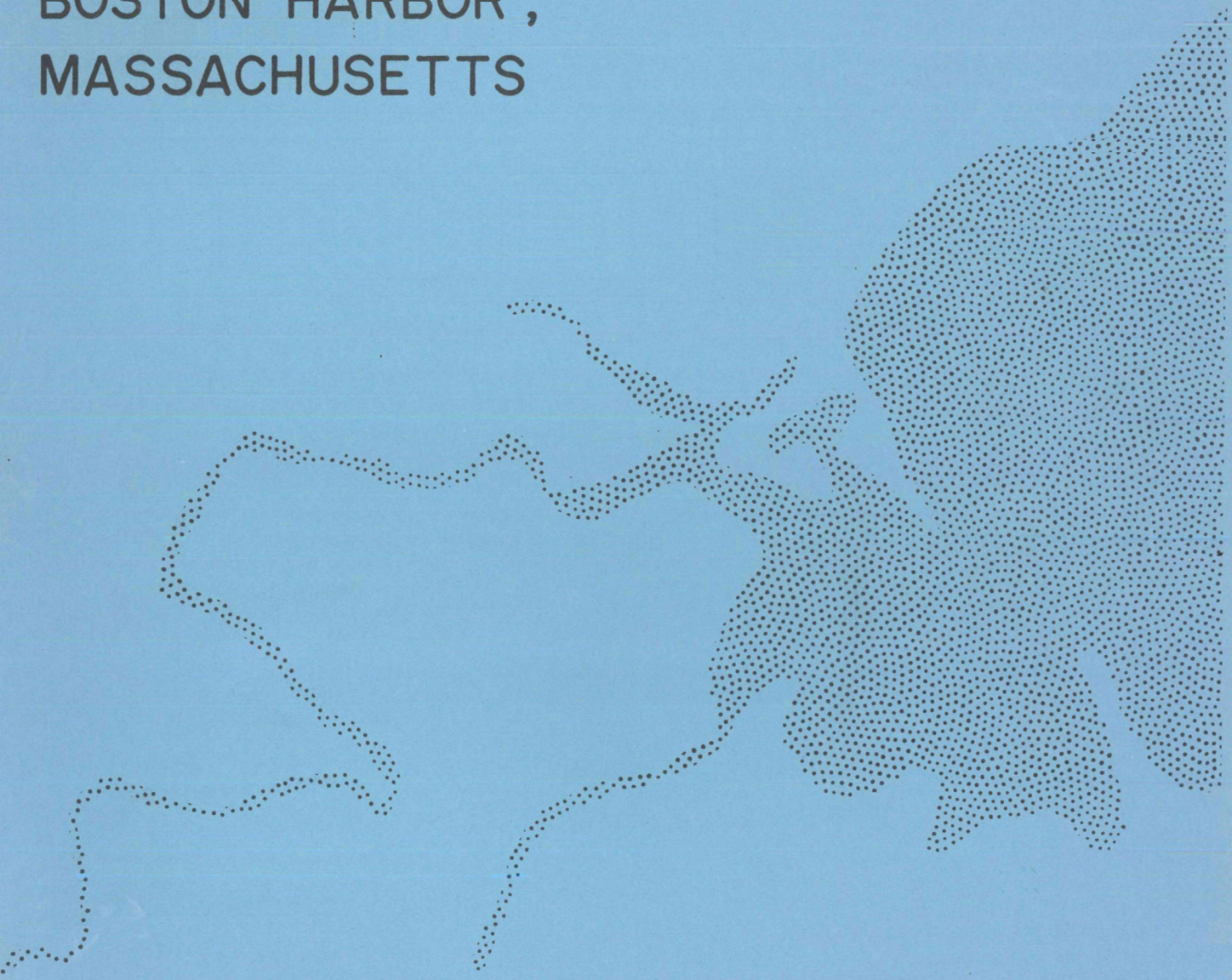
BIOLOGICAL ASPECTS OF WATER QUALITY CHARLES RIVER AND BOSTON HARBOR, MASSACHUSETTS



TECHNICAL ADVISORY & INVESTIGATIONS BRANCH
FEDERAL WATER POLLUTION CONTROL ADMIN.
U. S. DEPARTMENT OF THE INTERIOR

BIOLOGICAL ASPECTS OF WATER QUALITY

CHARLES RIVER AND BOSTON HARBOR, MASSACHUSETTS

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SUMMARY AND CONCLUSIONS

1. The Charles River is the principal tributary of Boston Harbor. It begins about two miles upstream from Milford, Massachusetts and follows a general northeasterly direction for about eighty miles to Boston, Massachusetts where it drains into Boston Harbor. Studies of bottom-associated aquatic life, nutrients, aquatic plants, and river deposits showed water quality degradation and sludge deposits from wastes originating in Milford, Massachusetts and with additional waste contributions in downstream reaches, polluted conditions extended through Medfield, Massachusetts, a distance of 32 stream miles.
2. Improved conditions in the Charles River existed from South Natick to Wellesley, Massachusetts as evidenced by a predominance of clean water bottom animals; however, nutrients from upstream sources caused dense growths of rooted aquatic plants and phytoplankton in the improved reaches.
3. Combined sewers discharged to the Charles River over a distance of fifteen stream miles in the Boston metropolitan area ultimately caused severely degraded water in the most downstream segments of the river.

4. A total of 75 stream miles of the Charles River was damaged by the discharge of inadequately treated waste waters.

5. The Charles River discharged severely polluted water to Boston Harbor.

6. Boston Harbor is approximately 44 square miles in area. It has salinity features controlled chiefly by tides and is a vertically-mixed estuary having more affinities with embayments than estuaries and aquatic life that is marine rather than estuarine. Boston Harbor received wastes from 2.5 million people plus industrial wastes from the Boston metropolitan area. The average discharge of wastes from this area exceeds 400 cubic feet per second, and the dry-weather discharge of tributary streams is near 100 cubic feet per second.

7. In addition to the Charles River, Boston Harbor has seven other tributaries, the Mystic, Malden, Chelsea, Neponset, Weymouth Back, Weymouth Fore, and Weir Rivers. Studies showed that five of these seven rivers were polluted by wastes originating in the Boston metropolitan area.

8. Combined sewers discharged wastes to the saline reaches of the Mystic, Malden, Chelsea, Weymouth Fore, and Neponset Rivers. A paucity of aquatic life indicative of clean marine waters, excessively abundant polychaete worms, and sludge deposits mixed with oily residues in these tributary reaches were indicative of grossly polluted waters.

9. At least six stream miles of the fresh-water segments of the Neponset River in the vicinities of Dedham and Milton, Massachusetts were grossly polluted, as shown by a predominance of pollution-tolerant sludgeworms and other waste-water-associated aquatic life.

10. The remaining tributaries to Boston Harbor were not perceptibly contaminated by waste waters. The most inland saline waters of the Weymouth Back and Weir Rivers supported a variety of animals suggestive of clean marine waters such as bivalve molluscs, cumaceans, shrimp, and limpets. Oily residues were not found in the bottom deposits of these tributaries.

11. Discharges of municipal and industrial wastes originating in the Boston metropolitan and harbor areas caused degraded water in all of Boston Harbor and associated bays inland from the harbor mouth near Massachusetts Bay, and included Winthrop Bay, Boston Outer Harbor, Boston Inner Harbor, the Fort Point Channel, Dorchester Bay, Quincy Bay, Hingham Bay and Hull Bay. A paucity in the variety of aquatic life in these waters showed such degradation.

12. Deposition of nutrients from these wastes effected overly-abundant, pollution-indicating populations of polychaete worms that exceeded 200 per square foot in 34 square miles (80 percent) of Boston Harbor. Populations less than 200 per square foot were associated with the inland sectors of Quincy Bay and those seaward along a

narrow course through Nantasket Roads to the southern mouth of the harbor at Massachusetts Bay.

13. About 14 square miles (30 percent) of Boston Harbor were grossly polluted as was suggested by polychaete worms that numbered 1,000 or more per square foot. Oily residues, foul odors, and suspended sewage-like particles often were apparent in most reaches of the harbor.

14. Inorganic nutrients, ammonia nitrogen and soluble phosphorus, were greater than 100 and 40 micrograms per liter, respectively, in all reaches of Boston Harbor and adjacent bays inland from its mouth near Massachusetts Bay. These effected excessively dense populations of phytoplankton that averaged more than 1,000 per milliliter (indicative of overly enriched waters) in about 35 square miles (66 percent) of the harbor, including the Weymouth Back and Fore Rivers, and the saline waters of the Charles, Mystic, Malden, and Chelsea Rivers.

15. The Fort Point Channel in the Boston Inner Harbor area contained sludge with very high percentages of organic carbon (23.5 percent) and organic nitrogen (1.29 percent) similar to those of raw wastes from packinghouses, sewage, or rapidly decomposing sludge. The waters of this channel were severely polluted, and septic.

16. Percentages of organic carbon and nitrogen in other harbor beds showed extensive bottom deposits of decayed organic materials.

17. Core samples of bottom deposits somewhat distant from immediate waste sources and known channel dredging activities indicated gradual increases in the percentages of organic matter deposited in recent times, i. e. highest values occurred near the top or most recently deposited portion of the core. Similar samples from areas close to major waste sources and remote from known channel dredging activities indicated variations in depositions of organic matter with no gradual trend between the upper or lower portion of the core.

INTRODUCTION

CHARLES RIVER

The Charles River begins about two miles upstream from Milford, Massachusetts and follows an irregular, but generally northeasterly course for about eighty miles to Boston, Massachusetts where it enters Boston Harbor. Principal tributaries influencing water quality are Mine Brook and the Stop River, both located in Massachusetts. Flowing through forested lands and several urban and rural communities, the Charles River drains many swampy and bog-like areas that contribute acidic waters with a pH below 7.0 along much of its course. Except for its most downstream reach near Boston, the entire river is slightly acidic, and in at least one upstream reach the river has pH values as low as 6.2.

In addition to the swampy and bog-like areas, several small man-made dams are situated on the river, and these provide a combination of features wherein the river is alternately impounded and free flowing with a great variety of habitats. At one point, about midway along its course at Dedham, Massachusetts some of the water in the

Charles River is diverted to the Neponset River via the Mother Brook tributary. The annual average discharge rate of the Charles River is near 500 cfs, and the dry weather flow typically is about 50 cfs.

BOSTON HARBOR

Boston Harbor, one of the most heavily utilized harbors on the Atlantic Coast, is a major natural economic asset of the State of Massachusetts. It is a watercourse that bridges the Atlantic Ocean to the Massachusetts coastline, serves both commercial and military navigation, provides berthage, protects from heavy seas, provides recreation, produces food, and assimilates untreated and partly treated sewage from 2.5 million people plus industrial wastes from the Boston metropolitan area. Wastes from an additional 0.4 million people and several industries are added to Boston Harbor or its tributaries from sources adjacent to the metropolitan area.

Boston Harbor has an area of approximately 44 square miles, (28,000 acres) with depths ranging generally between 10 and 50 feet at mean low tide. Extensive areas of the bay are less than 15 feet deep. Large-craft navigation channels are dredged to maintain minimal depths of 30 feet, and small-craft channels are maintained at a minimum depth near 12 feet. Hydraulic and salinity features of the harbor are controlled chiefly by tides and, to a much lesser extent, by fresh water discharges from tributaries. The relatively small discharge of fresh water coupled with other hydraulic features precludes development of a

salt-wedge water mass, and facilitates a vertically mixed type of estuary having more affinities with embayments than estuaries and aquatic life that is marine rather than estuarine.

Seven other tributaries in addition to the Charles River drain into Boston Harbor. Only four, the Malden, Mystic, Charles and Neponset Rivers, discharge significant amounts of fresh water. The Chelsea, Weymouth Back, Weymouth Fore, and Weir Rivers are tidal streams comprised mostly of saline harbor water. During periods of low precipitation, the tributary fresh-water discharge to Boston Harbor is near 100 cfs (cubic feet per second) and the discharge of sewage and industrial wastes exceeds 400 cfs. The total discharge of fresh waters during these periods does not drastically modify the salinity of the harbor. Except for mouths of tributaries, salinity values in all harbor reaches during periods of low precipitation are greater than 25 parts per thousand.

Biological studies of Boston Harbor and its tributaries were conducted to assay water quality and its effect on aquatic life, and to provide supplemental information to engineering, chemical, and bacteriological water quality data. Biological studies were comprised of two conjoined surveys: investigations of the Charles River from the vicinity of Milford, Massachusetts downstream to its confluence with Boston Harbor; and studies of Boston Harbor plus its other tributaries, the Chelsea, Malden, Mystic, Neponset, Weymouth Back, Weymouth Fore and Weir

Rivers. Segments of Boston Harbor that were surveyed for biological and other data included Boston Inner Harbor, Boston Outer Harbor, Dorchester Bay, Quincy Bay, Hingham Bay, Winthrop Bay, and Hull Bay. Supplemental stations for biological data only were established in the inland reaches of Winthrop Bay, the Fort Point Channel, and in Massachussets Bay at the Brewster Islands. The general study area is depicted in Figure 1.

Biological surveys can show gross as well as subtle changes in aquatic environments as these are modified by human activities or man-produced wastes. Aquatic life associated with the benthic reaches of water courses best show these changes because they have life cycles extending for one year or more and thus reflect water quality over a long period of time. In addition most bottom-associated organisms have limited methods of locomotion that restrict them to specific areas; these organisms are used to delineate superimposed water quality whether in a stream, lake, estuary, or embayment. Many previous studies have shown that changes in water quality sufficient to adversely alter the population structure of bottom dwelling organisms also similarly modify other living components of the aquatic environment such as algae and fish, the latter often comprising an important economic asset of the total aquatic resource.

Unpolluted waterways support several kinds of clean-water-associated bottom organisms such as mayflies, stoneflies, certain

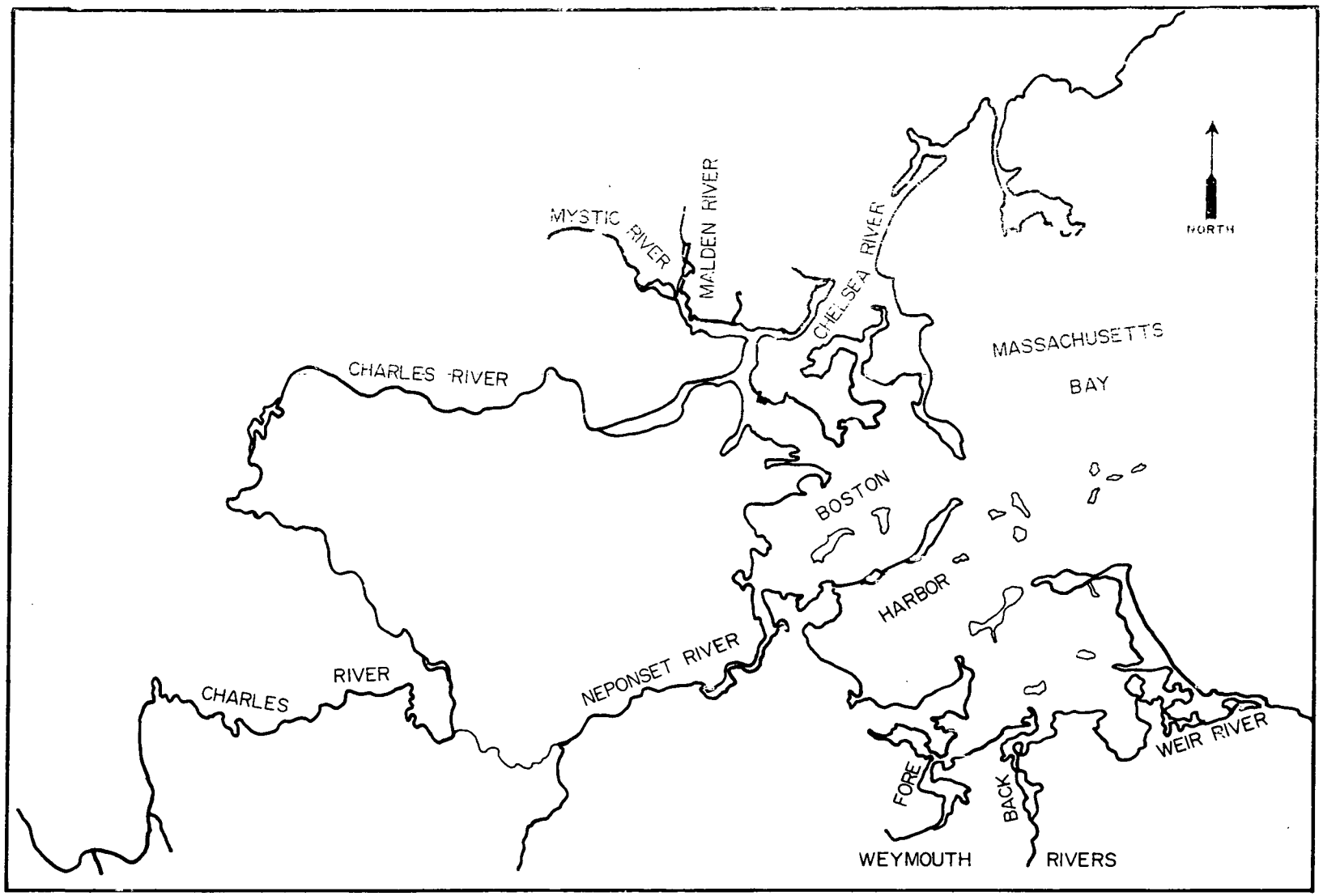

FIGURE I. BOSTON HARBOR - CHARLES RIVER STUDY AREA, JULY-AUGUST 1967.

beetles, and caddisflies that occur in clean fresh-water streams and lakes, or crabs, brittle-stars, shrimp, and starfish that are found in clean marine waters. Organisms that exhibit an intermediate response to pollutants also may be present in clean waters, but pollution-tolerant organisms usually are few in number. Water quality that permits the development of an assemblage of clean-water-associated forms provides food for fish, prevents development of nuisance organisms in large numbers, and provides for maximum recreational usage. Bottom dwelling organisms respond to domestic and industrial wastes in various ways that depend largely on amounts and kinds of such materials entering their environments. One response of such populations is manifest by the loss of a few kinds of organisms that thrive only in clean waters, while those associated with mildly polluted waters increase slightly in numbers. A more drastic response involves the disappearance of all clean water forms and the development of pollution-tolerant organisms often associated with sludges and slimes. Wastes that contain toxic substances or generate toxic conditions cause a loss of all kinds of organisms.

WATER QUALITY

CHARLES RIVER

Aquatic Life

Two principal changes occurred in the population of bottom-dwelling animals in the Charles River as the result of waste discharges. One change was evidenced by a reduction in the number of kinds of organisms by settleable solids and by slime growths resulting from organic waste discharges, and a concommittant increase in the numbers of remaining bottom-associated organisms effected by an increased food supply. The other change was shown by a loss of all bottom-associated animals. Such a change usually is associated with toxic wastes or other wastes that generate septic or toxic conditions.

Bottom samples collected from the Charles River at river mile 76.9 near the Route 16 bridge in Milford, Massachusetts (Figure 2) contained 15 different kinds of animals including clean water associated mayflies and caddisflies (Figure 3 and Table 1). This reach of the Charles River is located immediately downstream from a pond that discharges slightly acid water with a measured low pH of 6.2, and has been modified recently by construction activities. If not for such

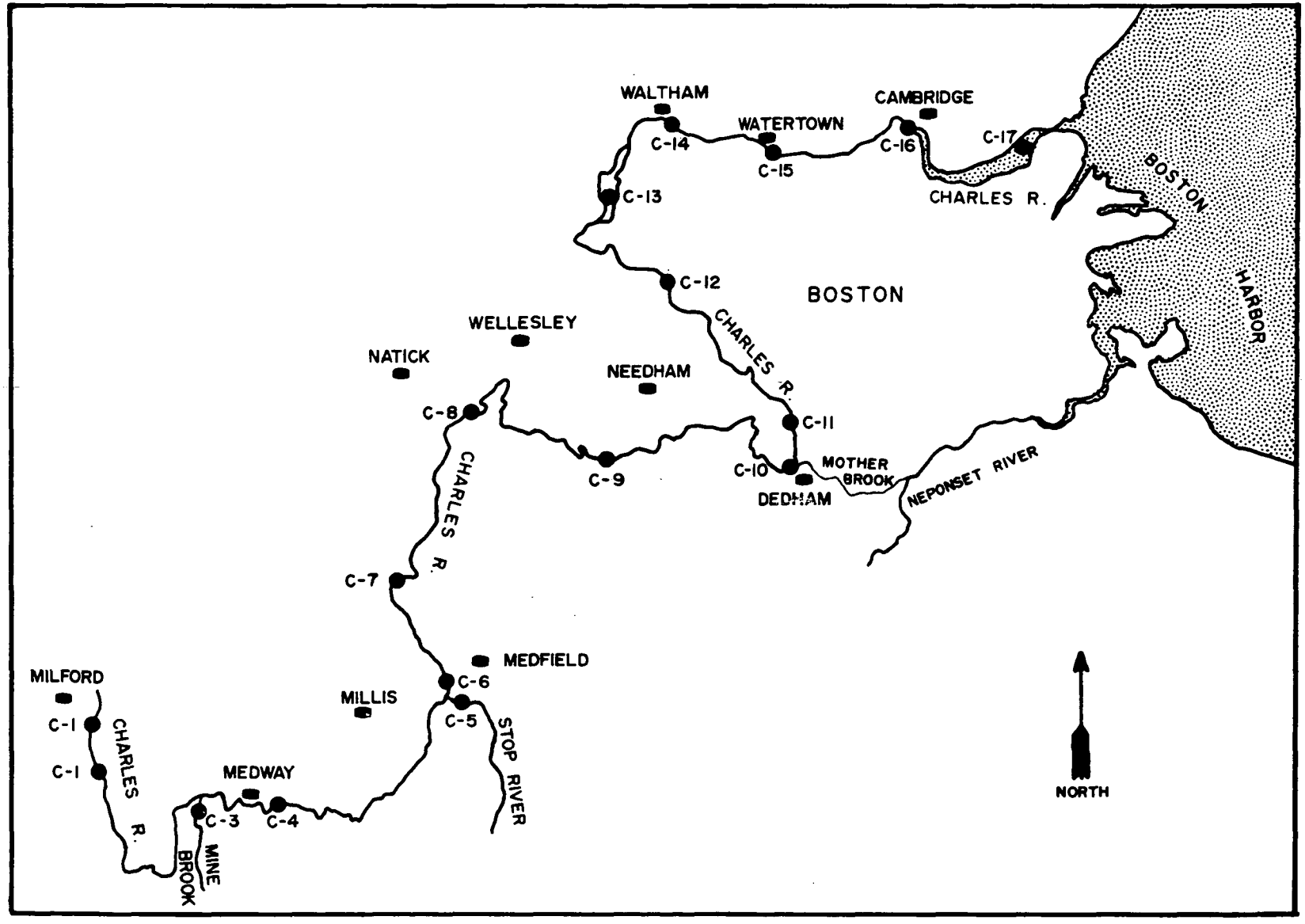

FIGURE 2. CHARLES RIVER SAMPLING STATIONS.

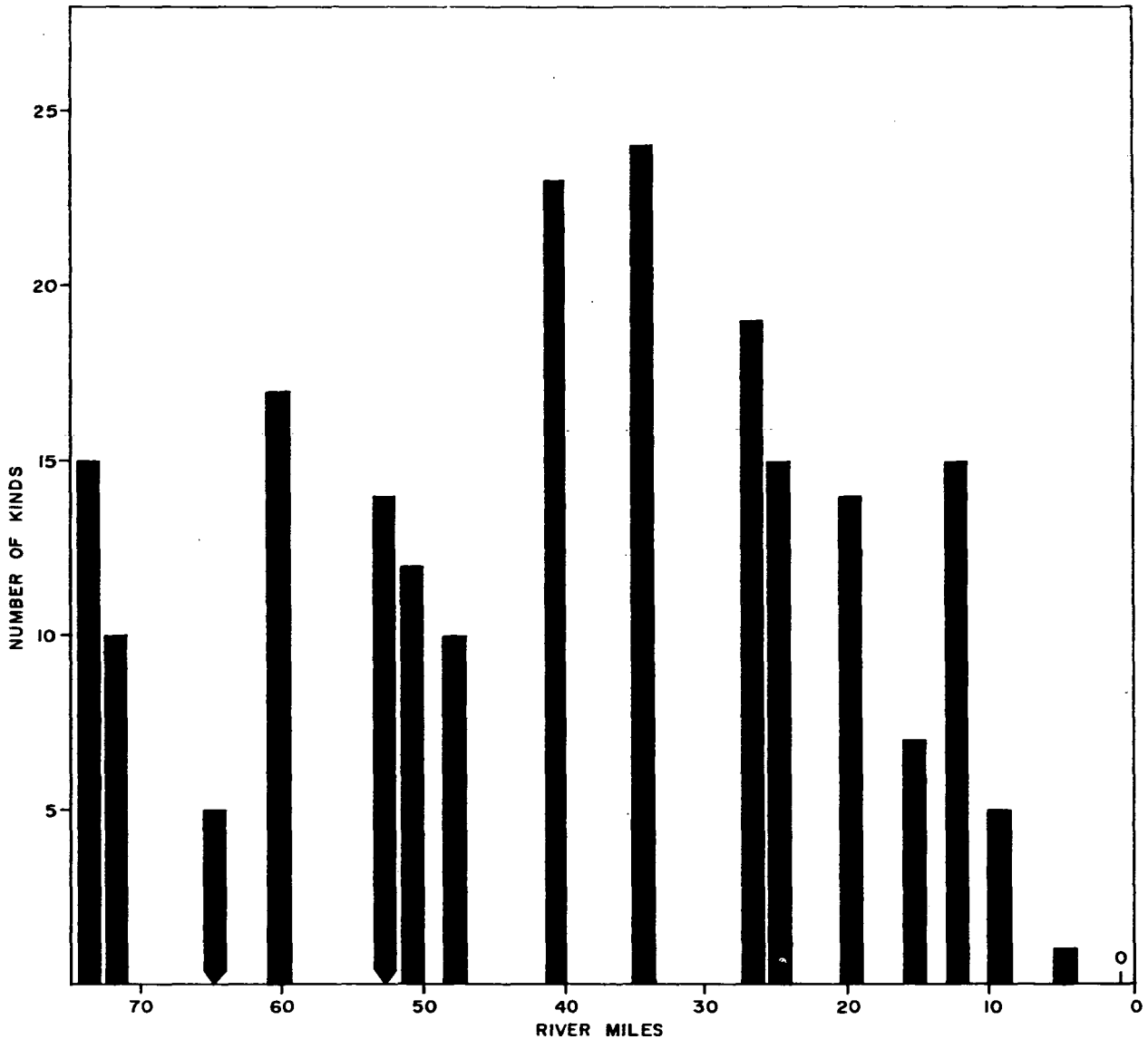

FIGURE 3. NUMBER OF KINDS OF BOTTOM ORGANISMS, CHARLES RIVER, JULY-AUGUST, 1967.

activities, this unpolluted reach would have supported an even more diverse population of benthic animals such as were found downstream in reaches not perceptibly modified by recent construction activities.

Because of recent construction, the Charles River at mile 76.9 did not support a dense population of benthic animals. Conventional quantitative sampling devices, such as the Petersen dredge, were not used to enumerate organism density, and only qualitative samples of benthic forms on artificial and natural substrates were taken. Data from samples of phytoplankton (suspended algae) support the fact that this reach contained clean water. These samples were comprised of clean-water-associated algae that collectively amounted to only 500 cells per milliliter, (0.35 parts per million by volume, ppm) compared to the 15,000 per milliliter found in organically enriched reaches (Figure 4 and Table 2). Sludges, oils, odors, and slimes indicative of defiled waters were not found in this segment of the river.

Municipal wastes from Milford, Massachusetts substantially degraded the river at mile 74.7 as was evidenced by the presence of foul, sewage odors in the turbid waters and in the settled oozy materials in this river reach. Water quality degradation was shown also by the benthic animal population in which 3,740 pollution-tolerant sludgeworms per square foot predominated (Figure 5). Pollution-sensitive organisms were lacking, and there was a decrease to 11 kinds of animals from 15 at the upstream reach. This pollution-tolerant sludgeworm population

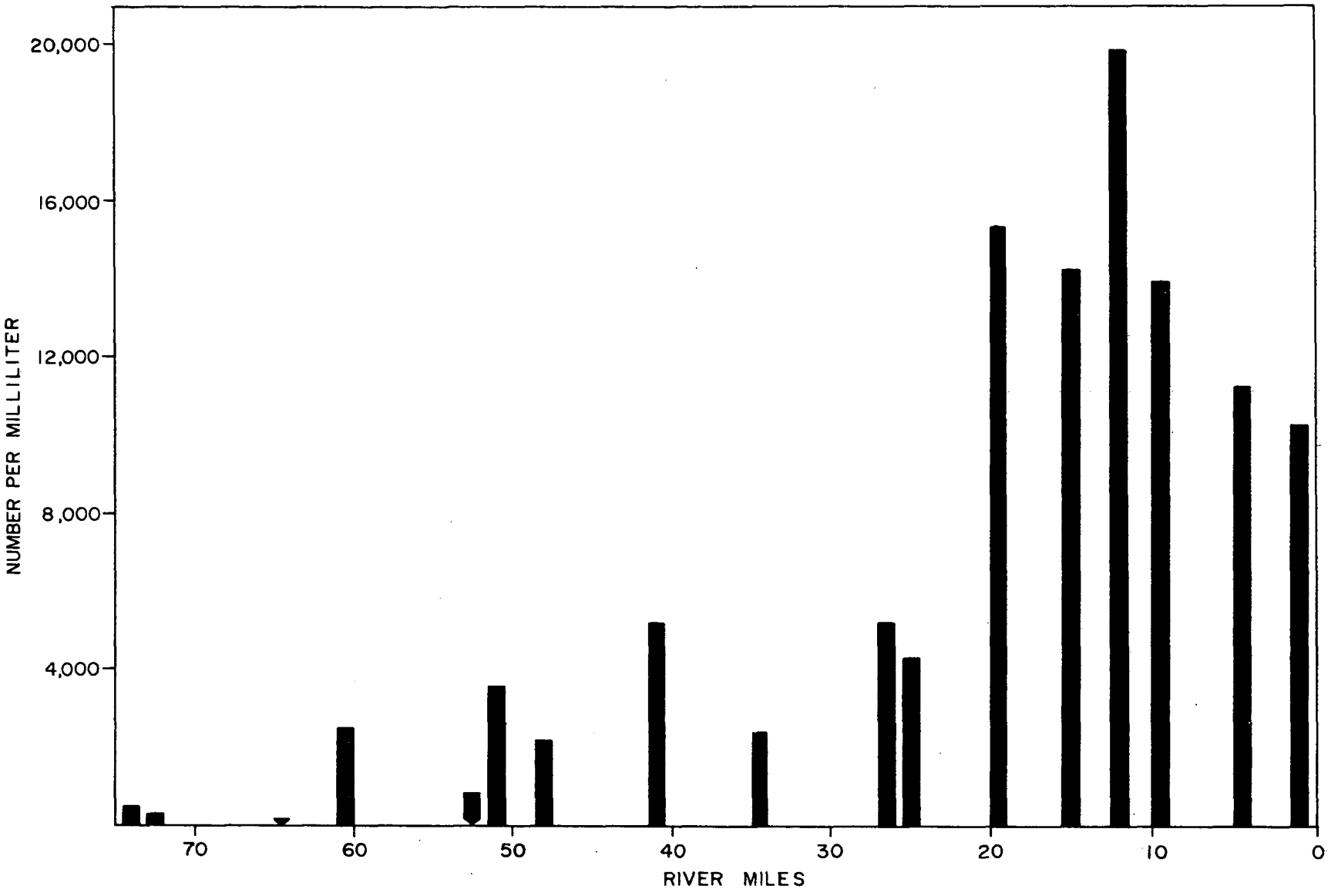

FIGURE 4. CHARLES RIVER PHYTOPLANKTON (number/ml.), AUGUST, 1967.

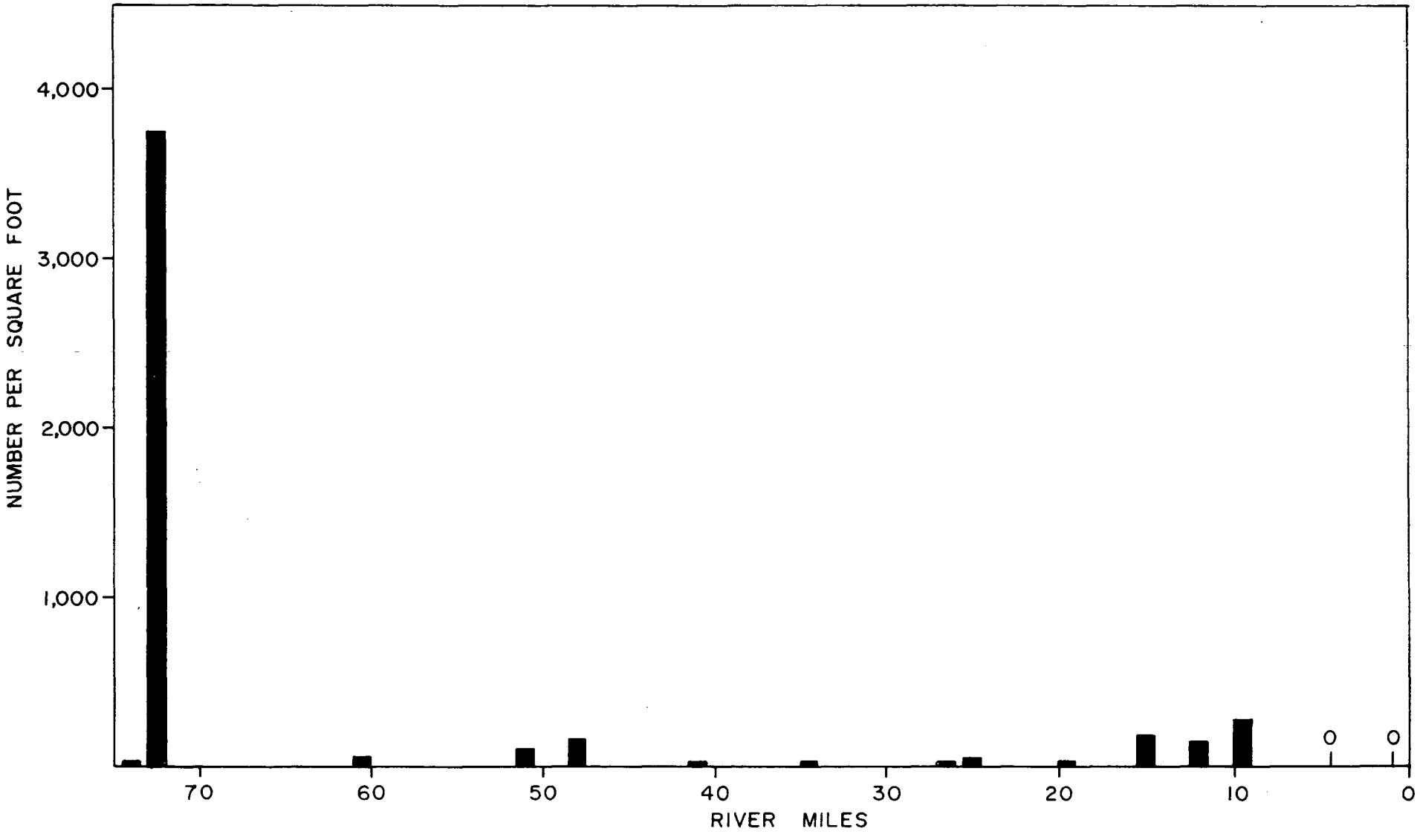

FIGURE 5. POLLUTION-TOLERANT SLUDGEWORMS, CHARLES RIVER, AUGUST, 1967

was dependent on an abundant supply of organic wastes such as those from the community of Milford, Massachusetts. Such data reflect the grossly polluted character of the river reach.

Wastes entering Mine Brook from the sewage disposal facility near Unionville, Massachusetts caused degradation of water quality in Mine Brook, and contributed polluted water to the Charles River at mile 64.7. The paucity of clean water forms, an abundance of intermediately tolerant sow bugs and physid snails (136 and 171 per square foot, respectively), and the presence of abundant algal slimes attest to the moderate pollution in Mine Brook as it entered the Charles River.

Compared with mile 74.7, an improvement in water quality in the Charles River was noted at mile 61.5 near Medway, Massachusetts. This reach supported 17 kinds of animals predominated by 129 pollution-sensitive, clean water forms per square foot of river bottom. Pollution-tolerant sludgeworms were very few in number (Figure 5 and Table 1). A luxurious growth of attached aquatic plants receiving inorganic nutrients such as nitrogen and phosphorus from Mine Brook and Milford, Massachusetts covered the rocks and other bottom materials of this reach. Phytoplankton also require such nutrients and these too were more abundant (2,500 per milliliter).

The Stop River, like Mine Brook, contributed polluted water to the Charles River at mile 52.7. Although 14 kinds of organisms were found in the Stop River just upstream from its confluence with the

Charles River at Medfield, Massachusetts, only two kinds were pollution sensitive and these were not abundant (Table 1). The population of benthic animals in this reach of the Stop River was predominated by intermediately tolerant forms such as scuds and sow bugs and by pollution-tolerant sludgeworms. As in Mine Brook, dense growths of pollution-associated blue-green algal slimes blanketed rocks and other suitable substrates in the Stop River.

The Charles River was polluted by wastes discharged via the Stop River. Downstream from this confluence, the Charles River at mile 51.9 supported 12 kinds of animals numbering 73 organisms per square foot. This is a decrease in both numbers and kinds of organisms compared to the reach near Medway at mile 61.5 (Figure 3 and Table 1). Only one kind of pollution sensitive animal was found at mile 51.9 and phytoplankton increased to 3,600 per milliliter, or a density of 2.8 ppm (Table 2). Sandy muds mixed with pebbles in this reach were covered with a one-inch layer of settled silt-like solids.

The Charles River received treated wastes from the Medfield sewage treatment facility at mile 48.3. These caused an additional depression in the benthic animal population to 10 kinds of organisms at mile 48.1 (Figure 3). Settleable components of such wastes provided a food source for an increase to 160 pollution-tolerant sludgeworms per square foot.

Wastes from the St. Stephens School outfall at mile 44.5 did not have a perceptible deleterious effect on the benthic aquatic life 3.2

miles downstream at mile 41.3. Substantially improved water quality was noted in this and subsequent reaches of the Charles River downstream through mile 19.6. These reaches, designated by river miles 41.3, 34.6, 26.8, 25.2, and 19.6 in Figure 3 and Table 1, contained populations of benthic animals predominated by clean water organisms such as mayflies, caddisflies, and certain beetles. Sludgeworms were present, but low in numbers, as in other clean waters. Two downstream reaches, miles 25.2 and 19.6 supported only three kinds of sensitive organisms in lieu of the six kinds found upstream (Table 1). Such reductions reflected minor water quality impairments resulting from changes in the physical habitat (stream channel modification by machinery) at mile 25.2 and urban storm drainage waters at mile 19.6 rather than discharges from municipal or industrial waste outfalls.

Although substantially improved water quality was indicated by populations of bottom associated organisms in the series of reaches from mile 41.3 downstream through mile 19.6, waste waters discharged to the tributaries or to the river upstream from mile 41.3 contained sufficient nutrients to cause degradation of water quality that was perceptible in phytoplankton populations. Except in the vicinity of mile 34.6 where there was an abundant growth of rooted aquatic plants, phytoplankton increased to 4,000 or more, and were as abundant as 15,000 per milliliter in this series of reaches (Figure 4 and Table 2). Such populations could interfere with any future domestic water uses because

they would contribute to or cause taste and odor problems in finished water supplies and would reduce the length of filter runs in any water treatment facility located nearby. They also unduly increase the turbidity of the stream, thereby reducing its aesthetic and recreational values.

Wastes discharged from combined sewers intermittently flowed into the Charles River in subsequent downstream reaches and became more numerous as the stream approached Boston Harbor. Such discharges effected a reduction in the number of kinds of clean water organisms and a significant increase in pollution-tolerant sludgeworms associated with reaches at miles 14.8, 12.0 and 9.0. Only one kind of clean water organism, and sludgeworms populations exceeding 100 per square foot were found in these polluted reaches.

Numerous additional waste sources from combined sewers, and possibly some from industries, severely polluted the Charles River in reaches used intensively for recreation further downstream as was evidenced by the occurrence of only one kind of organism at mile 4.0 near the John Weeks Foot Bridge, and by the lack of any bottom-associated animals at mile 0.6 near the Longfellow Bridge (Figure 3). The paucity of such organisms was suggestive that toxic conditions prevailed, thereby precluding establishment of bottom-associated animal life. Black oozy muds that emitted foul odors and contained much oily residue were found here, and the surface of the river was pock-marked with bursting bubbles of hydrogen sulfide.

Nutrients

Nitrogen and phosphorus stimulate aquatic plant growths. Some aquatic plants can utilize organic forms of nitrogen and certain others such as blue-green algae can fix atmospheric nitrogen. Most, however, depend on soluble inorganic forms of nitrogen for growth and maintenance, and all require soluble phosphorus. When sufficient quantities of inorganic nitrogen and phosphorus are available and other factors such as light, trace elements, temperature and substrate are not limiting, abundant growths of aquatic plants occur in fresh water lakes and streams.

In the Charles River at mile 76.9 upstream from Milford, Massachusetts, concentrations of inorganic nitrogen (N) and soluble phosphorus (P) were low, 170 and 20 micrograms per liter, respectively (Table 3 and Figures 6 and 7), and aquatic plants were not unusually abundant.

Wastes from the Milford sewage treatment facility increased the concentrations of inorganic nitrogen and soluble phosphorus in the river at mile 74.7 (Figures 6 and 7), and this resulted in very abundant rooted aquatic plants that restricted the flow of water in this reach. Competition for nutrients by rooted aquatic plants found here prevented an increase in phytoplankton (Figure 4).

In Mine Brook inorganic nitrogen and soluble phosphorus concentrations were high, amounting to more than 3,000 and 700 micrograms per liter respectively. Most of the inorganic nitrogen was ammonia nitrogen in this tributary (Table 3).

These nutrients and those from the Milford sewage treatment facility increased phytoplankton populations to 2,500 per milliliter (Figure 4) and caused dense growths of rooted aquatic plants in the Charles River in subsequent downstream reaches to Medway, Massachusetts, at mile 61.5. Even though aquatic plants were abundant, rich supplies of inorganic nitrogen and phosphorus were still present in this reach. Such nutrients were available for additional plant populations farther downstream.

The Stop River also contributed inorganic nutrients to the Charles River, but these contributions were less than those from upstream sources in Mine Brook and the sewage treatment facility at Milford, Massachusetts (Figures 6 and 7).

Downstream in the Charles River at mile 48.1 both rooted aquatic plants and phytoplankton populations decreased, the latter to 2,200 cells per milliliter. Sufficient concentrations of inorganic nitrogen and phosphorus (640 and 270 micrograms per liter, respectively) still were available for growth of aquatic plants in this reach, but increased turbidity and river depth may account for the plant populations reductions.

Subsequent reaches of the Charles River downstream through mile 14.8 near Newton, Massachusetts, had high concentrations of inorganic nitrogen (more than 500 micrograms per liter) and soluble phosphorus (130 or more micrograms per liter). Phytoplankton

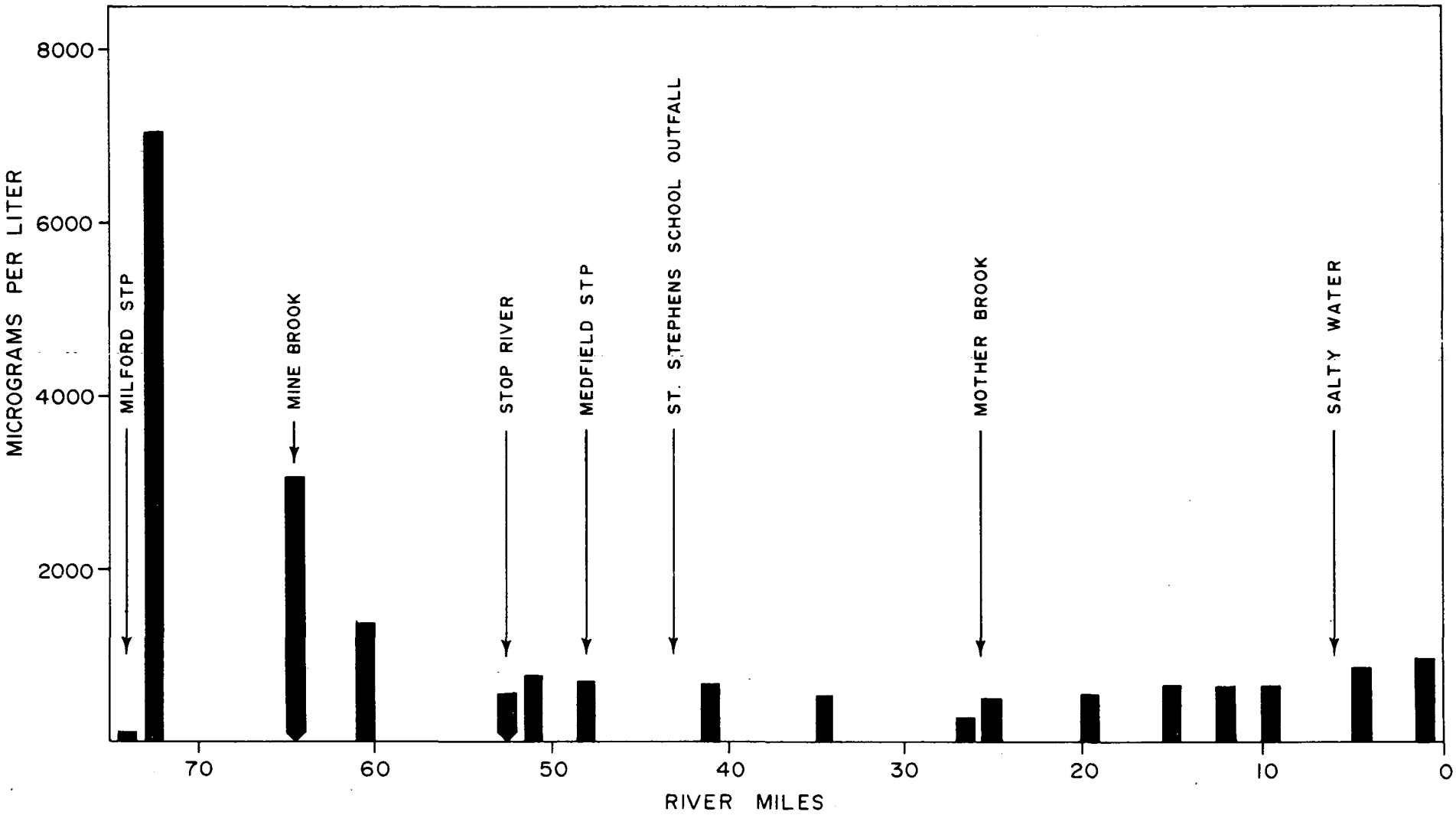

FIGURE 6. INORGANIC NITROGEN (μg/l) IN THE CHARLES RIVER AND TRIBUTARIES, JULY-AUGUST, 1967.

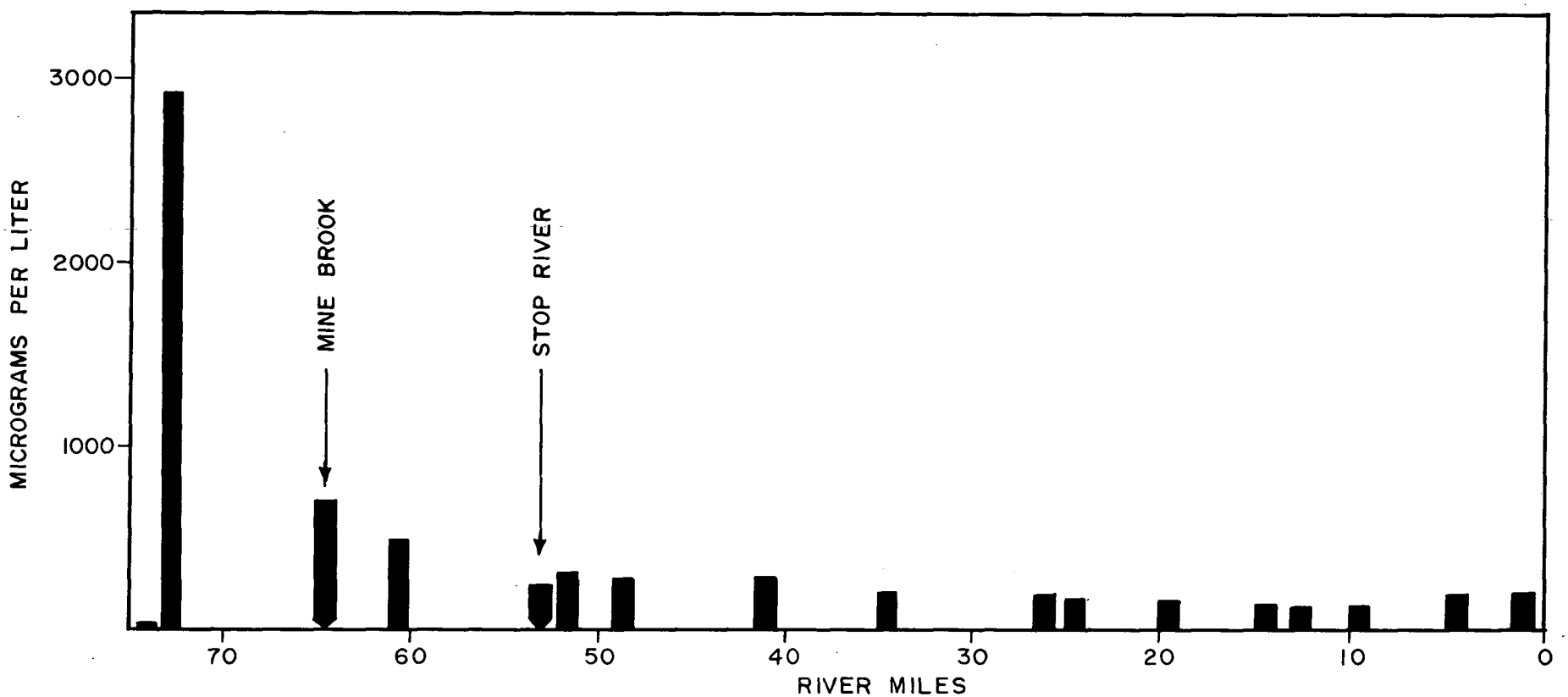

FIGURE 7. SOLUBLE PHOSPHORUS (μg/l) IN THE CHARLES RIVER AND TRIBUTARIES, JULY-AUGUST, 1967.

populations (Figure 4, Table 2), rooted aquatic plants, or both were abundant in these reaches (dense growths of rooted aquatic plants usually were accompanied by decreased density of phytoplankton, and vice versa).

Inorganic nitrogen in the Charles River also was high and amounted to 570 micrograms per liter at mile 12.0 (Figure 6, Table 3). Storm and combined sewers in the vicinity of Waltham Highlands and Newton, Massachusetts discharge wastes into this reach. No increase in soluble phosphorus was found here (Figure 7). Rooted aquatic plants were not observed, but phytoplankton increased to 19,800 cells per milliliter.

Downstream reaches of the river to its confluence with Boston Harbor contained increased concentrations of inorganic nitrogen (680 to 940 micrograms per liter) and soluble phosphorus (120-180 micrograms per liter) that supported abundant phytoplankton populations exceeding 10,000 cells per milliliter. Many combined sewers discharge to these reaches.

Bottom Deposits

Municipal sewage and certain industrial wastes contain substantial quantities of organic nitrogenous and carbonaceous materials that settle and form sludge deposits when discharged to receiving waters. These deposits decompose and consume oxygen from the

overlying water causing a decrease in the amounts of oxygen available for aquatic life such as fish and fish food organisms. In the Charles River, percentages of organic carbon and organic nitrogen were determined from dried river bed samples (Table 4, Figure 8).

Bottom materials in the Charles River at mile 76.9 contained 0.3 percent organic carbon and 0.07 percent organic nitrogen. These values are low and are not suggestive of organic pollution.

Suspended solids from wastes at the Milford sewage treatment facility settled to the bottom of the Charles River and formed sludge deposits rich in carbonaceous and nitrogenous materials in the polluted reach associated with mile 74.7. About 12 percent of this sludge was organic carbon (Figure 8), and 0.73 percent was organic nitrogen (Table 4).

Mine Brook and the Stop River (miles 64.7-07 and 52.7-0.2), lacked sludge deposits. The Charles River reach between these tributaries had abundant growths of rooted aquatic plants and lacked sludge deposits; the bottom sample contained less than 3 percent carbon, and this was due in part to the presence of aquatic plant fragments in the sample.

Downstream from the confluence with the Stop River, sludge-like bottom materials contained 6 percent organic carbon and 0.32 percent organic nitrogen (mile 51.9). Some organic matter in these deposits may have originated in the polluted Stop River.

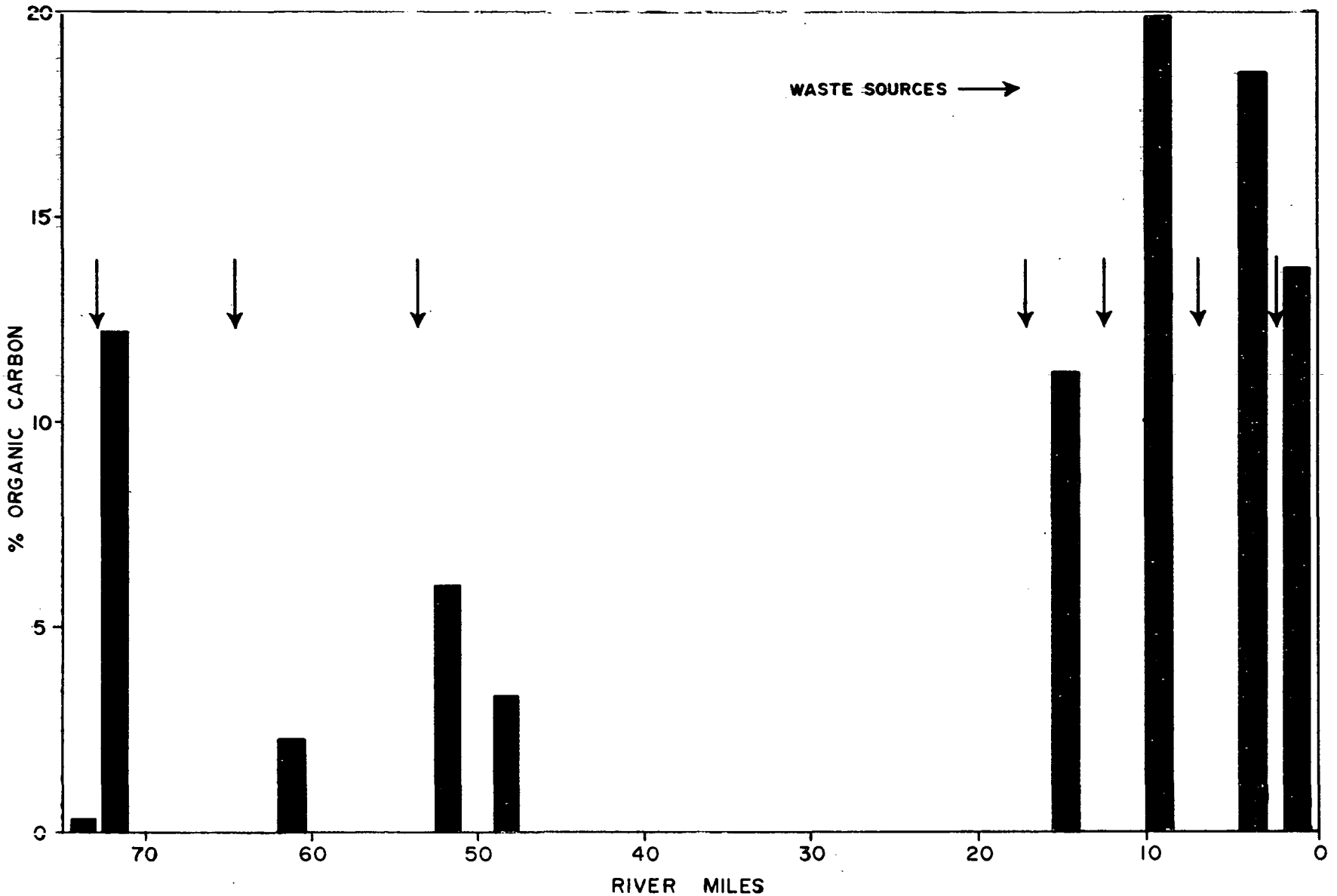

FIGURE 8. PERCENTAGE OF ORGANIC CARBON IN CHARLES RIVER MUDS, AUGUST, 1967.

Carbonaceous and nitrogenous matter decreased in bottom deposits of the Charles River at mile 48.1 downstream from the Medfield sewage treatment facility. Chemically the deposits were not characteristic of sludge. In the subsequent reaches downstream through mile 19.6 samples of bottom deposits were not chemically analyzed, because the bottom materials were composed of silty sand, pebbles, or rock.

Suspended organic matter from storm water discharges settled out in the reach at mile 14.8 where the organic carbon and organic nitrogen contents of the bottom deposits amounted to 11.2 and 0.41 percents, respectively. This segment of the Charles River is located at the upstream end of an impoundment where the velocity of the river was much reduced, thus providing an opportunity for settling of suspended organic matter. Sludge deposits were not found in the reach at mile 12.0 near the dam that impounded this river reach.

The many combined sewers that are located in the three remaining reaches downstream to the confluence with Boston Harbor deposited highly carbonaceous and nitrogenous wastes to the Charles River (Table 4). The organic carbon content of these sludges exceeded 12 percent (Figure 8), and the organic nitrogen ranged from 0.70 to 0.84 percent, indicating part organic pollution (Table 4).

Summary

A study of bottom organisms, aquatic plants, nutrients and chemical characteristics of bottom deposits in the Charles River showed water quality degradation from wastes originating in Milford, Massachusetts, and with additional waste contributions in downstream reaches polluted conditions extended through Medfield, Massachusetts, a distance of 32 stream miles. Improved water quality existed in subsequent reaches to Wellesley, Massachusetts, but nutrients from upstream waste sources caused dense growths of aquatic plants, including phytoplankton, in these improved reaches. Combined sewer discharges in the Boston metropolitan area ultimately caused severely degraded water in the most downstream segments of the Charles River (15 stream miles). A total of 75 miles of the river is damaged by the discharge of inadequately treated waste waters. The Charles River contributed grossly polluted water to Boston Harbor.

BOSTON HARBOR AND TRIBUTARIES

Aquatic Life

In addition to the Charles River, certain other tributaries contributed polluted water to Boston Harbor. Numerous outfalls discharge municipal and industrial wastes to the Mystic, Malden, and Chelsea Rivers. Sampling sites in these tributaries are shown in Figure 9.

The upstream reach of the Mystic River at the Route 16 bridge near Medford, Massachusetts, supported only one kind of bottom associated animal (Table 5). Substantial quantities of oily residues were observed in the black sludge that covered the river bottom. Additional downstream qualitative sampling disclosed that black sludge deposits predominated in the benthic environment of the Mystic River to its confluence with the Malden River. Phytoplankton density in surface waters of the Mystic River were high, exceeding 40 ppm, or 29,000 cells per milliliter (Table 6). If not severely polluted these benthic reaches of the Mystic River would support additional kinds of bottom animals such as sludgeworms and midges, or polychaete worms.

The Malden River was severely polluted upstream from its confluence with the Mystic River near the Revere Beach Parkway bridge at Medford, Massachusetts. Bottom-associated animals were not found here, and four inches of black sludge mixed with oily

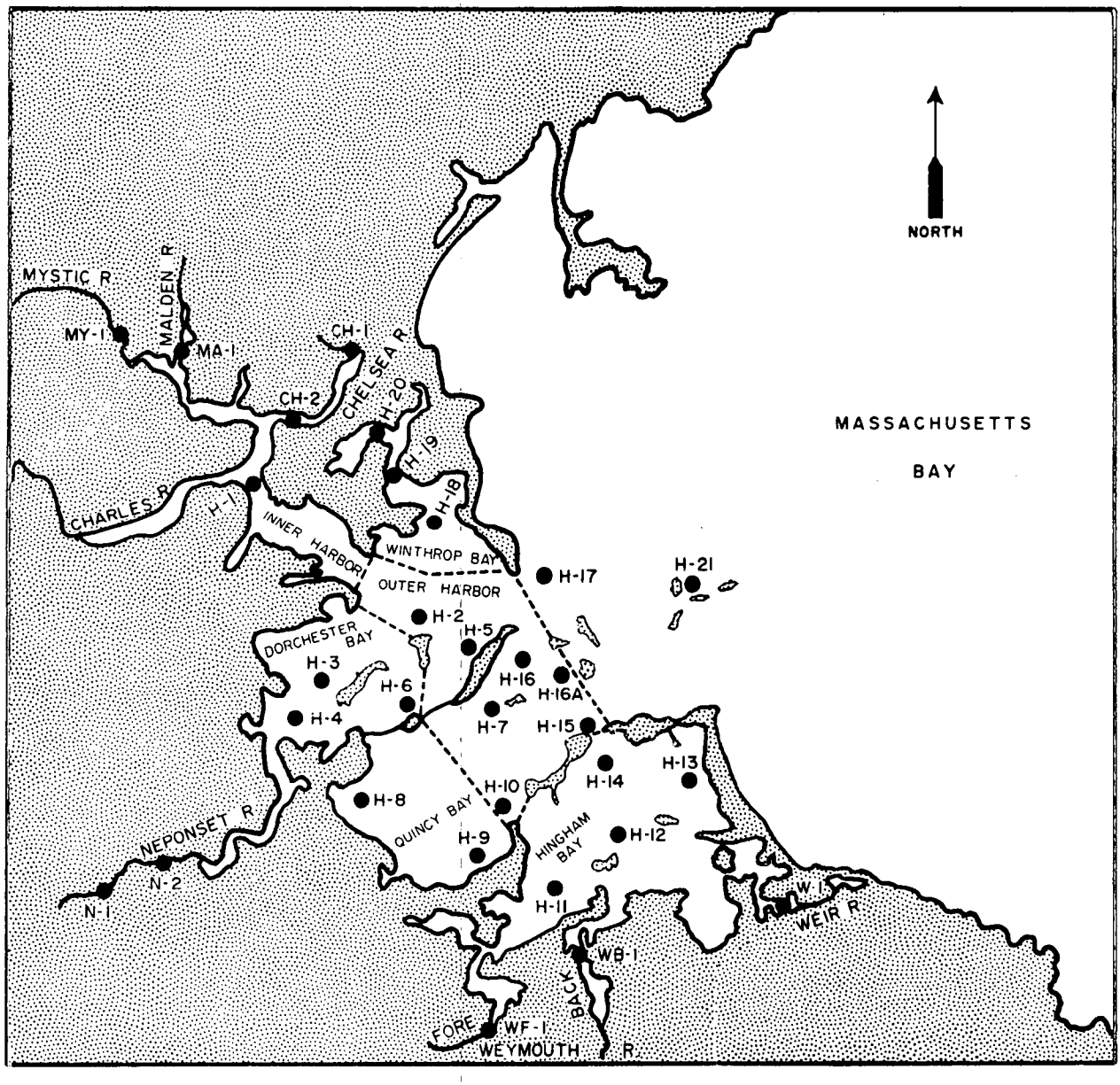

FIGURE 9. STATION LOCATIONS IN BOSTON HARBOR AND TRIBUTARIES.

residues covered the stream bottom. Surface waters of the Malden River contained more than 60,000 phytoplankton per milliliter that amounted to a density of 13.8 ppm. The Malden and Mystic Rivers contributed severely polluted water to the inner reaches of Boston Harbor.

Marine waters supporting polychaete worms prevailed in all but one of the remaining tributaries and in all Boston Harbor reaches. Polychaete worms were sufficiently common in these waters that their abundance was used to show areas and degrees of over-enrichment. The use of marine worms for these purposes is not unlike the use of sludgeworms to delineate areas of over-enrichment in fresh waters because the nutritional and substrate requirements of both groups of organisms are similar. Polychaete worm populations that exceed a density of 200 per square foot in the following marine waters of Boston Harbor were considered indicative of excessive enrichment (Figure 10).

The two lower marine reaches of the Chelsea River supported a minimal variety of bottom animals (Table 5). Samples from the upstream segment near the Broadway Street bridge contained organisms that represented only two groups of marine animals, polychaete worms and scuds. Suspended solids in wastes discharged to this segment of the river settled to the bottom and provided organic materials that supported 792 polychaete worms per square foot.

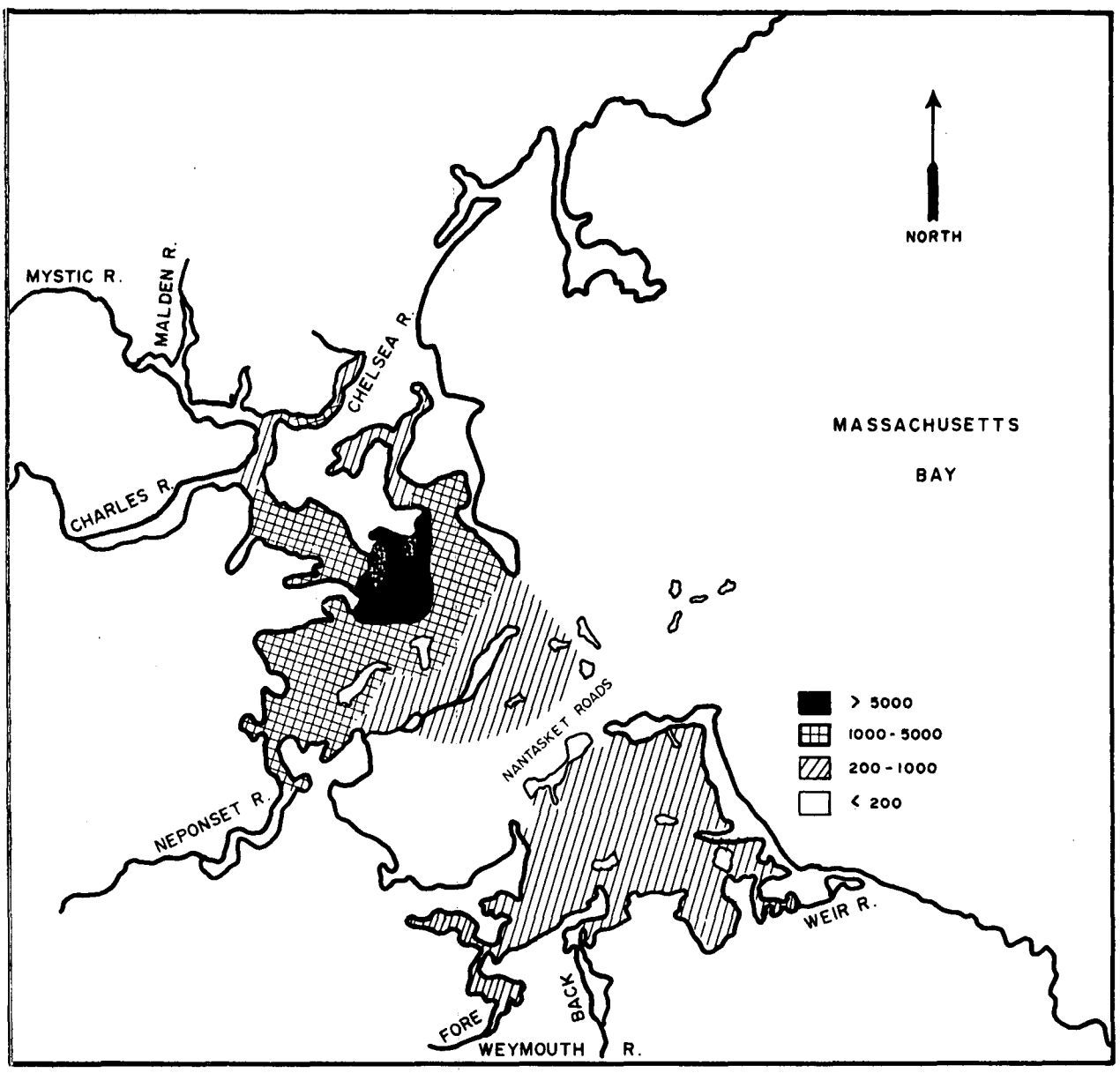

FIGURE 10. NUMBER OF POLYCHAETE WORMS PER SQUARE FOOT, BOSTON HARBOR AND TRIBUTARIES, JULY-AUGUST, 1967.

The slightly oily, black sludge found here emitted foul odors and surface waters of the reach were streaked heavily with oil from nearby petroleum storage facilities. Additional downstream wastes caused an increase to 2,500 per square foot in the polychaete worm populations of the Chelsea River near its mouth below the Meridian Street bridge. These were associated with only one other group of organisms, snails. If not grossly polluted, the Chelsea River bottom-animal populations would include organisms such as clams, crabs, nematode worms, and mussels, and polychaete worms would be few in numbers.

The confluence of the Chelsea, Mystic, and Charles Rivers forms a waterway that is known as Boston Inner Harbor (Figure 9). Tidal currents in Boston Inner Harbor are strong and rapidly would displace the wastes entering the area from these tributaries, but additional wastes entering the Inner Harbor exceed the waste dispersal capacity of the currents. Consequently, some wastes from local and tributary sources are deposited here as sludge. Qualitative samples taken in the vicinity of the confluence of these tributaries showed that oily sludge covered these bottom reaches of the Inner Harbor, and that the predominant associated aquatic life was polychaete worms. Quantitative samples from the Inner Harbor in the vicinity above the Sumner tunnel showed that the oily sludge deposits located here supported 964 polychaete worms per square foot

(Table 7, Station H-1). Other benthic organisms associated with unpolluted marine waters were not found. Such a population of polychaete worms shows excessive enrichment of this reach (Figure 10). It is likely that harbor dredging operations for channel maintenance sufficiently disturb these bottom deposits to preclude development of higher populations of polychaete worms.

Many other waste outfalls are located in seaward reaches of Boston Inner Harbor. Wastes from those entering the Fort Point Channel severely polluted the water there. Qualitative sampling showed an absence of bottom-associated organisms in this channel. Sludge deposits in the Fort Point Channel were more than 3 feet deep, contained oily residues, and emitted foul odors. Hydrogen sulfide bubbles effervesed from the sludge in this reach, rose to the surface and burst, creating readily apparent odors like those of raw sewage and rotten eggs.

Settleable solids from additional waste sources were deposited in the seaward reach of Boston Outer Harbor north of Spectacle Island where they formed sludge deposits that supported more than 5,000 polychaete worms per square foot (Table 7, Station H-2). Severely enriched conditions were apparent (Figure 10). Scuds were the only other organisms found here. Such high populations and the presence of only one additional kind of bottom animal attest that this harbor reach was grossly polluted.

Polychaete worms decreased in abundance and the variety of associated animals increased slightly farther seaward in areas near a

course toward the mouth of the outer harbor at Massachusetts Bay (Figure 9 and Table 7, Stations H-5, and H-17). These relationships are suggestive of progressive improvements in water quality. Samples from Station 17 near the Deer Island sewer outfalls at the mouth of Boston Harbor supported 115 polychaete worms and four other kinds of benthic organisms per square foot. Bottom materials in these samples consisted of scraps of mollusc shells, small pebbles, black silty particles, sand, and some sewage-associated wastes such as pieces of vegetables, aluminum foil, and soap-like particles. Sewage-like solids, other assorted rejectimenta, and oily slicks also were observed in the surface waters of this reach during both flood and ebb tides. Tidal currents here are very strong and likely prevent immediate settling of much suspended matter from the nearby waste outfalls of the Deer Island sewage treatment facility. Such observations in conjunction with the abundance of polychaete worms and the paucity of other kinds of organisms show that this reach also was polluted.

Clean water, as indicated by a great variety of benthic organisms, was found at a supplemental biological station located seaward of Boston Harbor in Massachusetts Bay between Green Island and the Brewester Islands (Figure 9). Qualitative samples from this area showed that it supported at least 14 different groups of organisms. Many of these were clean-water-associated animals such as chitons, sponges, starfish, shrimp, brittle-stars, and crabs (Table 7, Station H-21). Sludge-like

deposits were not present here, and bottom materials were comprised of clay, clean sand, rocks, and rubble that also supported a variety of attached brown, green, and red algae.

Additional wastes sources, primarily combined sewer outfalls, are located in certain other reaches of Boston Harbor. Some of these drained into Winthrop Bay and effected polluted conditions. The most inland reach of Winthrop Bay north of Logan International Airport supported only two groups of bottom animals, polychaete worms that numbered 404 per square foot and certain shrimp often found on soft sediments (Figure 9 and Table 6, Station H-20). Benthic deposits comprised of dark gray oozy muds emitted a detectable odor of hydrogen sulfide, and contained perceptible oily residues. Samples from the seaward reach of Winthrop Bay between Winthrop, Massachusetts and Logan International Airport contained sand mixed with black particles, emitted faint odors of hydrogen sulfide, and included six groups of organisms predominated by 716 polychaete worms per square foot of substrate. Tidal currents in the narrow channel are strong and prevent excessive deposition of suspended materials (Station H-19). The lack of a greater variety of bottom animals and the abundance of polychaete worms are suggestive of polluted water in these two excessively enriched inland reaches of Winthrop Bay (Figure 10).

Near the mouth of Winthrop Bay, polychaete worm populations exceeded a density of 4,000 per square foot (Station H-18, seaward and southeasterly from Logan International Airport). Other associated

organisms were not found. It is reported that wastes from the Deer Island sewage treatment facility may enter this reach of Winthrop Harbor during flood tides.* Settling of suspended solids from these wastes could form the grayish-brown deposits sampled here and would furnish an adequate food supply for this abundant worm population. Strong odors and oily residues were not perceived in such deposits. This seaward reach of Winthrop Bay was polluted (Figure 10).

As in Winthrop Bay, other wastes discharged from the Boston metropolitan area effected pollution of Dorchester Bay and its fresh-water tributary, the Neponset River (Figure 9). In the upstream fresh-water reach of the Neponset River at the Neponset Valley Parkway, raw sewage and combined sewer effluents grossly polluted the water. Pollution-tolerant sludgeworms amounting to 10,000 individuals per square foot and short attached streamers of sewage-associated bacteria (*Sphaerotilus sp*) predominated the substrates here (Table 5, Station N-1). Sludge containing oily residues and foul odors also were noted. No improvement in water quality was observed downstream at Station N-2 in the vicinity of the Central Avenue Bridge at Milton, Massachusetts where oily bottom material supported only 3 kinds of animals not represented

*Sawyer, C. N. 1965. The Sea Lettuce Problem in Boston Harbor. Journal of the WPC Federation, Volume 37, No. 8, pp 1122-1133.

by pollution-sensitive forms. Qualitative samples in this reach showed sludge deposits, and rocks stuck together with red precipitates similar to iron oxide. Such deposits and the associated aquatic life are suggestive that upstream wastes were toxic and of sewage and industrial origin. Both reaches of the Neponset River were severely polluted, and each contributed grossly polluted water to the Dorchester Bay area of Boston Harbor.

Apparent pollution and excessive enrichment of Dorchester Bay, principally caused by associated combined sewer discharges, was evidenced by a lack of organisms other than polychaete worms in samples from Station H-4 just north of the Boston Harbor Marina (Figures 9 and 10). Samples from these black sludge deposits contained 1,184 polychaetes per square foot, emanated strong hydrogen sulfide odors, and contained oily residues. Seaward from this reach, near the west side of Thompson Island, two kinds of bottom animals were found including polychaete worms amounting to 1,756 per square foot (Table 7, Station H-3). Perceptible quantities of oily residues were noted.

Wastes discharged at Moon Head and those from the Nut Island sewage treatment facility caused excessive enrichment of harbor reaches around Long Island (Figure 10). Benthic deposits supported polychaete worm populations that ranged from 288 to 572 individuals per square foot (Table 7, Stations H-5, H-6, H-7, H-16, and H-16A). Suspended sewage solids were observed in the reach at Station 6 near Moon Head, and the

dark gray, soft bottom materials here supported four additional kinds of organisms such as snails, two kinds of scuds, and nematode worms. If not polluted, this reach would support additional kinds of organisms such as starfish, crabs, and shrimp that are associated with clean water.

Similarly polluted water was found at Station 5 which receives pollutants chiefly from outfalls at the north end of Long Island during flood tides. About two inches of oozy material blanketed the scraps of shells mixed with dark sand and pebbles here.

Black sludge-like deposits at Station H-7 supported only three groups of organisms, including the polychaete worms that exceeded a density of 200 per square foot.

The primary waste source that caused pollution at Stations H-16 and H-16A is the outfall at Long Island. Five kinds of organisms predominated by polychaete worms were found in these polluted reaches containing black sludge and oily residues between Long, Gallops, Georges, and Rainsford Islands.

Excessively enriched waters were not apparent in Quincy Bay and in reaches seaward through Nantasket Roads to the mouth of Boston Harbor between Georges Island and Pemberton. Samples in these reaches, however, lacked the great variety of organisms contained in the clean water reach associated with Green and the Brewster Islands beyond the mouth of Boston Harbor in Massachusetts Bay.

Samples from the inland reach of Quincy Bay at Stations H-8 and H-9 contained only two kinds of bottom animals, and observations of associated surface waters disclosed flocculent sewage-like particles, assorted waste solids, and much oily residue. The paucity of kinds of organisms at these sites is evidence that such waters are polluted.

Disposal of wastes from the Nut Island sewage porcessing facility include outfalls in the vicinity of Station H-10 in addition to those located north of Long Island. Most settleable solids are not deposited in the reach at Station H-10 because of strong tidal currents. Dark colored sand, small rocks, and shell scraps rather than oozy deposits were collected here and these supported a minimal variety of associated animals, polychaete worms, scuds, and snails. The lack of other forms such as starfish, crabs, chitons, and sponges is suggestive of polluted conditions.

Moderately polluted water was indicated at Station H-15 between Pemberton Point and Peddocks Island. Six kinds of organisms, including starfish, sow bugs, and nematode worms, were associated with the sandy and pebble laden bottom material of this turbulent reach. Brittle-stars, chitons, and sponges were not found, and polychaete worms were represented by a small number of individuals (Table 7). Oily residues and flocculent solids resembling sewage wastes were present in surface waters.

Excessively dense polychaete worm populations indicate that much of the Hingham Bay area of Boston Harbor, one of its tributaries, the

Weymouth Fore River, and Hull Bay were polluted (Figure 9 and 10). Organisms associated with polychaete worms in the vicinity of the seaward reach of Hingham Bay east of Peddocks Island at Station 14 included cumaceans, four kinds of scuds, and snails. This combination of benthic animals is discordant with those found in clean water. Benthic materials were black and oozy, and contained oily residues, many scraps of paper, cellophane and aluminum foil. Oil slicks and suspended flocculent solids were observed in this polluted reach, as in the turbulent reach at Station H-15 just seaward of Hingham Bay.

The Weymouth Back River at Station WB-1 was not significantly polluted. Polychaete worms were not excessively abundant, and were predominated by organisms often associated with clean marine water, such as bivalve molluscs, shrimp, and limpets (Table 5). Suspended flocculent materials resembling those in sewage waste were lacking in the surface waters of this reach. Oily residues and noxious odors were not presenr in samples of the clean brown sands and pebbles collected from the river bottom.

The Weir River was not perceptibly polluted in the vicinity of the Washington Bridge (Table 5, Station W-1). Bottom materials of the river in this vicinity were a mixture of clay, mud, pebbles, vegetation and empty shells that supported ninekinds of organisms, including bivalve molluscs, cumaceans, and limpets. Polychaete worms and scuds were not abundant.

Hull Bay lies northeasterly of Hingham Bay and, like the seaward reaches of Hingham Bay, was grossly polluted. It supported a minimal variety of bottom animals predominated by polychaete worms that exceeded a density of 200 per square foot.

Nutrients

Sewage waste waters discharged through the many outfalls in Boston Harbor and associated bays and tributaries caused very high concentrations of ammonia nitrogen (N) and soluble phosphorus (P) that averaged or exceeded 100 and 40 micrograms per liter, respectively in 390 samples from all reaches of the harbor inland from Massachusetts Bay, including those near the mouth of the harbor at Stations H-17 and H-15 (Table 9).* The highest average concentrations (22 samples) of such nutrients occurred in Boston Inner Harbor at Station H-1, where ammonia nitrogen was 200 micrograms per liter and soluble phosphorus was 70 micrograms per liter. Maximum single sample concentrations were 300 micrograms per liter ammonia nitrogen (N) and 120 micrograms per liter soluble phosphorus (P) at Station H-1. The average concentration of ammonia nitrogen ranged from 100 to 128 micrograms per liter in southern sectors of Boston Harbor associated with the waters of Nantasket Roads, and Hingham and Hull Bays. The average concentrations of soluble phosphorus in these reaches ranged from 40 to 70 micrograms per liter.

*As a control point, Sawyer reported values of 20 and 16 micrograms per liter in Massachusetts Bay at the Beacon Street jetty (Sawyer, C. N. 1965. The Sea Lettuce Problem in Boston Harbor, Journal of the WPC Federation, Volume 37, No. 8, pp 1122-1133.)

High concentrations of inorganic nutrients in these and certain associated waters caused excessively dense populations of phytoplankton that averaged more than 1,000 per milliliter in about 35 square miles or 66 percent of Boston Harbor, including the Weymouth Back and Fore Rivers, and the saline reaches of the Chelsea, Charles, Malden, and Mystic Rivers (Figure 11, Tables 6 and 9).* The highest average phytoplankton densities occurred in Boston Inner Harbor, Winthrop Bay, and in the vicinity circumscribed by Georges, Peddocks, Rainsford and Long Islands. Hull, Hingham, and the inland reaches of Quincy and Dorchester Bays had phytoplankton populations amounting to less than 1,000 per milliliter.

In addition to causing excessive phytoplankton populations, the nutrients stimulated dense growths of attached marine plants. Observations throughout Boston Harbor disclosed such growths on most buoy, pier, and marina facilities. Several intertidal and shallow areas of the harbor and certain reaches of Winthrop Bay also supported dense growths of attached marine algae. These cause noxious conditions in Winthrop Bay, unsightly growths at marina facilities, and increase maintenance costs associated with buoys and piers. In Winthrop Bay, decomposing masses of sea lettuce have caused hydrogen sulfide emissions sufficient to discolor white paint on adjacent dwellings.

*Studies in other marine and estuarine waters have disclosed that phytoplankton populations more dense than 1,000 per milliliter are indicative of over-enrichment in such waters.

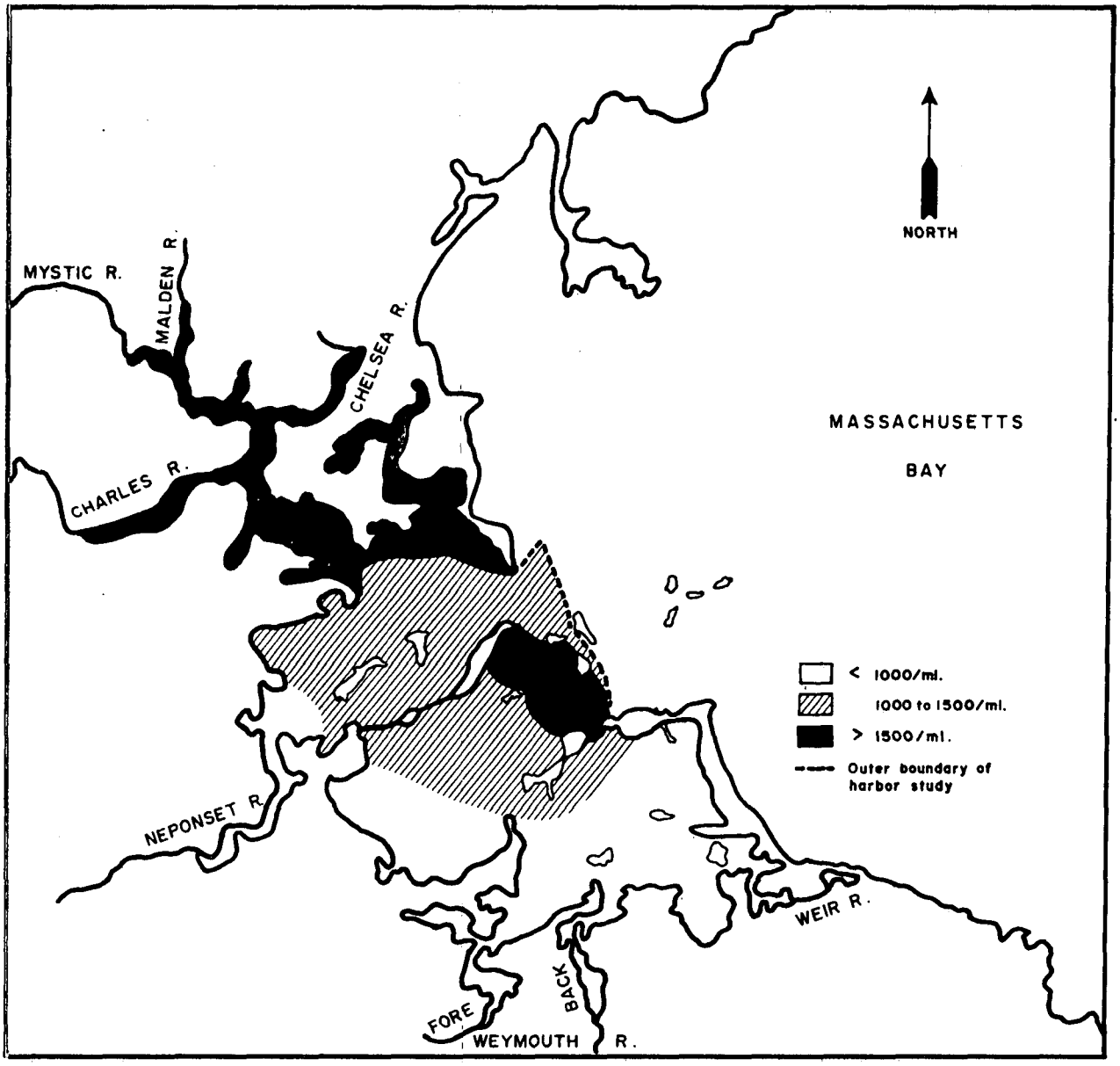

FIGURE 11. AVERAGE NUMBER OF PHYTOPLANKTON (number/ml.), IN BOSTON HARBOR, AUGUST, 1967.

Boston Harbor and Tributary Bottom Deposits

Wastes discharged from the Boston metropolitan area contain organic carbon and organic nitrogen that settle and form soft deposits in the receiving waters of Boston Harbor, its associated bays, and saline reaches of the Chelsea, Malden, Mystic, Neponset, and Weymouth Fore Rivers. The percentages of organic carbon and organic nitrogen in such bottom deposits were determined from dried samples (Tables 10 and 11).

The highest percentages of organic carbon (12.5) and organic nitrogen (0.34) in sludge of saline tributaries were found in the most inland reach of the Chelsea River near the Broadway Street bridge; these values are indicative of actively decomposing organic solids. (Table 10, Station Ch-1). Sludges from the bayward reach of the Chelsea River, and from the Malden, Mystic and Neponset Rivers had more than four percent organic carbon, and more than 0.10 percent organic nitrogen. Such values are suggestive of excessively enriched deposits.

The polluted Weymouth Fore River had deposits with less than four percent organic carbon and less than 0.10 percent organic nitrogen, and samples from Weir River contained aquatic plant fragments that resulted in 4.0 and 0.29 percentages of organic carbon and nitrogen, respectively.

The highest percentages of organic carbon (23.5) and organic nitrogen (1.29) associated with harbor sludges were found in the Fort Point Channel (Table 11, Station FP-1). This reach was very intensively polluted, and septic. Such values are not unlike those associated with raw wastes from packinghouses, sewage, or rapidly decomposing sludge.

Other harbor reaches had sludges with lesser percentages of organic carbon and nitrogen than the Fort Point Channel (Table 11). More than four percent organic carbon, and 0.20 percent organic nitrogen were found in sludge samples from Stations H-1 (Boston Inner Harbor), H-4 (Dorchester Bay, north of marina near mouth of Neponset River), H-6 (adjacent to waste outfall at Moon Island), and Station H-18 (seaward reach of Winthrop Bay). Samples from the remaining harbor stations contained less than four but more than two percent organic carbon, and organic nitrogen that varied from 0.06 to 0.27 percent. Organic carbon and nitrogen in bottom deposits seaward from the harbor in the clean reaches of Massachusetts Bay amounted to 0.4 and 0.04 percents respectively, and these deposits consisted of clay overlaid by sand, pebbles, and rocks. These data show that all of Boston Harbor, its inland bays, and the saline reaches of the Chelsea, Malden, Mystic, Neponset, and Weymouth Fore Rivers contained extensive bottom deposits of decayed organic material, much of which probably originated from associated waste discharges.

In addition to surface deposits, core samples from several harbor stations also were chemically analyzed (Table 12). Core samples from stations somewhat distant of immediate waste sources and known channel dredging activities, such as the 15-inch core from Station 7 southeast of Long Island, had decreasing percentages of organic carbon (from 4.7 at the top of the core to 0.3 at the bottom) and organic nitrogen (from 0.48 to 0.03, respectively) suggestive of gradual increases in percentage

of organic matter with time. Core samples from stations close to major waste sources and remote from known channel dredging activities and strong currents, such as the 22-inch core from Station 18 in the mouth of Winthrop Bay and the 13-inch core from Station 6 near the Moon Island outfall, had varying percentages of organic carbon and organic nitrogen (ranging from 1.3 to 6.2 and from 0.09 to 0.52 respectively) indicative of variations in rates of settling of organic matter, in quantity of mineral matter incorporated in the sediments, and in the decomposition of organic sediments before new materials were deposited.

Summary

All reaches of Boston Harbor and each of its tributary streams, except the inland marine reaches of the Weymouth Back and Weir Rivers, were polluted as was evidenced by a paucity of kinds of organisms associated with benthic deposits. About 14 square miles or 30 percent of the harbor inland from Massachusetts Bay were frossly polluted. Deposition of suspended sewage waste particles effected dense populations of polychaete worms that exceeded 200 per square foot in all of Boston Harbor except those waters associated with the inland sectors of Quincy Bay, and those seaward along a relatively narrow course through Nantasket Roads to the southern mouth of the harbor at Massachusetts Bay.

Ammonia nitrogen (N) and soluble phosphorus (P) were equal to or greater than 100 and 40 micrograms per liter, respectively, in all areas of Boston Harbor inland from its mouth near Massachusetts Bay. Such high concentrations of nutrients caused overly-enriched conditions that stimulated dense populations of phytoplankton exceeding 1,000 per milliliter in about 35 square miles or 66 percent of the harbor, including the Weymouth Back and Fore Rivers and the saline reaches of the Chelsea, Charles, Malden, and Mystic Rivers. Extensive deposits of decayed organic matter and incorporated oily residues covered much of the harbor bed.

APPENDIX

Tables

Table 1. Charles River Bottom Organisms

Kinds and Numbers per Square Foot

August 1967

Organism	Station Number and River Mile ( )																
	C-1 (76.9)	C-2 (74.9)	C-3 (64.7-0.7)	C-4 (61.5)	C-5 (52.7-0.2)	C-6 (51.9)	C-7 (48.1)	C-8 (41.3)	C-9 (34.6)	C-10 (26.8)	C-11 (25.2)	C-12 (19.6)	C-13 (14.8)	C-14 (12.0)	C-15 (9.0)	C-16 (4.0)	C-17 (0.6)
Pollution Sensitive Organisms																	
Mayflies																	
Tricorythodes sp.	-	-	-	-	-	-	-	3	Q	6	-	Q	-	-	-	-	-
Baetis sp.	-	-	-	Q	-	-	2	8	1	-	-	-	-	-	-	-	-
Caenis sp.	Q*	-	-	-	2	2	-	-	36	Q	Q	-	-	2	-	-	-
Stenonema sp.	-	-	-	4	-	-	-	3	1	32	Q	-	-	-	-	-	-
Caddisflies																	
Agralea sp.	-	-	-	-	-	-	-	Q	1	2	-	-	-	-	-	-	-
Cheumatopsyche sp.	Q	-	1	114	-	-	-	70	112	250	Q	128	-	-	Q	-	-
Hydropsyche sp.	-	-	-	10	-	-	-	35	-	30	-	5	-	-	-	-	-
Water-penny Beetles																	
Psephenus	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
Riffle Beetles																	
Stenelmis sp.	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-
Dubiraphia sp.	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
Aquatic Caterpillars																	
Elophila sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal Numbers	2	0	1	129	3	2	2	123	154	321	-	134	2	2	1	0	0
Subtotal Kinds	2	0	1	4	2	1	1	8	7	6	-	3	1	1	1	0	0
Intermediate Organisms																	
Crawling Water Beetles																	
Haliplus sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Dryopid Beetles																	
Helichus sp.	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Blackflies																	
Simulium sp.	-	-	-	15	-	-	-	2	Q	-	-	3	-	-	-	-	-
Prosimulium sp.	Q	-	-	3	-	-	-	Q	-	-	-	-	-	-	-	-	-
Midges																	
Tanypus sp.	-	456	-	-	-	-	-	-	-	-	4	-	-	Q	-	-	-
Chironomus sp.	Q	2	-	Q	2	1	25	-	38	4	-	Q	-	66	-	Q	-
Tanytarsus sp.	Q	Q	-	66	-	10	3	36	13	26	-	5	-	Q	-	-	-
Pentaneura sp.	Q	Q	-	12	Q	8	16	1	2	6	7	8	5	10	-	-	-
Polypedilium sp.	Q	Q	-	20	1	14	12	21	26	6	Q	7	-	15	-	-	-
Spaniotoma sp.	Q	-	-	10	3	-	-	7	4	4	Q	16	2	5	Q	-	-
Cricotopus sp.	-	-	-	-	4	-	-	Q	-	-	-	-	-	Q	-	-	-
Crytochironomus sp.	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-
Dance-flies																	
Empididae	-	-	-	4	-	-	-	27	Q	-	-	6	-	-	-	-	-
Biting Midges																	
Bezzia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-
Scuds																	
Hyallela sp.	Q	-	-	6	41	1	Q	Q	63	Q	-	-	-	78	-	-	-
Gammarus sp.	-	-	-	-	-	-	Q	-	14	Q	-	-	-	-	-	-	-
Sow-bugs																	
Asellus sp.	Q	Q	136	12	21	-	Q	3	1	Q	Q	Q	-	-	-	-	-
Crayfish																	
Cambarinae	Q	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Limpets																	
Ancylidae	-	-	-	-	-	-	-	-	3	Q	Q	-	-	-	-	-	-
Snails																	
Physidae	Q	16	171	-	1	-	-	-	-	Q	Q	-	2	-	Q	-	-
Clams																	
Plecepoda	-	8	-	-	-	Q	-	9	5	2	-	-	-	-	-	-	-
Planarians																	
Planariidae	-	-	-	Q	Q	Q	-	2	2	Q	Q	-	40	174	-	-	-
Leeches																	
Hirudinea	Q	Q	120	8	Q	1	Q	6	5	-	1	9	20	79	128	-	-
Subtotal Numbers	11	437	427	158	77	37	60	118	183	54	27	56	69	424	130	1	0
Subtotal Kinds	11	9	3	12	11	8	8	14	16	12	10	9	5	12	3	1	0
Pollution Tolerant Organisms																	
Bloodworms																	
Chironomus sp.	Q	88	-	-	-	3	-	-	-	-	Q	Q	-	Q	-	-	-
Sludgeworms																	
Tubificidae	Q	3744	10	10	56	30	160	2	1	Q	20	12	160	120	256	-	-
Subtotal Numbers	2	3832	10	10	56	33	160	2	1	1	21	13	160	121	256	0	0
Subtotal Kinds	2	2	1	1	1	2	1	1	1	1	2	2	1	2	1	0	0
Grand Total Numbers	15	4319	438	297	136	73	222	243	338	376	51	203	231	557	387	1	0
Grand Total Kinds	15	11	5	17	14	12	10	23	24	19	15	14	7	15	5	1	0

* Q = Present in qualitative samples; given an arbitrary value of 1 in the totals.

Table 2. Charles River Phytoplankton

Numbers and Volume

August 1967

River Mile	Number per milliliter					Volume (parts per million)				
	Diatoms	Greens	Flagellate Greens	Other	Total	Diatoms	Greens	Flagellate Greens	Other	Total
76.9	-	400	100	-	500	-	0.15	0.20	-	0.35
74.7	100	-	200	-	300	0.01	-	0.08	-	0.09
64.7-0.7	100	100	-	-	200	0.03	0.01	-	-	0.04
61.5	100	100	2,250	50	2,500	0.04	0.18	1.06	0.01	1.29
52.7-0.2	300	50	350	150	850	0.40	0.01	0.19	0.49	1.09
51.9	800	1,100	900	800	3,600	0.81	0.87	1.16	0.01	2.85
48.1	400	800	900	100	2,200	1.02	0.11	0.68	0.01	1.82
41.3	600	3,200	1,400	-	5,200	1.17	2.71	3.37	-	7.25
34.6	2,000	200	-	200	2,400	1.28	0.01	-	0.01	1.30
26.8	3,000	1,500	700	-	5,200	1.69	0.96	0.35	-	3.00
25.2	1,100	1,500	1,700	-	4,300	0.77	7.03	13.96	-	21.76
19.6	12,800	1,500	1,000	-	15,300	7.26	2.38	0.97	-	10.61
14.8	12,100	1,700	400	-	14,200	5.23	0.97	0.20	-	6.40
12.0	17,200	1,800	700	100	19,800	8.55	8.52	3.50	3.20	23.71
9.0	12,700	900	300	-	13,900	5.04	1.10	1.58	-	7.72
4.0	4,700	5,400	700	400	11,200	2.97	43.90	1.05	0.01	47.93
0.6	1,400	6,700	1,300	800	10,200	1.77	4.32	1.19	0.09	7.37

Table 3. Average Concentrations of Nutrients

Charles River, Mine Brook and Stop River

July-August 1967

Station Location (River mile)	Micrograms per liter				
	NO_3-N	NH_3-N	Org-N	Total P	Sol. P
76.9	< 100	70	900	70	20
74.7	4,000	3,040	1,700	3,140	2,920
64.7-0.7 (Mine Brook)	100	2,930	1,500	1,090	710
61.5	1,000	380	1,200	650	480
52.7-0.2 (Stop River)	200	300	1,100	380	240
51.9	600	150	1,100	460	320
48.1	500	140	1,100	420	270
41.3	500	130	1,300	370	280
34.6	400	120	1,100	300	200
26.8	400	110	1,100	280	190
25.2	400	100	1,200	280	170
19.6	400	130	1,200	260	150
14.8	500	120	1,200	240	130
12.0	400	170	1,200	240	120
9.0	500	180	1,200	250	120
4.0	400	430	1,100	310	180
0.6	400	540	900	270	180

Table 4. Charles River Muds
Percentages of Organic Carbon and Organic Nitrogen
(Dry Weight)

July-August 1967

Sampling Stations (River miles)	Percentage Organic Carbon	Percentage Organic Nitrogen
76.9	0.3	0.07
74.7	12.2	0.73
61.5	1.3	0.12
51.9	6.0	0.32
48.1	3.3	0.15
14.8	11.2	0.41
9.0	20.0	0.74
4.0	18.4	0.82
0.6	13.7	0.70

Table 5. Bottom Organisms in

Mystic, Malden, Chelsea, Neponset, Weymouths and Weir Rivers

Numbers and Kinds per Square Foot

July-August 1967

	Station Designation									
	Mystic River		Malden River	Chelsea River		Neponset River		Weymouth Rivers		Weir River
Organisms	MY-1	MY-1A	MA-1	CH-1	CH-2	N-1	N-2	Fore WF-1	Back WB-1	W-1
Marine Annelids										
Polychaeta	-	-	-	796	2496	-	-	564	120	173
Scuds-Amphipoda										
Caprellidae	-	-	-	-	-	-	-	-	-	3
Corophiidae										
Corophium sp.	-	-	-	16	-	-	-	3	320	16
Photidae	-	-	-	-	-	-	-	-	1408	13
Sow bugs										
Isopoda	-	-	-	-	-	-	-	-	232	16
Cumaceans										
Diastalis sp.	-	-	-	-	-	-	-	-	-	2
Shrimp										
Natantia	-	-	-	-	-	-	-	2	Q	-
Bivalve Molluscs										
Pelecepoda	-	-	-	-	-	-	-	3	3632	Q*
Snails										
Gastropoda	-	-	-	-	48	Q*	3	26	Q	3
Phantom Midges										
Chaoborinae	16	-	-	-	-	-	-	-	-	-
Limpets										
Gastropoda	-	-	-	-	-	-	-	26	Q	Q
Leeches										
Hirudinea	-	-	-	-	-	Q	259	-	-	-
Sludgeworms										
Tubificidae	-	-	-	-	-	10,000	584	-	-	-
Total Organisms	16	0	0	812	2544	10,002	846	624	5715	228
Total Kinds	1	0	0	2	2	3	3	6	8	9

* Q = Present in qualitative samples; given an arbitrary value of 1 in totals.

Table 6. Phytoplankton in Mystic, Malden, Chelsea, Neponset, Weymouth Fore, Weymouth Back, and Weir Rivers

Numbers and Volumes

August 1967

Tributary Station Number	Number per milliliter					Volume (parts per million)				
	Diatoms	Greens	Flagellate Greens	Other	Total	Diatoms	Greens	Flagellate Greens	Other	Total
Mystic River										
MY-1	16,750	9,000	3,500	-	29,250	8.73	21.56	10.16	-	40.45
Malden River										
MA-1	1,500	10,250	50,250	-	62,000	0.07	2.34	11.46	-	13.87
Chelsea River										
CH-1	-	31,250	-	-	31,250	-	5.26	-	-	5.26
CH-2	2,300	-	-	600	2,900	0.59	-	-	0.15	0.74
Neponset River										
N-1	-	150	550	-	700	-	0.01	0.50	-	0.51
N-2	-	-	200	200	400	-	-	0.07	0.01	0.08
Weymouth Fore River										
WF-1	-	-	900	300	1,200	-	-	0.23	0.10	0.33
Weymouth Back River										
WB-1	100	-	700	300	1,100	0.14	-	0.18	0.08	0.40
Weir River										
W-1	50	-	50	-	100	0.06	-	0.01	-	0.07

Table 7. Boston Harbor Bottom Organisms

Kinds and Numbers per Square Foot

July-August 1967

Organisms	Station Designation																					
	H-1	H-2	H-3	H-4	H-5	H-6	H-7	H-8	H-9	H-10	H-11	H-12	H-13	H-14	H-15	H-16	H-16A	H-17	H-18	H-19	H-20	H-21
Marine Annelids																						
Polychaeta	964	5285	1756	1184	312	572	288	68	128	11	312	560	264	211	8	512	262	115	4288	716	404	Q *
Scuds-Amphipoda																						
Photidae																						
Eurystheus sp.	-	-	-	-	-	-	-	-	-	-	-	-	28	203	-	6	2	-	-	-	-	-
Microprotopus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	16	-	-
Other	-	80	55	-	-	-	-	-	-	-	-	-	-	30	-	8	13	29	-	3	-	Q
Caprellidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38	-	-	-	-	-	-	Q
Coryphiidae																						
Corophium sp.	-	-	-	-	-	-	-	-	-	-	-	-	76	165	-	19	-	-	-	-	-	-
Stenothoidae																						
Metope sp.	-	-	-	-	44	-	-	-	-	-	-	-	72	94	-	19	3	-	-	11	-	Q
Other	-	-	-	-	128	38	476	52	796	352	1288	248	-	-	104	-	-	-	-	-	-	-
Sow bugs																						
Isopoda	-	-	-	-	-	37	8	-	-	-	-	-	-	-	Q	3	6	5	-	Q	-	-
Cumaceans																						
Diastalis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	13	-	6	-	32	-	-	-	-
Shrimp																						
Natantia	-	-	-	-	-	Q*	-	-	-	-	Q	-	-	-	-	-	-	-	-	-	32	Q
Bivalve Molluscs																						
Pelecepoda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24	-	Q
Snails																						
Gastropoda	-	-	-	-	2	Q	-	-	-	5	-	-	-	Q	-	-	-	-	-	-	-	Q
Nematode Worms																						
Nematoda	-	-	-	-	4	-	-	-	-	-	Q	16	-	-	128	-	-	-	-	-	-	Q
Starfish																						
Asteroidea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	-	-	-	-	Q
Brittle-stars																						
Ophiurodea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Crabs																						
Reptantia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Barnacles																						
Cirripedia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Chitons																						
Polyplacophora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Sponges																						
Porifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Q
Total number of organisms per square foot	964	5365	1811	1184	490	649	772	120	924	368	1602	824	440	717	280	573	286	186	4288	771	436	14
Total Number of Kinds	1	2	2	1	5	5	3	2	2	3	4	3	4	7	6	7	5	5	1	6	2	14

* Q = Present in qualitative samples; given an arbitrary value of 1 in the totals.

Table 8. Boston Harbor Phytoplankton
Numbers and Volumes

August 1967

Station Number	Depth (Feet)	HIGH TIDE (8-17-67) Numbers per milliliter Diatoms	Other	Total	Volume (parts per million) Diatoms	Other	Total	LOW TIDE (8-28-67) Numbers per milliliter Diatoms	Other	Total	Volume (parts per million) Diatoms	Other	Total
H-1	S*	200	2,300	2,500	2.39	0.88	3.27	1,100	2,900	4,000	0.35	0.53	0.88
	20	100	600	700	0.38	0.20	0.58	200	100	300	0.20	0.03	0.23
H-2	S	600	200	800	1.73	0.05	1.78	700	900	1,600	1.72	0.23	1.95
	20	400	400	800	1.54	0.15	1.69	700	1,500	2,200	1.92	0.38	2.30
H-3	S	800	1,300	2,100	1.92	0.34	2.26	300	600	900	0.34	0.16	0.50
	10	300	1,500	1,800	5.91	0.38	6.29						
H-4	S	500	300	800	0.13	0.08	0.21	200	400	600	0.07	0.50	0.57
H-5	S	-	1,200	1,200	0.00	0.30	0.30	500	600	1,100	1.59	0.29	1.88
	10	400	500	900	1.53	0.13	1.66	200	900	1,100	0.38	0.52	0.90
H-6	S	-	1,400	1,400	0.00	0.43	0.43	400	800	1,200	0.23	0.20	0.46
H-7	S	200	700	900	0.58	0.26	0.84	200	500	700	0.07	0.13	0.20
	10	100	1,400	1,500	0.21	0.35	0.56						
H-8	S	-	900	900	0.00	0.25	0.25						
H-9	S	-	400	400	0.00	0.15	0.15						
H-10	S	200	500	700	1.15	0.10	1.25	200	600	800	0.25	0.23	0.48
	10	200	1,300	1,500	0.58	0.65	1.23	1,000	300	1,300	2.05	0.08	2.13
H-11	S	-	400	400	0.00	0.10	0.10	100	200	300	0.19	0.05	0.24
	10	-	1,100	1,100	0.00	0.35	0.35	200	100	300	0.19	0.03	0.22
H-12	S	100	1,100	1,200	0.38	0.38	0.76	300	100	400	0.67	0.03	0.70
	10	400	800	1,200	0.96	0.20	1.16						
H-12A	S	100	300	400	0.14	0.08	0.22						
H-13	S	700	200	900	1.73	0.10	1.83	-	500	500	0.00	0.15	0.15
H-14	S	200	1,000	1,200	0.58	0.28	0.86	800	400	1,200	1.42	0.10	1.52
	20	100	1,000	1,100	0.19	0.30	0.49	500	400	900	1.66	0.09	1.75
H-15	S	300	500	800	1.23	0.18	1.41	2,900	600	3,500	9.52	0.13	9.65
	10	900	500	1,400	11.62	0.13	11.75	1,100	700	1,800	4.57	0.18	4.75
H-16	S	200	1,200	1,400	0.20	0.38	0.58	1,300	2,000	3,300	1.47	0.50	1.97
	10	100	1,000	1,100	0.19	0.23	0.42	1,100	1,500	2,600	1.69	0.40	2.09
H-17	S	1,400	800	2,200	3.11	0.19	3.30	300	700	1,000	0.20	0.20	0.40
	20	100	400	500	0.20	0.13	0.33	400	600	1,000	0.96	0.15	1.11
H-18	S	300	1,300	1,600	1.63	0.38	2.01						
	10	600	1,700	2,300	1.16	0.46	1.62						

*S = surface sample taken at a depth of 2 feet.

Table 6. Phytoplankton in Mystic, Malden, Ch·

Table 9. Average Concentration of Nutrients
Boston Harbor
Ammonia Nitrogen and Soluble Phosphorus

July-August 1967

Station	Micrograms per liter	
	NH_3-N	Sol. P
H-1	200	70
H-2	215	50
H-3	177	60
H-4	225	60
H-5	205	60
H-6	163	70
H-7	180	60
H-8	150	70
H-9	132	60
H-10	135	60
H-11	128	70
H-12	124	60
H-13	100	50
H-14	112	50
H-15	113	40
H-16	186	50
H-17	195	40
H-18	167	60

Table 10. Percentages of Organic Carbon and Organic Nitrogen Chelsea, Malden, Mystic, Neponset, Weymouth Back, Weymouth Fore, and Weir Rivers

July-August 1967

River & Station Number	% Organic C	% Organic N
Chelsea River		
Ch-1	12.5	0.34
Ch-2	4.2	0.18
Malden River		
Ma-1	6.5	0.24
Nystic River		
My-1	4.1	0.11
Neponset River		
N-2A *	4.7	0.23
Weymouth Fore River		
WF-1	3.8	0.09
Weymouth Back River		
WB-1**		
Weir River		
W-1	4.0	0.29

* This reach of the Neponset River is saline, and is located in the vicinity of the Neponset Avenue bridge near Quincy, Massachusetts.

** The most upstream reach of the Weymouth Back River contained sand, pebbles, and small rocks; such materials would be expected to have very low percentages of organic carbon and nitrogen, that is, less than 1.0 and 0.1 percents, respectively.

Table 11. Percentages of
Organic Carbon and Organic Nitrogen
Boston Harbor Bottom Deposits

July-August 1967

Station Number	% Organic Carbon	% Organic Nitrogen
H-1	5.5	0.20
FP-1*	23.5	1.29
H-2	2.1	0.19
H-3	2.4	0.14
H-4	4.6	0.27
H-5	3.6	0.22
H-6	5.0	0.26
H-7	4.6	0.37
H-8	3.6	0.20
H-9	2.3	0.20
H-10**	-	-
H-11	2.8	0.12
H-12	3.8	0.25
H-13	2.6	0.19
H-14	2.5	0.22
H-15**	-	-
H-16	2.0	0.15
H-16A	3.2	0.20
H-17	2.1	0.06
H-18	4.9	0.41
H-19	2.9	0.13
H-20	3.3	0.16
H-21	0.4	0.04

* FP-1 is located in the Fort Point Channel.

** These stations had sand, pebbles and small rocks and would have very low percentages of organic carbon and nitrogen, that is, less than 1.0 and 0.1 percents, respectively.

Table 12. Percentages of Organic Carbon and Organic Nitrogen Cores from Selected Deposits in Boston Harbor

July-August 1967

Depth from top of core (mm)	Station Number H-7 % Org. Carbon	H-7 % Org. Nitrogen	H-6 % Org. Carbon	H-6 % Org. Nitrogen	H-18 % Org. Carbon	H-18 % Org. Nitrogen
0-20	4.7	0.48	4.4	0.39	2.8	0.20
20-40	4.5	0.42	4.1	0.33	-	-
40-60	4.8	0.37	4.7	0.32	3.1	0.17
60-80	4.5	0.40	5.7	0.36	-	-
80-100	4.9	0.42	5.9	0.37	2.6	0.20
100-120	4.3	0.39	5.9	0.38	-	-
120-140	3.4	0.25	5.9	0.37	3.0	0.21
140-160	2.3	0.21	5.9	0.31	-	-
160-180	1.7	0.16	6.2	0.31	3.0	0.21
180-200	1.7	0.19	6.1	0.34	-	-
200-220	1.3	0.11	5.0	0.25	1.7	0.13
220-240	1.2	0.16	4.8	0.25	-	-
240-260	1.9	0.14	4.9	0.30	1.6	0.12
260-280	1.1	0.16	5.1	0.33	-	-
280-300	1.0	0.09	5.5	0.33	1.8	0.11

Table 12. (Con't.)

Depth from top of core (mm)	Station Number H-7 % Org. Carbon	H-7 % Org. Nitrogen	H-6 % Org. Carbon	H-6 % Org. Nitrogen	H-18 % Org. Carbon	H-18 % Org. Nitrogen
300-320	1.1	0.13	5.3	0.33	-	-
320-340	1.0	0.04	5.7	0.34	1.3	0.09
340-360	1.0	0.06			-	-
360-380	0.5	0.02			2.7	0.19
380-400	0.3	0.03			-	-
400-420					3.1	0.27
420-440					-	-
440-460					3.1	0.30
460-480					-	-
480-500					3.3	0.33
500-520					-	-
520-540					5.0	0.52
540-560					-	-
560-580					5.0	0.44