CENTRAL FILE

NORTHEAST MONITORING PROGRAM
ANNUAL REPORT - LEVEL 2
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by

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Dissolved Oxygen

During the stratified season, dissolved oxygen concentrations consistently decrease to relatively low levels in subpycnocline water near the New York Bight apex dump sites and in nearshore water off the coast of New Jersey between Barnegat Inlet and Cape May. This recurrent pattern is seen in depictions of near-bottom dissolved oxygen concentrations measured during Ocean Pulse surveys (AL-79-07, 79-10, 80-07, 80-09), New York Bight water column monitoring cruises (NEMP-80-12, 80-16) and during the August 1980 survey of contaminants in the New York Bight (KE-80-07/08), Figures 1-6.

Low oxygen concentrations were also measured in the deeper water at the shelf break (Figures 1-4) near the Hudson Canyon and in water near bottom in the eastern end of Long Island Sound (Figure 6b). Reid et al. (1979) reported relatively low (1.4-2.8 ml/O_2/L) oxygen concentrations in these same areas during their extensive summer survey of Long Island Sound. The presence of relatively low dissolved oxygen concentrations (3.5 ml/L) in the deep (300-800 m) saline (35.3 o/oo) water at the shelf break has been described by Gordon et al. (1976; Figure 5, "Slope O_2 min") and by Worthington (1958). These areas stand apart from the rest of the shelf environments between Cape Hatteras and Nova Scotia.

In an annual NEMP report, Whitledge (1980) reports that dissolved oxygen measurements on the New Jersey shelf made during four New York Bight water column monitoring surveys fall within the historical (excluding 1976) range of values. With respect to "water quality", Whitledge's summary and the dissolved oxygen distributional maps (Figures 1-6) indicate that dissolved oxygen levels in the New York Bight were within expectations for the stratified season and that the extremely stressful conditions in 1976 were not extant in the summers of 1979 and 1980.

The annual cycle of near-bottom oxygen concentrations in the New York Bight during "normal" (no anoxia) years has been described by Armstrong (1979). Several other papers, discussing meterology, hydrography, chemical, and biological oceanography of the New York Bight during "normal" years and the anoxia 1976 have been drawn together by Swanson and Sindermann (1979) and will not be repeated here. There is, however, some new information gained from extensive phytoplankton monitoring surveys which may provide additional insight into the mechanisms responsible for maintaining chronically low dissolved oxygen levels in shelf water off New Jersey. O'Reilly et al. (1980) in their annual report presented distributional maps of phytoplankton biomass concentration (chlorophyll <u>a</u>) throughout the NEMP area during 18 surveys. In several of the figures in their report (Figures 14, 15, 19, 20, 22, 24, 25, 27, 29, 31) a band of high phytoplankton concentration is seen along the New Jersey coast. In several surveys (O'Reilly et al., 1980; Figures 16, 17, 22, 24, 27, 29) high concentrations of phytoplankton were measured in coastal water between Barnegat Inlet and Atlantic City, New Jersey, the same area chronically low in dissolved oxygen. In Figure 7, August 1978, the band of high chlorophyll <u>a</u> is continuous along the New Jersey coast from the apex to Cape May, whereas in Figure 8, August 1979, the band is interrupted at the perimeter of the apex by water having relatively lower concentrations of phytoplankton. Mueller et al. (1976) estimate that about 4% of the total nitrogen entering the New

York Bight comes from the New Jersey coastal zone, 65% from the Raritan-Hudson estuary, and 29% from direct Bight discharges. It is not clear, at this time, whether the high phytoplankton biomass regions south of Barnegat Inlet are the consequence of localized neretic stimulation or an extension of stimulation from nutrients (inorganic and organic) leaving the Bight apex, or the result of shelf/slope water stimulation combined with relatively weak flushing of this region which permits a high net accumulation of phytoplankton.

A major key to understanding the chronically low oxygen environment off New Jersey lies in studies of the "background" factors (organic loading, production, decomposition, advection, residence times, vertical partitioning of organic matter, and biological rates above and below pycnocline, etc.) affecting organic matter content of these waters.

In their paper discussing a diagnostic model of water and oxygen transport for the New York Bight 1976, Han et al. (1979) concluded that "oxygen depletion in the critical region during the May-June period was due to oxygen utilization about 3 times greater than in other regions of the inner shelf and nearly 10 times greater than that occurring over the outer shelf, rather than simply being due to the length of stratified season, stagnation or advection of low-oxygen water. The most critically affected regions, in fact, had a relatively advective oxygen input substantially greater than the other areas." Much of this oxygen consumption was due to abnormally high concentrations of _Ceratium tripos_ (Malone et al., 1979) which exeracerbated the situation in areas having chronically low dissolved oxygen concentrations.

Walsh (in press) in his Figure 7 presents a shelf-wide map of the ratio of organic carbon/organic nitrogen in sediments. Walsh suggests that sediments with C/N ratios greater than 10 indicate a terrestrial or marine vascular plant source while C/N ratios in sediments less than 6 indicate a marine (plankton) source of sediments. According to Walsh's C/N map, the New York Bight apex and the area adjacent to Barnegat, New Jersey have C/N ratios <6. Possibly, the large standing stocks of phytoplankton often seen over this area are the prime source of organic matter for sediments off Barnegat. Rates of seabed consumption of oxygen also appear to be relatively higher off Barnegat than areas of the shelf east and south (Phoel, 1980; Figure 11, station 17).

The observations of persistently high standing stocks of phytoplankton and very high rates of phytoplankton production in coastal water off New Jersey (O'Reilly et al., 1980) represents only one potential element of the synergism of factors reponsible for the low oxygens repeatedly seen during the stratified season off New Jersey.

The role which sewage-derived dissolved organic nitrogen (DON) and dissolved organic carbon (DOC) compounds play in eutrophication and in stimulating increases in phytoplankton biomass may be quite important, either directly through stimulation of algae possessing heterotrophic ability or indirectly through stimulation of microheterotrophic bacteria which mineralize DON and DOC compounds in sewage effluents, thereby releasing inorganic nutrients which are readily assimilated by autotrophic phytoplankton. The latter "indirect" stimulation may apply to the New York Bight situation, and may constitute a second piece of the synergism. Dissolved organic nitrogen compounds from sewage effluents, contaminated dredged materials, and other wastes may represent a significant portion of the total nitrogen discharged into estuarine and coastal waters. Concentration of dissolved organic nitrogen may approach the combined concentrations of inorganic nitrogen pollutants (ammonium, nitrate, nitrite) contained in sewage effluents discharged in coastal areas (Eppley et al., 1972; Segar and Berberian, 1976; Thomas et al., 1979). The "Expanded Apex Hypothesis" of Thomas and associates (1979) proposes that the initial effects of the sewage-derived inorganic nitrogen is the stimulation of autotrophy in the Bight apex. The "unused" apex DON compounds plus the organic compounds photosynthesized in the apex stimulate heterotrophy. However, the full effect of this heterotrophic stimulation (P/R<<1, and reduced oxygen concentrations) is delayed in time and occurs down the plume of the estuary, seaward of the apex along the New Jersey coast.

Organic Carbon and Nitrogen

At present, very little information exists concerning the distribution of dissolved and particulate organic nitrogen and carbon in water within the NEMP region. Some information on DOC measured during a single survey of the New York Bight in 1976 has been presented by Thomas et al. (1979).

During this one-time, late summer survey the highest average water column concentrations of DOC (4-6 mg/L) were measured in the Bight apex and inside the estuary. Seaward of the apex to Cape May, DOC concentrations were between 1.6 and 2.2 mg/L.

The New York Bight MESA Project sponsored a study of "Synoptic Investigations of Nutrient Cycling (SINC) in the New York Bight apex (Malone et al., 1979). DOC was measured throughout the water column during four SINC surveys. According to Thomas et al. (1979), DOC concentrations were usually between 1 and 2 mgC/L throughout the four surveys (May, June, November 1977, March 1978). DOC concentrations were usually highest at stations nearest the mouth of the Hudson-Raritan estuary. DOC concentration was inversely related to sigma-t. This was interpreted to mean that the estuary is a major source of DOC.

Dissolved organic carbon and dissolved organic nitrogen represent the largest pools of organic carbon and organic nitrogen in most marine environments (Pomeroy, 1974). DOC and DON are major constituents of sewage effluents entering the New York Bight via the Hudson-Raritan estuary (O'Connors and Duedall, 1975; Thomas et al., 1979). Yet, with the exception of the small studies cited above, extremely little is known about the distribution, sources, biological and chemical fates and chemical composition of the

DOC/DON pool in shelf waters within the NEMP region. A spatially and temporally comprehensive series of samples of seawater has been collected during 24 shelf surveys and frozen-archived for future analyses of dissolved organic nitrogen by members of the Environmental Chemistry Investigation, Sandy Hook (O'Reilly et al., 1980; Table 1). These samples will be extremely useful in constructing budgets for nitrogen and useful in mapping organically bound nitrogen in coastal water adjacent to the estuaries. Additionally, ratios of NH4:nitrate:nitrite:DON will provide a "fingerprint" on water masses (estuarine, slope water) and provide insight into the relatively roles played by nutrient sources from estuaries, slope water and in situ nitrogen recycling in supplying nitrogen to primary producers. Samples of seawater filtrates for dissolved organic carbon were taken during the October Superflux (Thomas) survey of the Chesapeake plume. Analytical results are not available at this time.

Inorganic Nutrients

Three Annual NEMP Reports describe macro-nutrient (nitrate-nitrite, ammonium, phosphate, silicate) concentrations in seawater (Wong, 1980; Whitledge, 1980; and O'Reilly et al., 1980). Wong's report describes the distribution of inorganic nutrient data in and around the plume of the Chesapeake estuary during the June 1980 Superflux survey. Wong found that the elevated concentrations of nutrients observed in the southern part of Chesapeake Bay did not extend far offshore or southward in the easily identified plume defined by the 32% salinity isopleth. Wong reported that levels of ammonia could be traced further east and south from the mouth of the Bay in the tongue of freshwater than nitrate, nitrite, phosphate, and silicate. Wong interpreted the paucity of nitrate-nitrite-phosphate-silicate nutrients in surface water to indicate active uptake of these nutrients by phytoplankton in the plume. He further speculated that the presence of ammonium in the plume and at the edge of the plume could be the net result of particularly active additions of NH4 from zooplankton (and mineralization) in the plume relative to active removal of NH4 by phytoplankton in the plume. In Wong's Figures 10-12 phosphate, ammonium, and silicate are relatively abundant in the deeper, more saline water near bottom (10-20 m) at the shoreward end of the west-east shelf transect. Wong offered two explanations of this pattern: 1) the higher nutrient levels near bottom reflect offshore water (salinities are relatively higher in inshore bottom water than in overlying water), and 2) the higher levels of these nutrients near bottom result from active mineralization of nutrients at the seabed and diffusion from interstitial water into bottom water.

Another interesting speculation made by Wong is that phosphorus, not nitrogen, may be the limiting nutrient, since ammonium was present and phosphate scarce in coastal water off Chesapeake during the two June surveys. O'Reilly et al. (1980) also reported that phosphorus was conspicuously scarce at stations south of Delaware Bay during the shelf-wide survey in May 1979 (DE-79-05).

Ryther and Dunstan (1971) have proposed that nitrogen may be the "critical limiting factor to algal growth and eutrophication in coastal marine waters". However, ambient concentrations of inorganic nitrogenous nutrients (or any nutrients) which are below detection may not necessarily mean that nitrogen (or any nutrients) is "limiting" algal growth. Some recent and extremely interesting research by McCarthy and Goldman (1979) indicated that "variability in the small-scale temporal and spatial patterns in nitrogeneous nutrient supply, coupled with an enhanced uptake capability for nitrogenous nutrients induced by nitrogen limitation, make it possible for phytoplankton to maintain nearly maximum rates of growth at media concentrations that cannot be quantified with existing analytical techniques".

In the light of this finding, inferences that phytoplankton production is nutrient limited, which are based on field-observations of low to below detection levels of nutrients, should be made with caution.

Several patterns in nutrient distribution across the Hudson Shelf transect appear in the NEMP reports by Whitledge (1980) and O'Reilly et al. (1980). Highest standing stocks of nitrate and nitrite were consistently found in deep water (80 m) at the shelf break during the April, June, July, and September 1980 New York Bight water column monitoring surveys. During the April and September surveys, nitrate and nitrite concentrations decreased from 2-6 ug-atN/L in the upper 10 m at the mouth of the Hudson-Raritan estuary to 0.1 ug-atN/L 15 km seaward of the estuary. During the June and July 1980 surveys this plume of nitrate and nitrite was not seen. During the stratified months relatively low concentrations of nitrate and nitrite and ammonium are seen in the euphotic layer from the perimeter of the apex to the shelf break. O'Reilly et al. (1980) also found low levels of NH_4 in the euphotic layer seaward of the apex along the Hudson transect during surveys in May, July, and September 1979. Low but detectable levels of NH_4 (0.2-0.8 ug-at/L) were seen in water above the pycnocline during the June and August 1979 surveys.

Whitledge (1980) reported the presence of high concentrations of ammonium in mid-shelf "cold pool" water below the seasonal pycnocline during the June and July 1980 survey. Similarly, O'Reilly et al. (1980) report high concentration of NH_4 (1-4 ug-atN/L) in subpycnocline water in the mid-Hudson shelf region in May, June, July, and August 1979. The low concentrations of ammonium observed in surface water in summer is probably the net result of high nutrient removal by phytoplankton relative to additions of NH_4 to standing stocks via the estuary and <u>in situ</u> upper water column mineralization. The relatively high stocks of ammonia seen throughout the Hudson transect below the pycnocline (O'Reilly et al., 1980; Figures 39, 40, 41, 42) are probably the result of very active benthic mineralization and subpycnocline water column mineralization. Ammonium nitrogen is considered to represent recently regenerated nitrogen (Dugdale and Goering, 1971). Whitledge (1980) commented on a strong inverse relationship between reductions in ambient dissolved oxygen and increases in ammonium stocks as the result of organic matter mineralization. He believes that because of this relationship, the measurement of ammonium levels constitutes a useful monitoring tool. Thomas et al. (1979) found inorganic phosphorus was correlated (r=-0.85) inversely with oxygen concentration during an August-September 1976 New York Bight survey. These nutrient-oxygen inverse relationships become especially useful in assessing the amount of anaerobic metabolism which has occurred in a water mass since these nutrients continue to accrue while dissolved oxygen remains at 0 ml/L (Thomas et al., 1979; Figure 11).

From the Hudson Shelf profiles discussed above it is clear that estuarine/neretic sources of nutrients are superimposed on nutrient stocks actively supplied by in situ benthic and water column mineralization and by slope water inputs to the shelf and by nutrients stored in residual water masses such as the "cold pool".

During the September 1980 Ocean Pulse survey A. Draxler and W. Phoel (Sandy Hook Laboratory) measured rates of nutrient flux at the seabed at sites located throughout the NEMP region to quantify the potential role which the seabed plays as a source of nutrients. In September average rates of daily phytoplankton carbon production on the shelf are about 1.4 $gC/m^2/d$ (O'Reilly et al., 1980). Assuming a C:N uptake ratio of 6.63 C:1N, then the daily N requirements of the September phytoplankton community are 17,610 umoles $N/m^2/d$. Average (shelf) rates of ammonium flux in sediments in September were roughly equal to 10 umole $NH4/m^2/hr$ or about 1.4% of the nitrogen required by phytoplankton. Data on nitrite and nitrate flux from sediment cores is not yet available, however it is likely that total inorganic nitrogen flux (ammonium, nitrate, nitrite) from sediments to the overlying water is equivalent to less than 5% of the daily nitrogen assimilation requirements of phytoplankton in September 1980.

The highest sediment ammonium flux rates observed during the September 1980 Ocean Pulse survey (300-500 $umole/m^2/hr$, at the New York Bight apex sludge dump site and at the mouth of the Delaware estuary) could potentially supply 40-68% of the daily nitrogen requirements of the phytoplankton (O'Reilly et al., 1980). The significance of mineralization in the sediment as a nutrient source for plankton productivity has been suggested to range from over 30% of their requirements inshore, to less than 20% at the shelf break (Harrison, 1980). During a survey of the New York Bight in 1977 Thomas et al. (1979) report that the seabed contributed an average of 6% to total (water column and seabed) aerobic oxygen consumption. If the ratio of nutrients released to oxygen consumed is similar at the seabed and in the water column then the seabed is not the predominant source of nutrients required by the actively assimilating summer stocks of phytoplankton in the New York Bight. Studies of the New York Bight and Georges Bank (Thomas et al., 1978, 1979) have pointed out that organic mineralization in the water column may represent a major source of recycled nutrients. Walsh (1980) estimated that approximately 46% of the annual nitrogen demand of phytoplankton in the New York Bight is supplied by recycling mineralization processes.

Results of descriptive-baseline monitoring programs such as NEMP should be used to identify and define areas where additional descriptive baselines and "process-oriented studies" are needed to "explain" and provide additional insight into monitoring studies already underway.

More shelf-wide descriptive baseline studies of in situ heterotrophic mineralization of organic matter and concomitant release of nutrients are needed before an accurate assessment can be made concerning the relative roles played by estuarine/neretic and slope water sources of nutrients in supplying the nitrogen required by the very productive phytoplankton communities throughout the Cape Hatteras-Nova Scotia shelf system (section 4.2 in O'Reilly et al., 1980).

It has been suggested to me by M. Ingham and others that we pay particular attention to nutrient and primary productivity data collected during the summer in 1979 and 1980. The discharge of freshwater from Mid-Atlantic Bight estuaries into the NEMP coastal region was significantly lower in the summer of 1980 than in 1979. 1979 represents the first year of intensive (10 surveys/yr) shelf-wide Ocean Pulse surveys of the distribution of nutrients and primary productivity. This data as well as the New York Bight water column monitoring surveys represent a baseline for comparison against the 1980 data. Comparisons of coastal standing stocks of nutrients, phytoplankton biomass, and organic production and subpycnocline dissolved oxygen levels measured in the summer of 1979 with those measured in summer 1980 may provide insight into the relative role played by estuarine nutrient sources (and man) in stimulating phytoplankton production.

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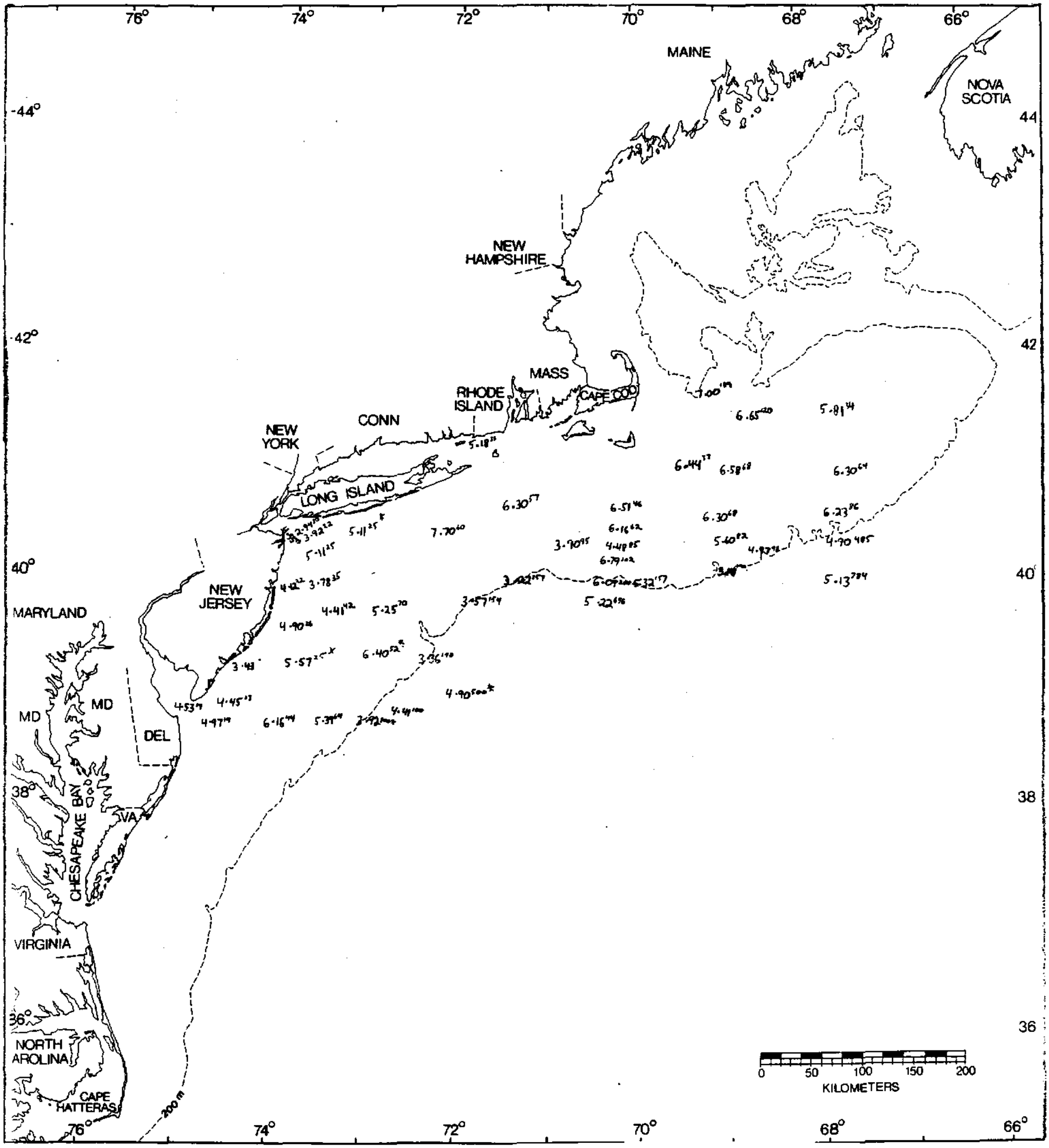

Figure 1. Near-bottom concentrations of dissolved oxygen (ml O_2/L). measured during the July AL-79-07 survey. Superscripts = sampling depth (m).

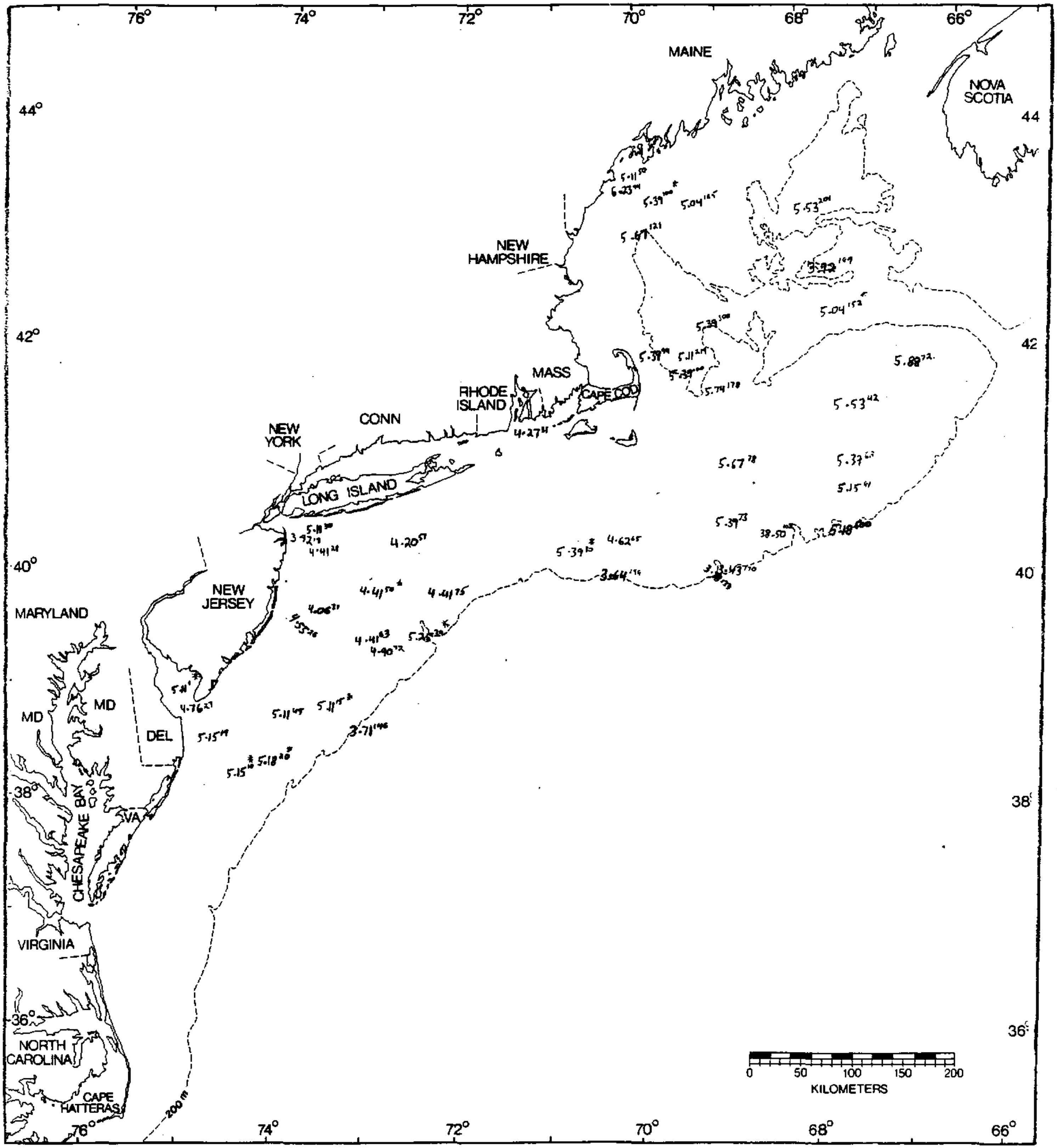

Figure 2. Near-bottom concentrations of dissolved oxygen (ml O_2/L) measured during the September AL-79-10 survey. Superscripts = sampling depth (m).

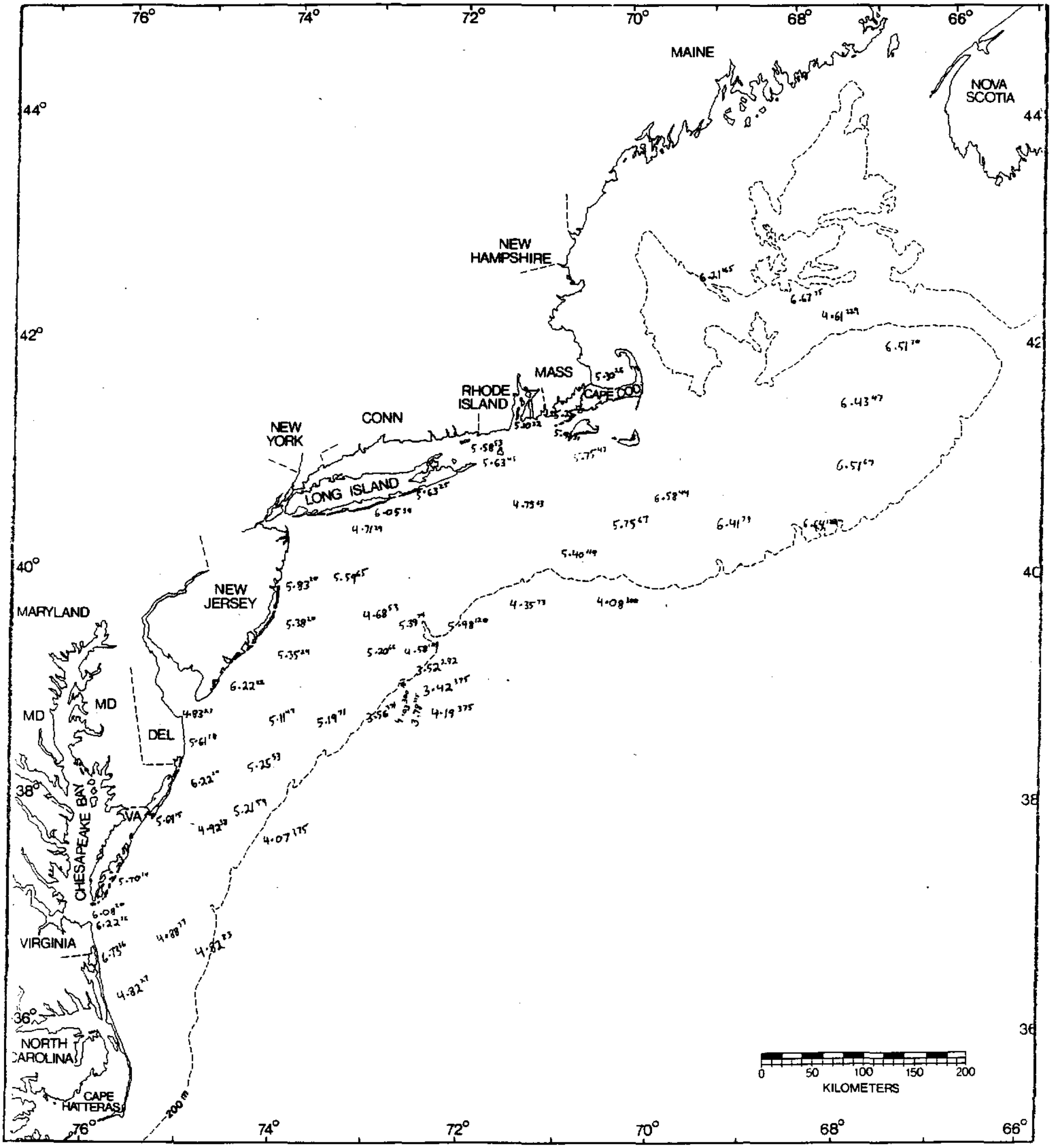

Figure 3. Near-bottom concentrations of dissolved oxygen (ml O_2/L) measured during the July AL-80-07 survey. Superscripts = sampling depth (m).

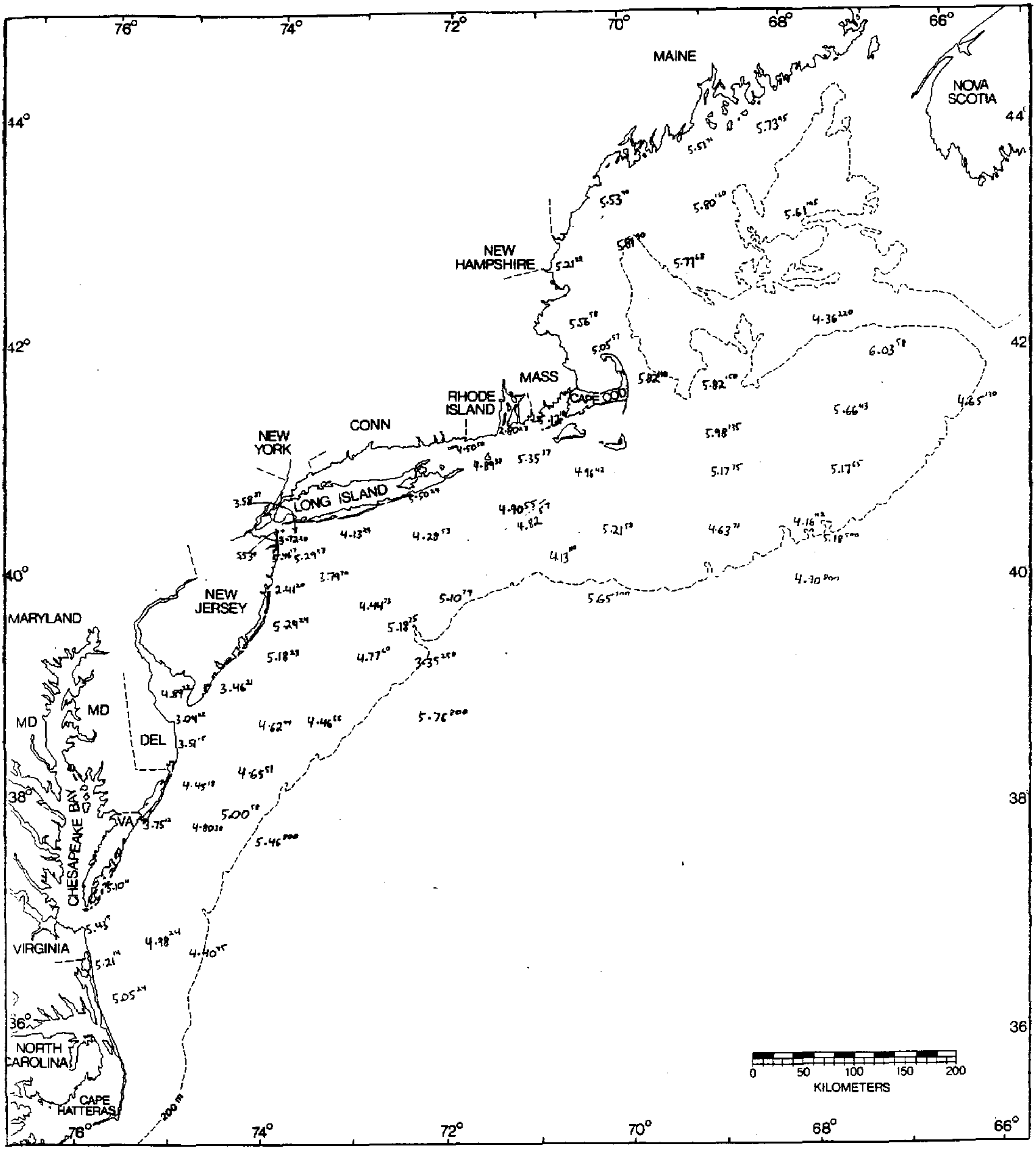

Figure 4. Near-bottom concentrations of dissolved oxygen (ml O_2/L) measured during the September AL-80-09 survey. Superscripts - sampling depth (m).

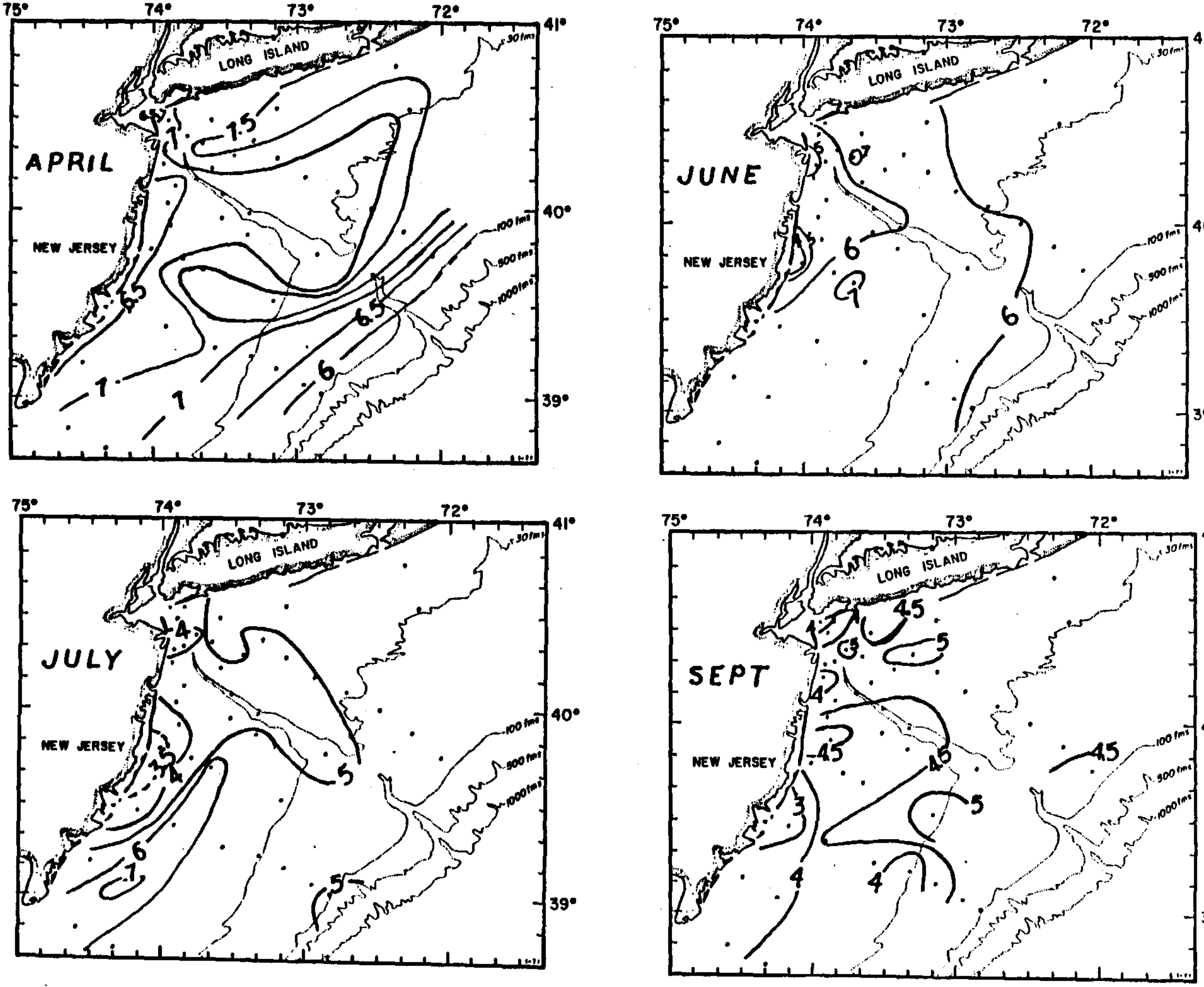

Figure 5. Bottom dissolved oxygen (ml O_2/L) during four 1980 New York Bight Water Column Monitoring survey (from Whitledge, 1980).

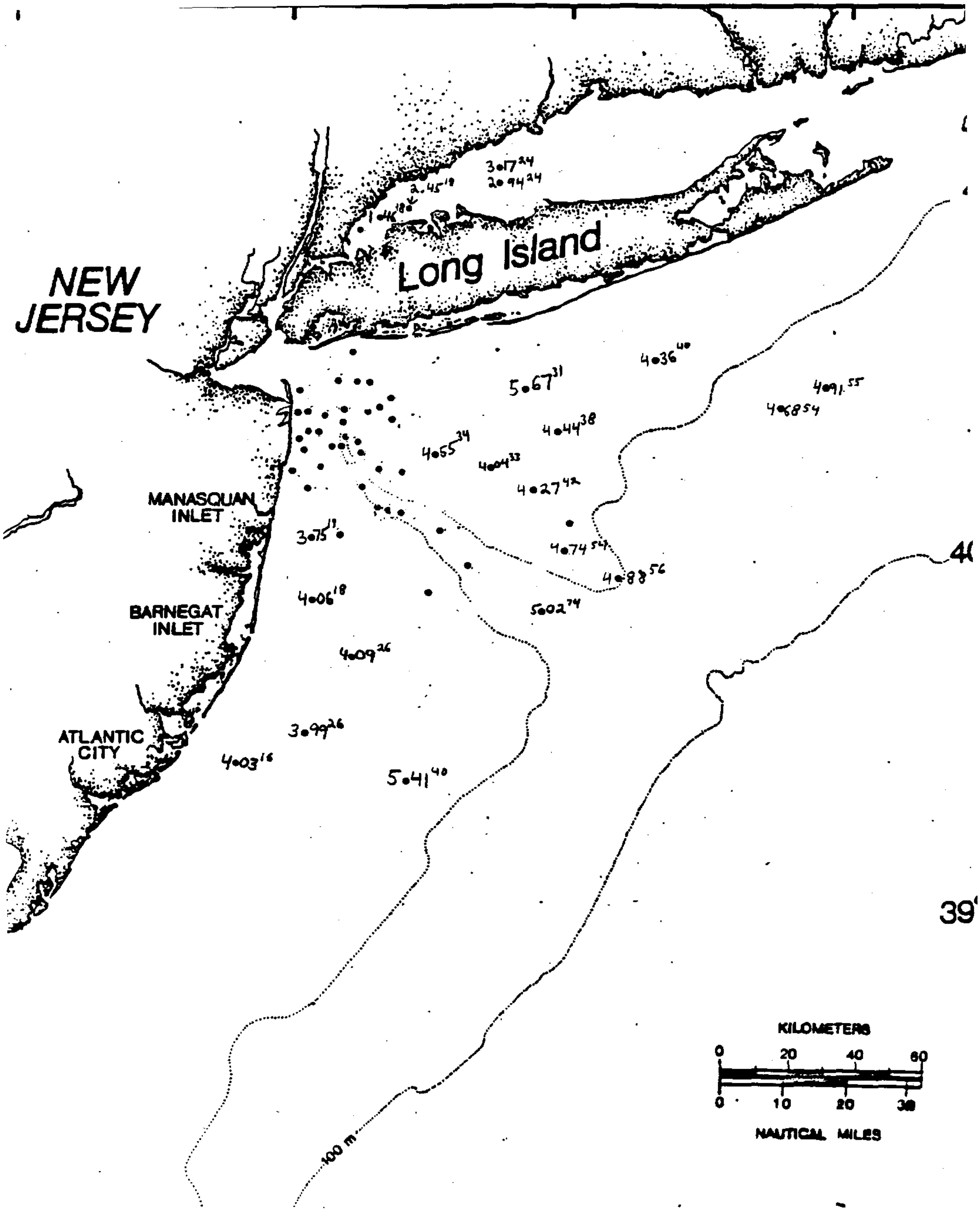

Figure 6a. Near-bottom concentrations of dissolved oxygen (ml O_2/L) measured during the August KE-80-07/08 survey. Super-

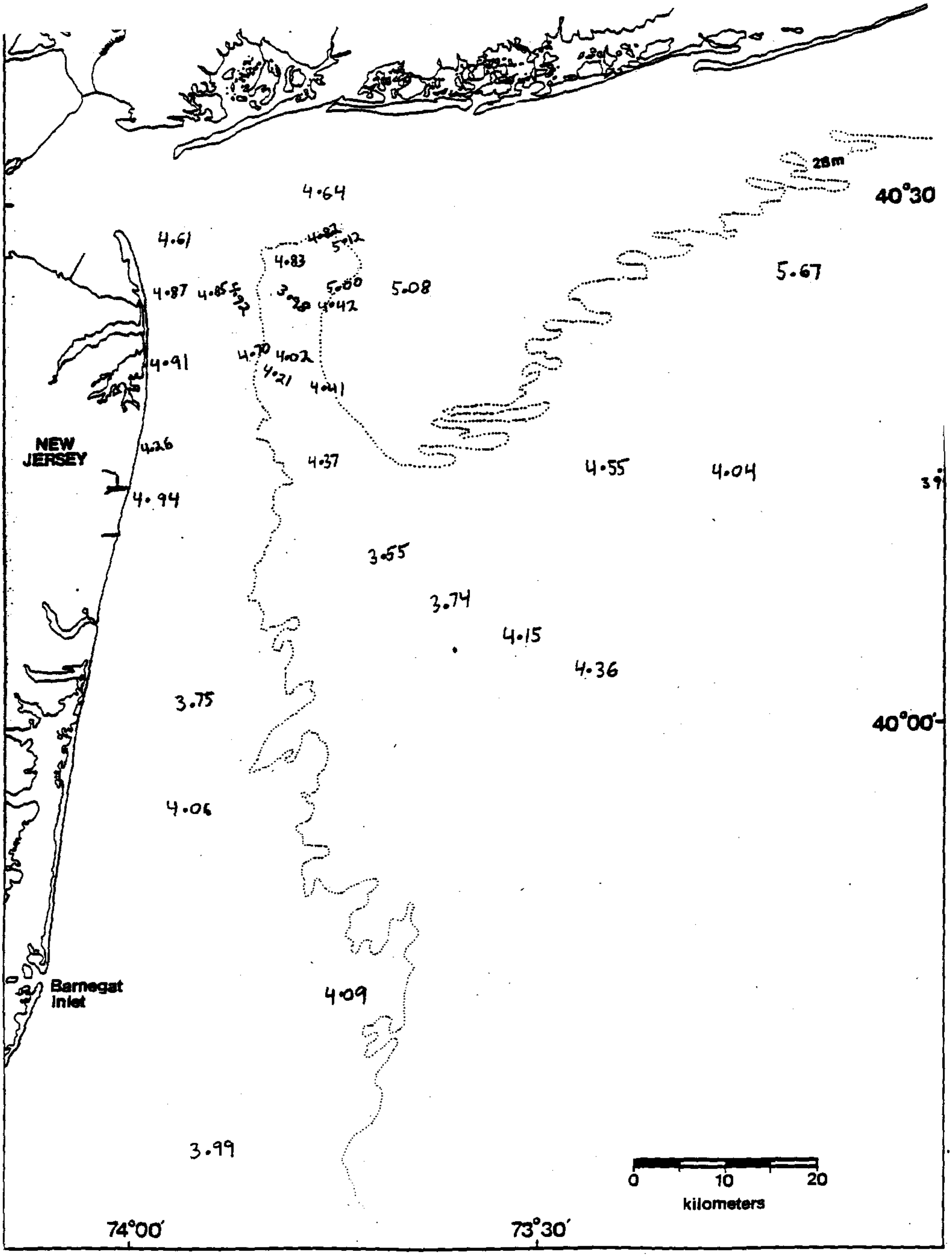

Figure 6b. Near-bottom concentrations of dissolved oxygen (ml O_2/L) measured during the August KE-80-07/08 survey. Superscripts = sampling depth (m).

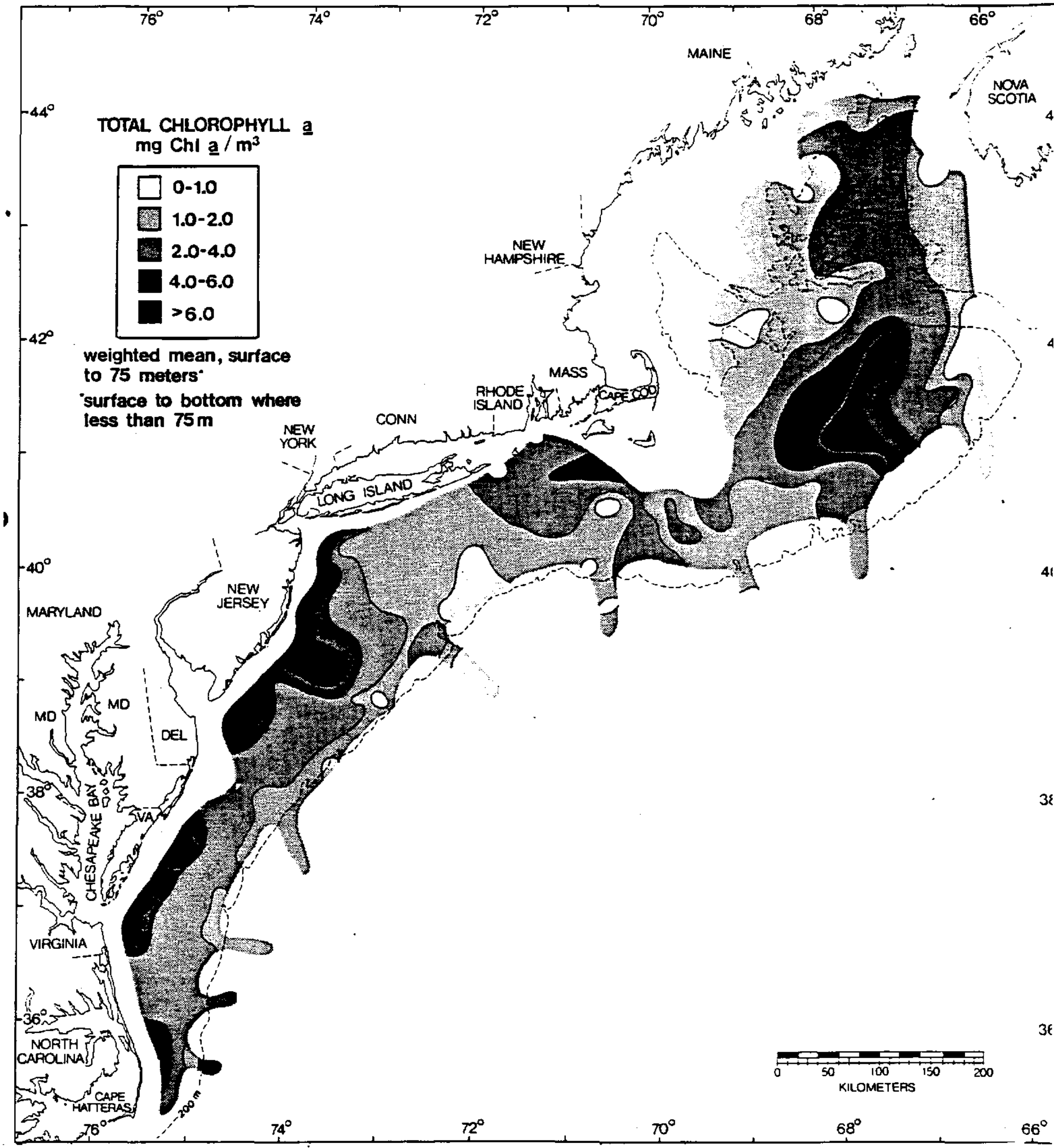

Figure 7. Distribution of average water column chlorophyll a, August 1978.

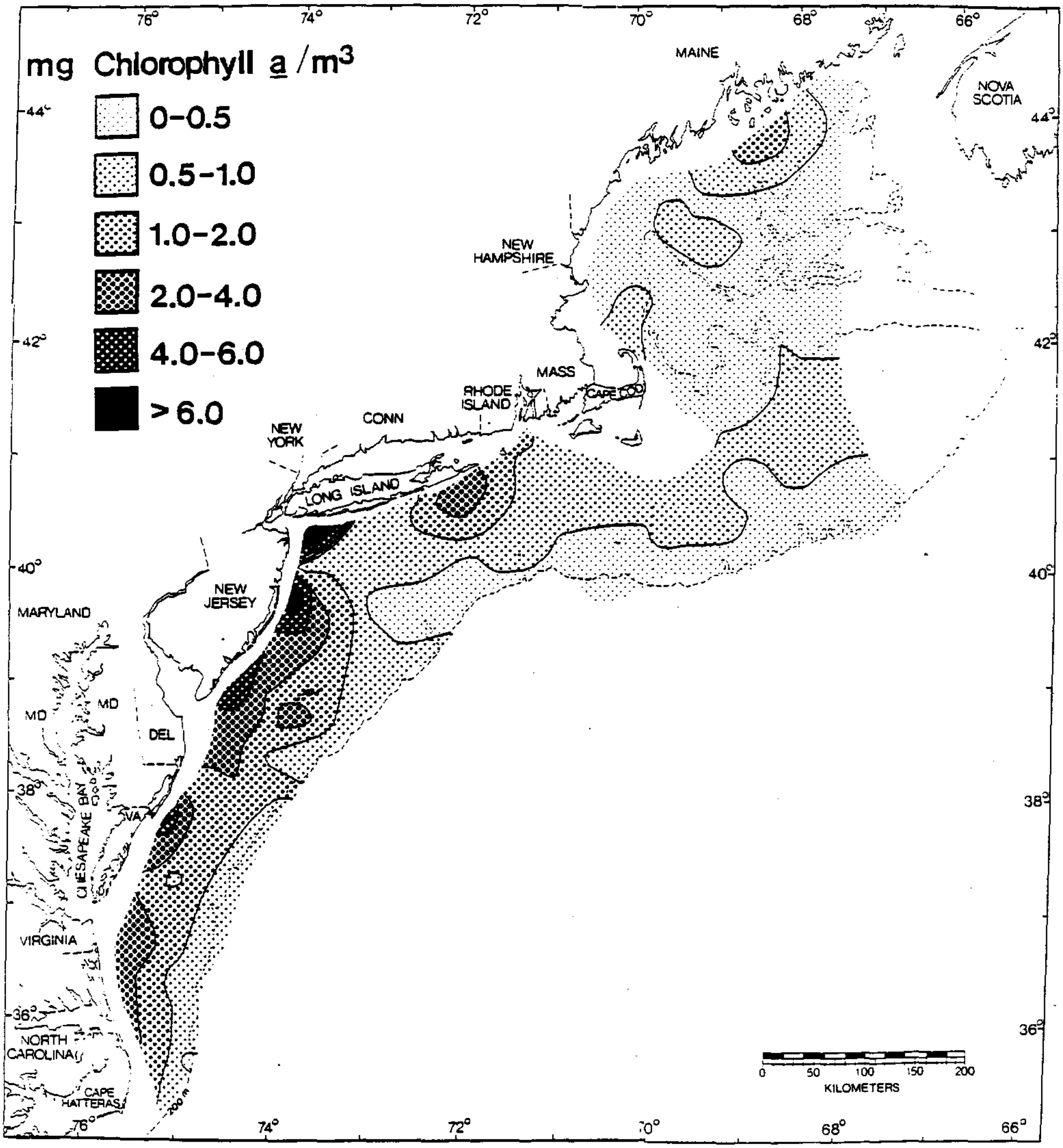

Figure 8. Distribution of average water column chlorophyll a, August 1979.