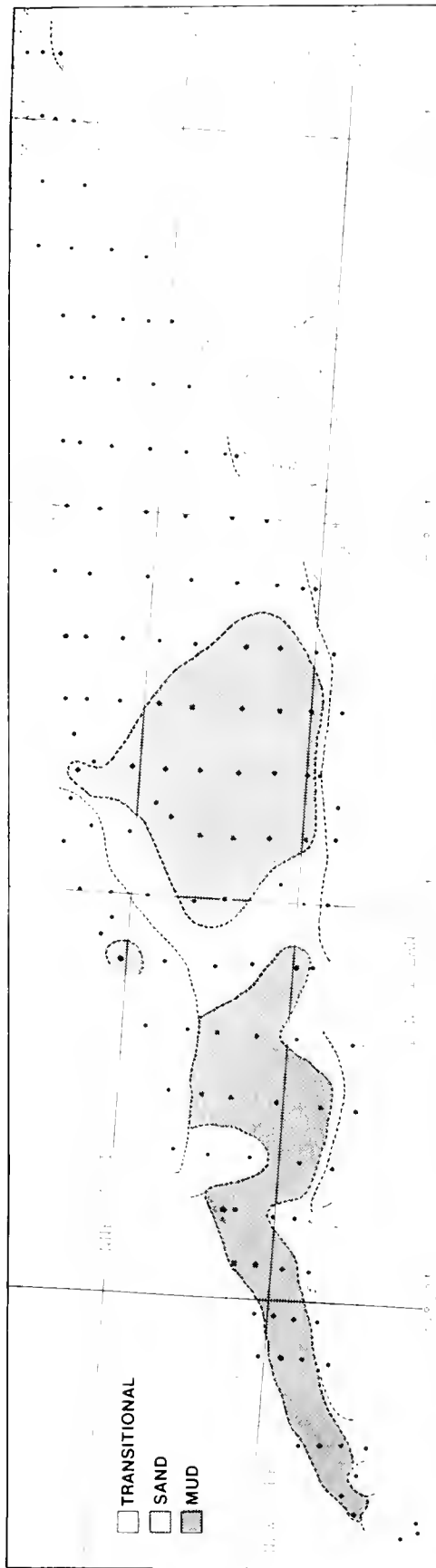



Figure 40.—Distribution of mud, sand, and transitional faunal assemblages, Long Island Sound, summer 1972.

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