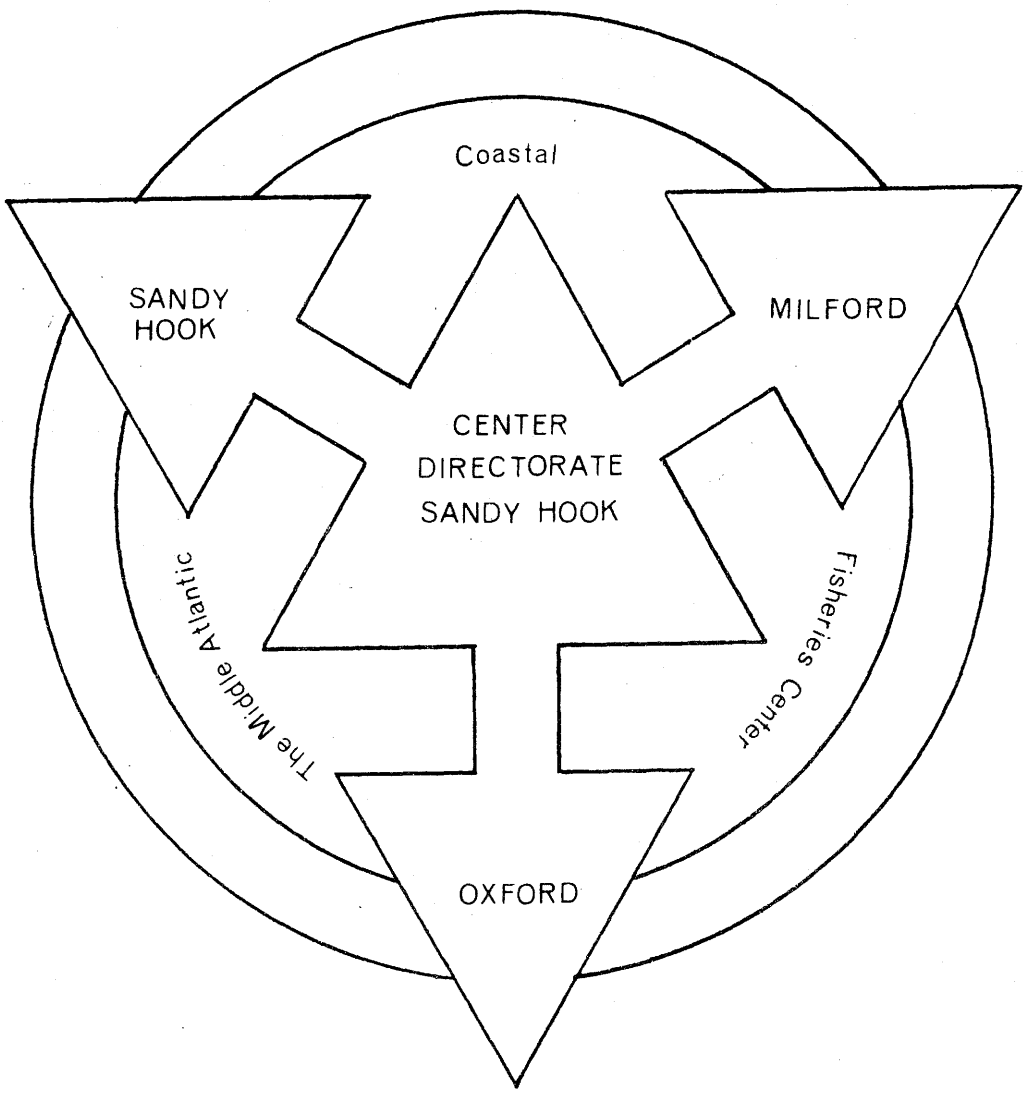
RESULTS IN 1974 OF MESA-FUNDED BIOLOGICAL STUDIES CONDUCTED BY THE MIDDLE ATLANTIC COASTAL FISHERIES CENTER (MACFC) AND BY ITS CONTRACTORS

by J. K. McNulty

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region

MIDDLE ATLANTIC COASTAL FISHERIES CENTER



Informal Report No. 60

March 26, 1975

NOTE: This report has been prepared for administrative use only. It does not constitute publication; conclusions reached must be considered tentative; and the material contained must not be referenced or cited in any way in scientific publications.

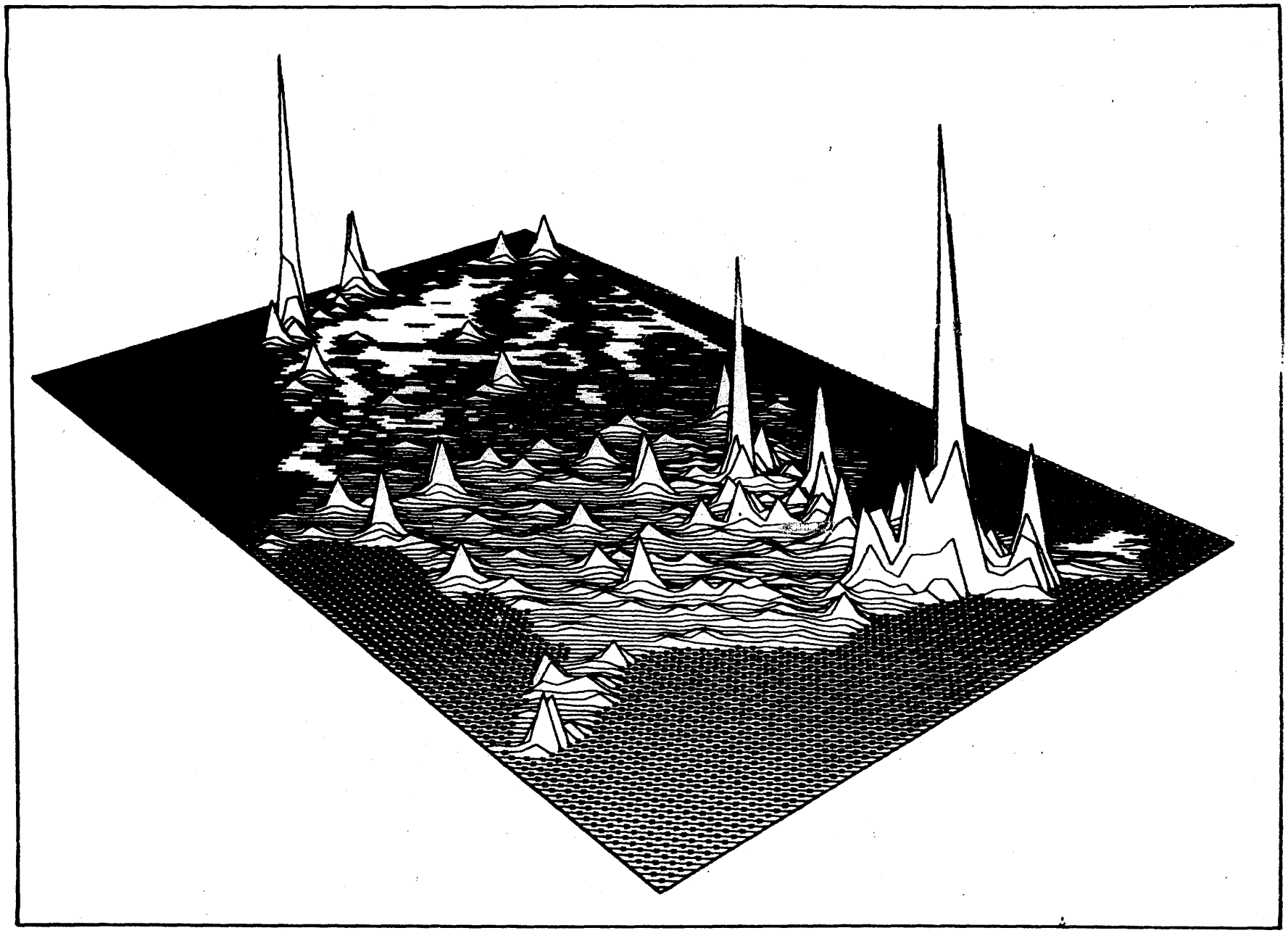
RESULTS IN 1974 OF MESA-FUNDED BIOLOGICAL STUDIES CONDUCTED BY THE MIDDLE ATLANTIC COASTAL FISHERIES CENTER (MACFC) AND BY ITS CONTRACTORS

by

J. K. McNulty

NOTE: The following account is based on a review given by Dr. McNulty at a meeting of the MESA Citizens and Industrial Advisory Panel held at Sandy Hook, N. J., on February 11, 1975.

The context within which our research was conducted is illustrated by the accompanying diagram of population density nationwide (Fig. 1). The New York metropolitan area stands out as the nation's most heavily populated region. Its volume of municipal sewage effluent, which approaches two billion gallons per day, is about double the volume of that discharged to California coastal waters from San Francisco to San Diego, and about ten times that discharged along the southeastern Florida coast from Palm Beach to Miami. The result is the greatest concentration of municipal and industrial waste being discharged along a few miles of coastline in the Nation.



Pen-blotter relief map of population density in the U.S. from 1970 census data.

Fig. 1

One can visualize the quantity of municipal sewage being discharged each day by imagining it to be confined in a huge box having the same basal dimensions as the Empire State building (Fig. 2). The height of such a box would far exceed the height of the building, and it would closely approach the height of another mythical box containing the daily low-flow discharge of the Hudson River (Fig. 2).

We have studied the effects of this enormous discharge on the growth of phytoplankton (primary productivity). The study is divided geographically into the Bight apex, covered by Dr. Malone of the City University of New York, and the estuarine areas south and southwest of The Narrows, covered by MACFC scientists. Sewage both inhibits and stimulates the growth of phytoplankton, inhibiting by toxic and light-scattering effects of its constituents, and stimulating by providing fertilizing substances. The net effect is stimulatory, but for reasons still not clearly understood, the growth of very small plants that are less than 20 microns maximum dimension is favored over the growth of larger plants such as diatoms. Furthermore, growth is greater in Sandy Hook Bay which lies south and east of Sandy Hook than in other nearby areas, as measured by chlorophyll a concentrations in April 1974, because water movements

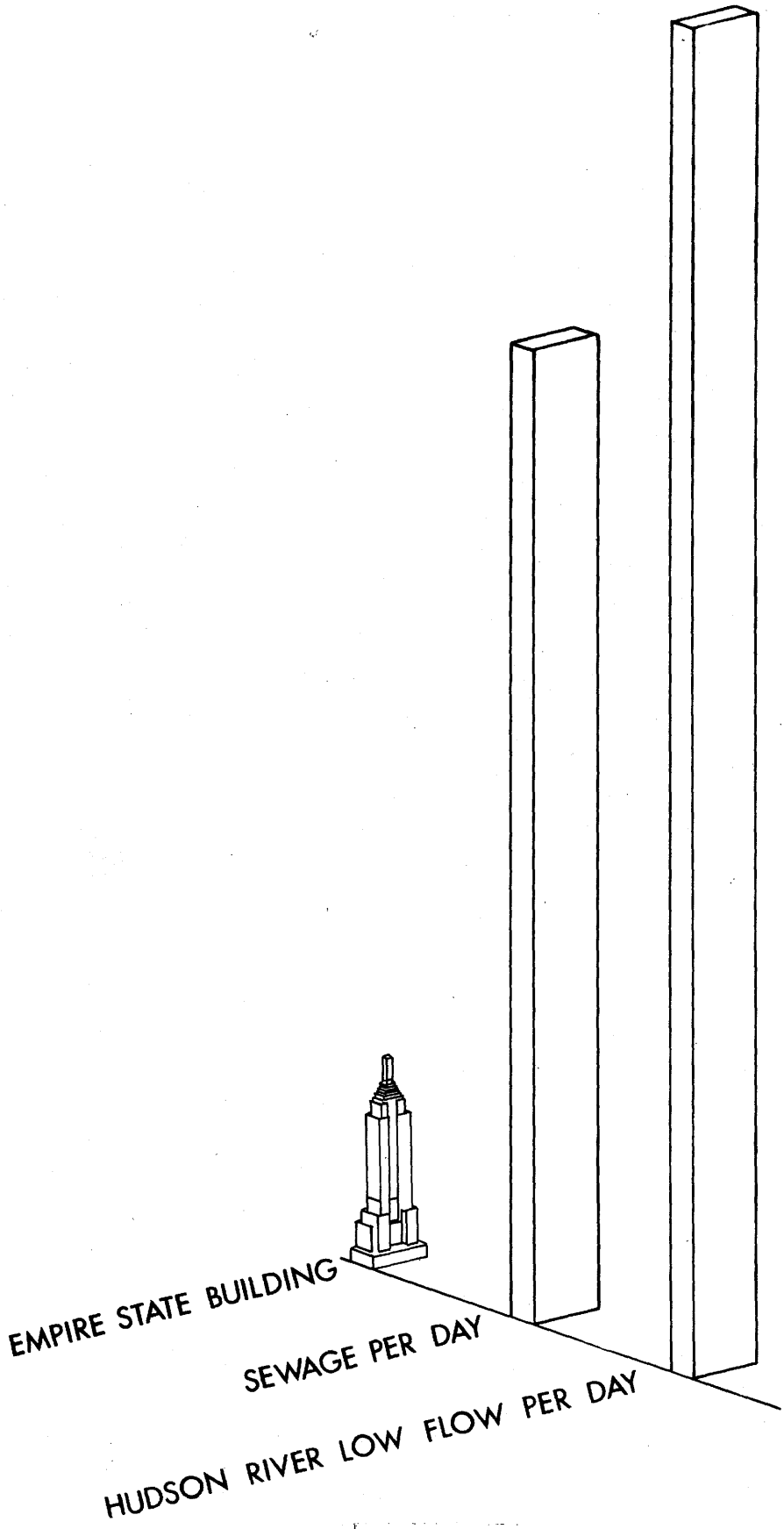

EMPIRE STATE BUILDING
SEWAGE PER DAY
HUDSON RIVER LOW FLOW PER DAY

Fig. 2

carry nutrient-rich water into Sandy Hook Bay where it tends to accumulate and stimulate the production of phytoplankton (Fig. 3). Note that in April 1974 chlorophyll a was over 10 times more concentrated in Sandy Hook Bay than in offshore areas near the dump sites, which are shown in Fig. 3 by the small square, triangle, and circle (see legend in Fig. 5). The combined studies demonstrate that even though primary productivity in the vicinity of the dump sites is very high compared with other oceanic coastal waters, productivity is even higher in Sandy Hook Bay by perhaps an order of magnitude, and that the major source of nutrients which maintains the high productivity is the Hudson River estuary.

Approximately 80% of all of the nation's ocean dumping of sewage sludge and industrial wastes including acids takes place in the New York Bight, as well as the dumping of harbor dredge spoils from the Port of New York. If the quantities of dumped wastes are visualized as was done above with sewage effluent, the quantities which were dumped in 1973 tend to dwarf the Empire State building (Fig. 4). About 2.7 million cubic yards of industrial wastes including acids, 5.6 million cubic yards of municipal sludge, and 11.8 million cubic yards of dredge spoils were dumped in 1973.

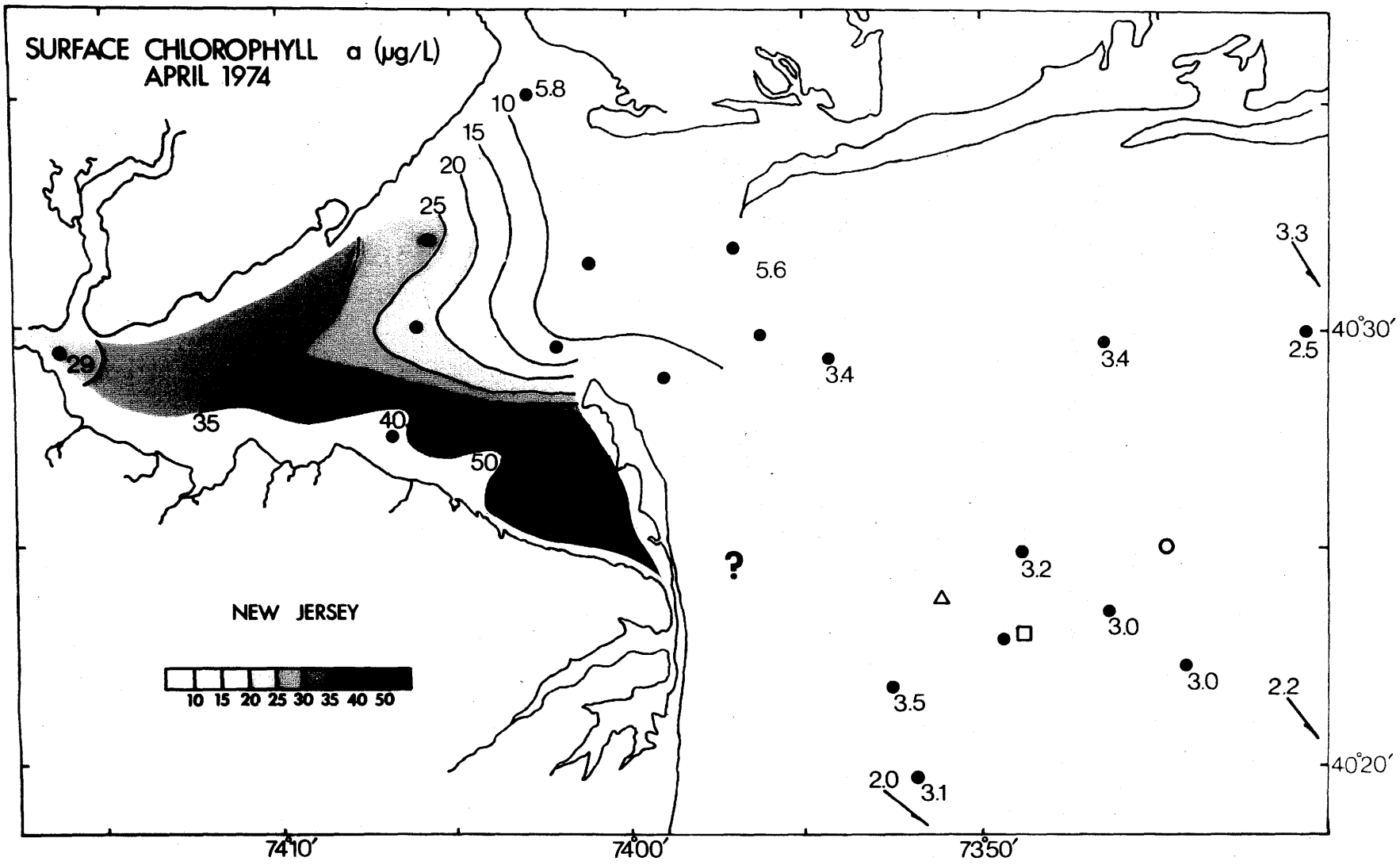

SURFACE CHLOROPHYLL a (µg/L)
APRIL 1974
10
15
20
25
35
40
50
29
5.8
5.6
3.4
3.4
3.3
2.5
3.2
3.0
3.0
2.2
3.5
2.0
3.1
?
NEW JERSEY
10 15 20 25 30 35 40 50
74°10′
74°00′
73°50′
40°30′
40°20′

Fig. 3

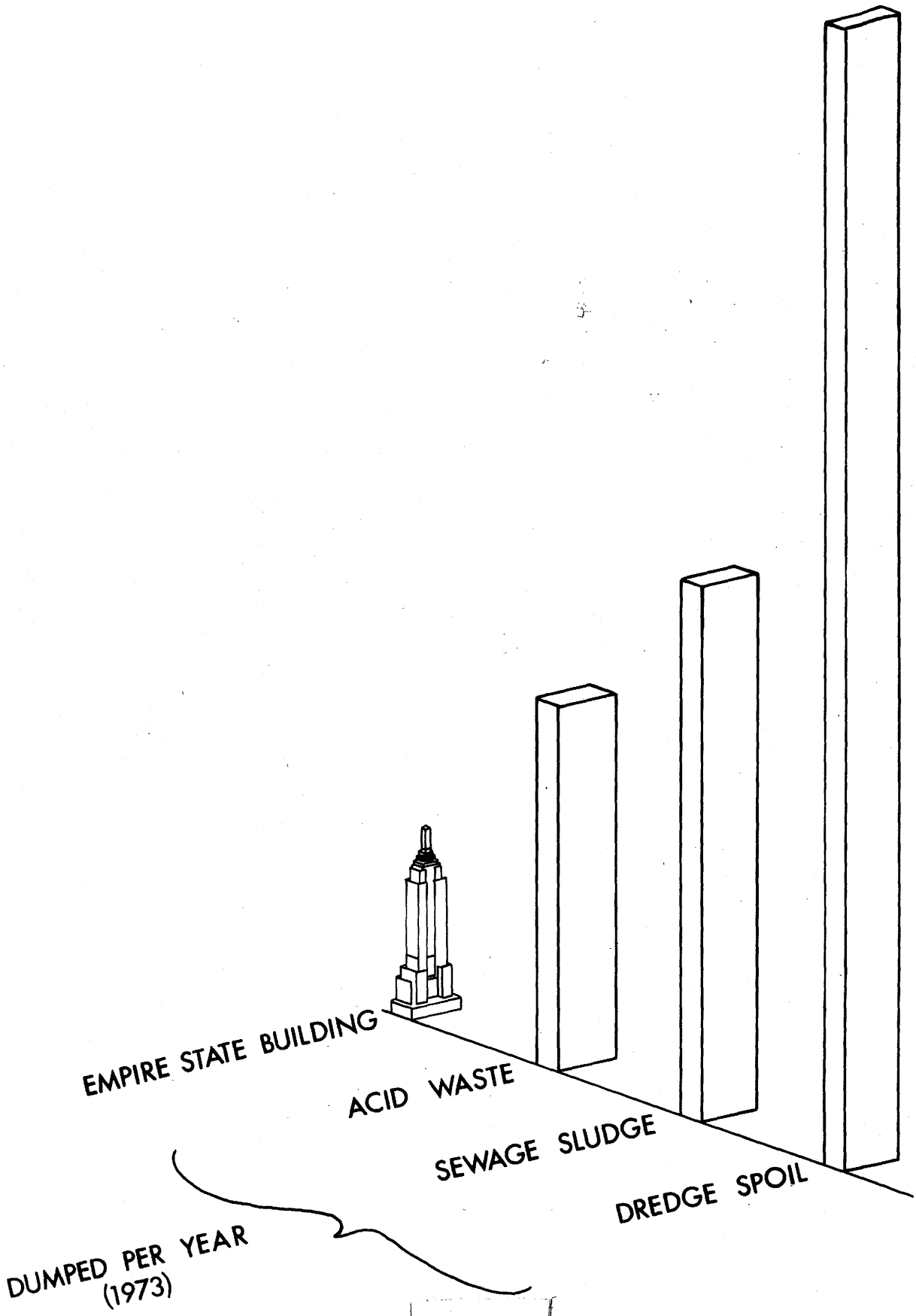

EMPIRE STATE BUILDING
ACID WASTE
SEWAGE SLUDGE
DREDGE SPOIL
DUMPED PER YEAR
(1973)

Fig. 4

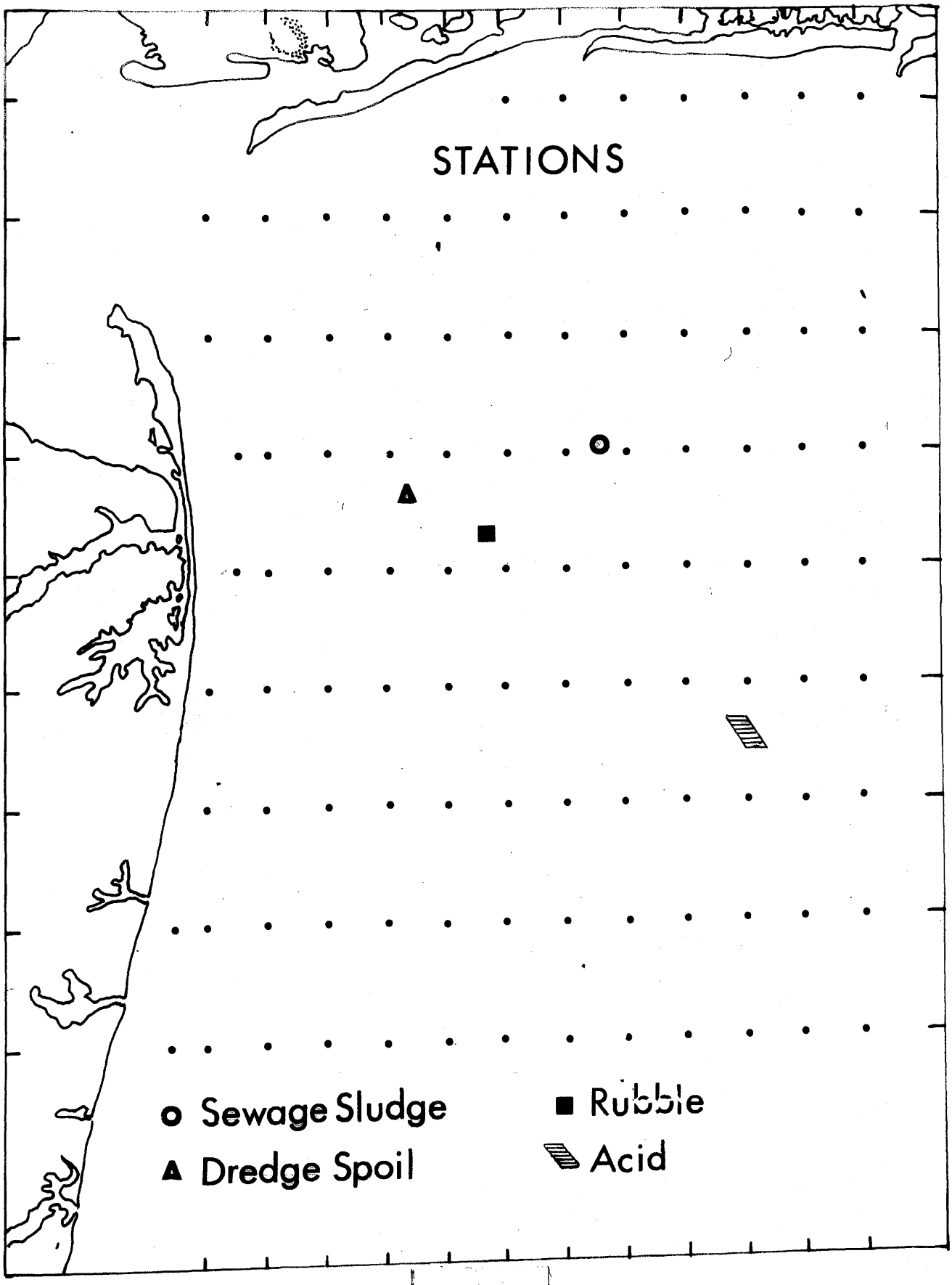


Fig. 5

Early in the project a network of sampling locations called the "MESA grid" was established at which all MESA samples would be taken (Fig. 5). Stations are one nautical mile apart from north to south and one-half mile apart from east to west. We have completed quarterly sampling for one year at all or most of the 105 stations for benthic macroinvertebrates, meiofauna, sediments, and seabed oxygen demand. In addition, we have conducted much special-purpose sampling to satisfy specific needs for data on the distribution of coliforms and metals in sediments, the dissolved oxygen in bottom water, the occurrence of bacteria that are resistant to metals and antibiotics, the statistical validity of macrofaunal sampling, the distribution of ciliates, and the prevalence of fin rot disease in fish.

The heavier particles of organic material in sewage sludge and dredge spoil settle differentially to the bottom where they become incorporated in the sediments. Accumulations of organic material near dump sites and in the Hudson Shelf Valley south of the sites are mapped in Fig. 6. Results are expressed as percentage of peroxide-oxidizable material in dry sediment. The accumulations of organic materials exert at least three important effects. First,

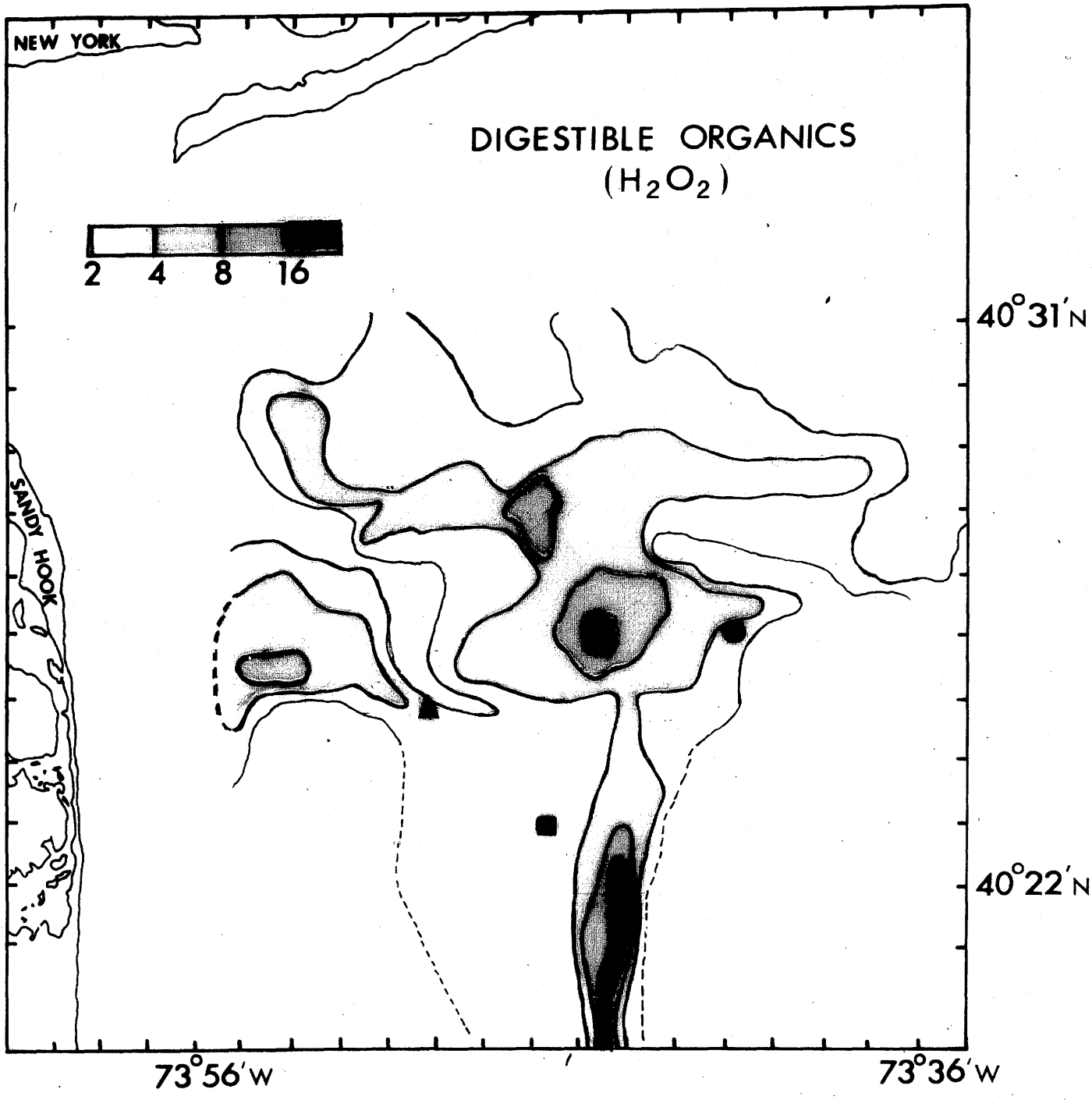

NEW YORK
DIGESTIBLE ORGANICS
(H_2O_2)
2 4 8 16
40°31′N
40°22′N
SANDY HOOK
73°56′W
73°36′W

Fig. 6

the texture of sediments is altered by the addition of fine materials. Second, aerobic bacteria feeding on the organic material tend to deplete the available supply of dissolved oxygen. Third, heavy metals adsorbed to organic particulates in sludge and harbor sediments accumulate in and around dump sites. For example, Fig. 7 demonstrates the accumulation of zinc in sediments that is associated with dumping.

Because dissolved oxygen is essential to all marine life, its partial depletion is a matter of grave concern. In late summer of 1974, we found that bottom dissolved oxygen concentrations of less than 4 parts per million were widespread in the apex of the Bight, and that near sludge and dredge spoil dumping sites, concentrations of less than 2 parts per million were present (Fig. 8). The prevailing consensus among biologists is that concentrations below 4 parts per million are associated with changes in the species composition and abundance of marine organisms, and that these changes increase markedly with even lower concentrations. We have never measured zero dissolved oxygen but values of less than 1 ppm have been observed in the Bight and if such values obtain certain bacteria, using sulfates as their oxygen source and releasing hydrogen sulfide as a metabolic product, tend to flourish and become predominant. Hydrogen sulfide is poisonous to most marine life except the sulfur bacteria and certain taxa of metazoans which have adapted to these conditions.

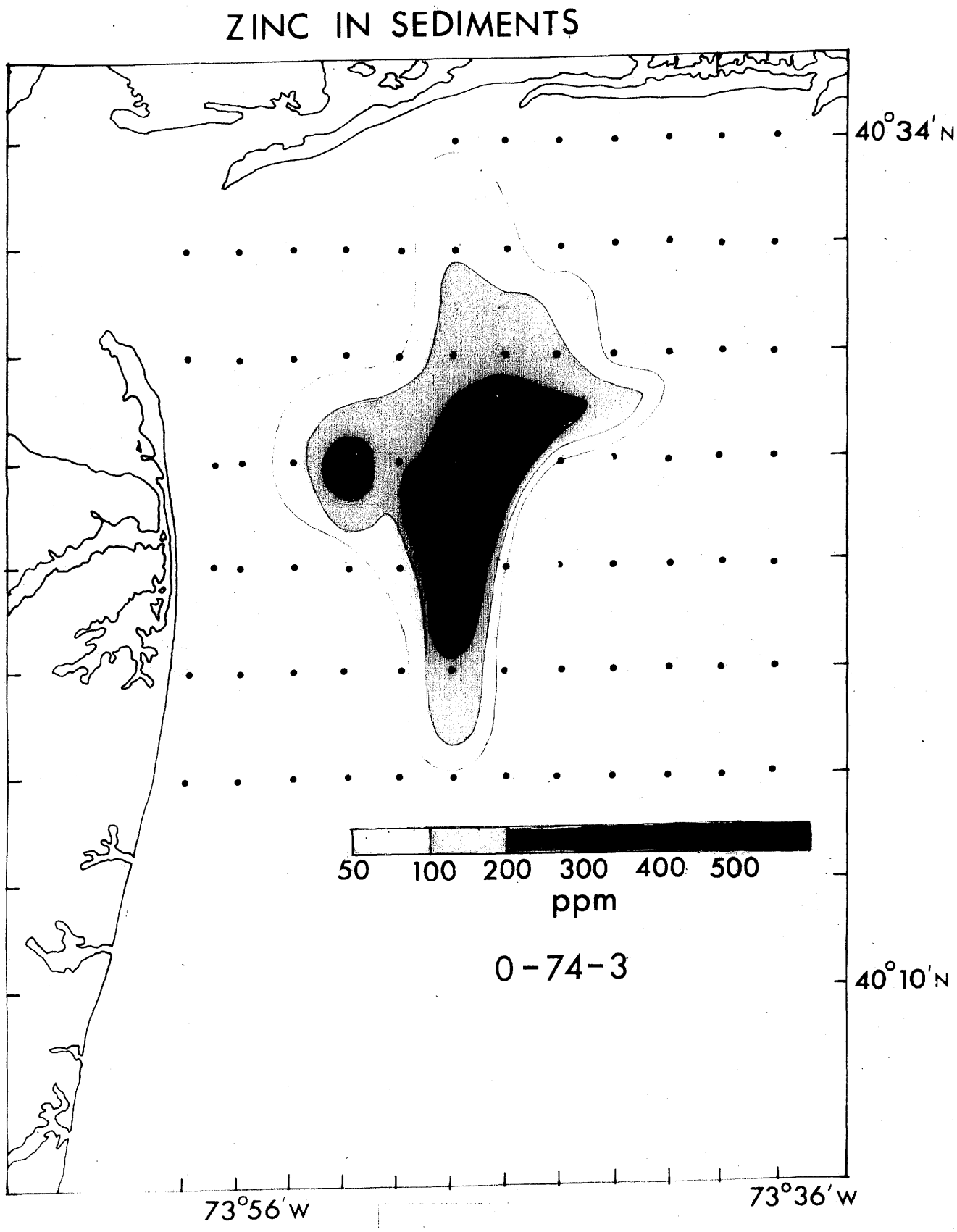

ZINC IN SEDIMENTS
40°34′N
40°10′N
73°56′W
73°36′W
50
100
200
300
400
500
ppm
0-74-3

Fig. 7

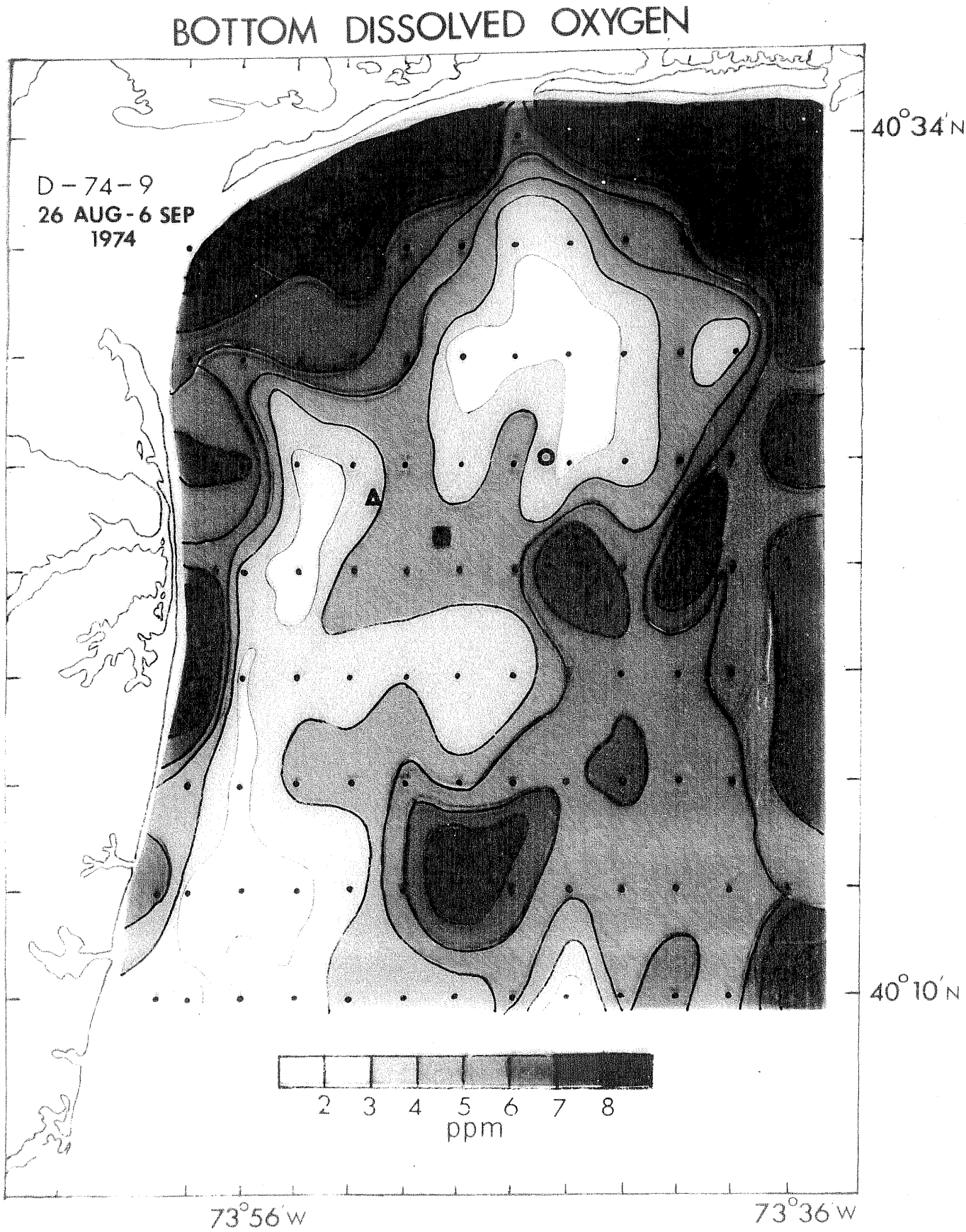

BOTTOM DISSOLVED OXYGEN
D-74-9
26 AUG-6 SEP
1974
40°34'N
40°10'N
73°56'W
73°36'W
2 3 4 5 6 7 8
ppm

Fig. 8

We have measured the rate of seabed oxygen consumption seasonally throughout the inner Bight to gain an understanding of its spatial and seasonal characteristics. Spatially, consumption is greatest in the vicinity of the sewage sludge and dredge spoil dump sites and in relatively deep areas which are the northerly part of the Hudson Shelf Valley, as well as in an area along the New Jersey shore which may be enriched by sewer outfalls and drainage from polluted estuaries and fresh water ponds (Figs. 9 and 10). Seasonally, oxygen consumption is much greater in late summer than in early spring because the higher temperatures of summer accelerate the metabolism of microorganisms which decompose the organic materials. We found a spatial anomaly in late summer, however, extending north and south between the sludge and dredge spoil dumping sites. Here, consumption was low relative to surrounding areas whereas in early spring it was high, indicating that the area is overstressed in summer, i.e., more organic material is present than can be decomposed efficiently by microorganisms.

It seems appropriate to consider at this point a classical view of the biodegradation of sewage as published by Alfred Bartsch and William Ingram in 1959 (Public Works, Vol. 90, p. 104-110). Biodegradation was seen as consisting of a three-stage food chain consisting of bacteria proliferating in response to the abundance of food, ciliates feeding on bacteria and suitable organic material, and, finally, microcrustaceans feeding in large parts on ciliates (Fig. 11).

SEABED OXYGEN CONSUMPTION
(ml O_2 /m^2/ hr)
21 MARCH — 4 APR 1974

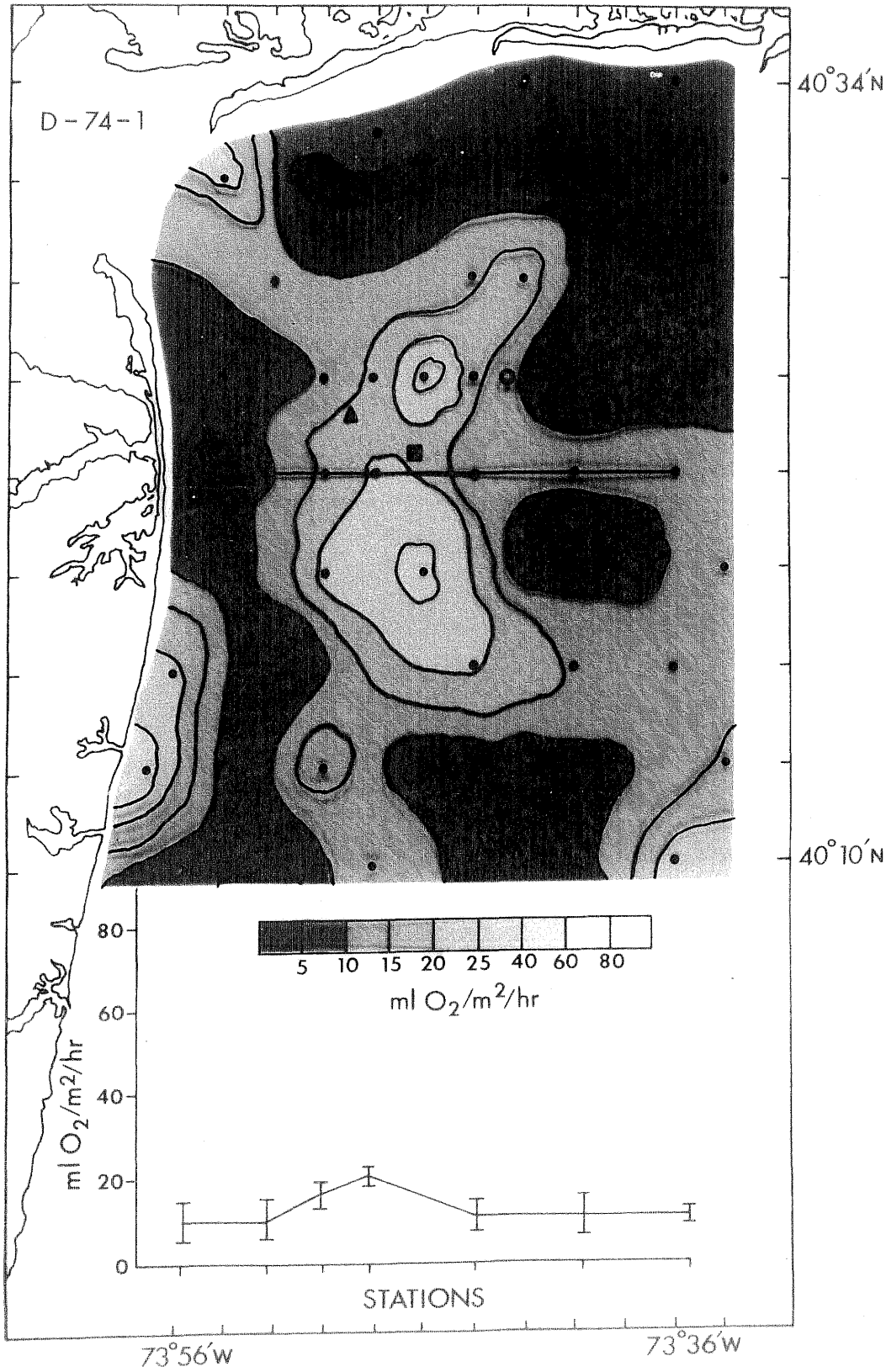


Fig. 9

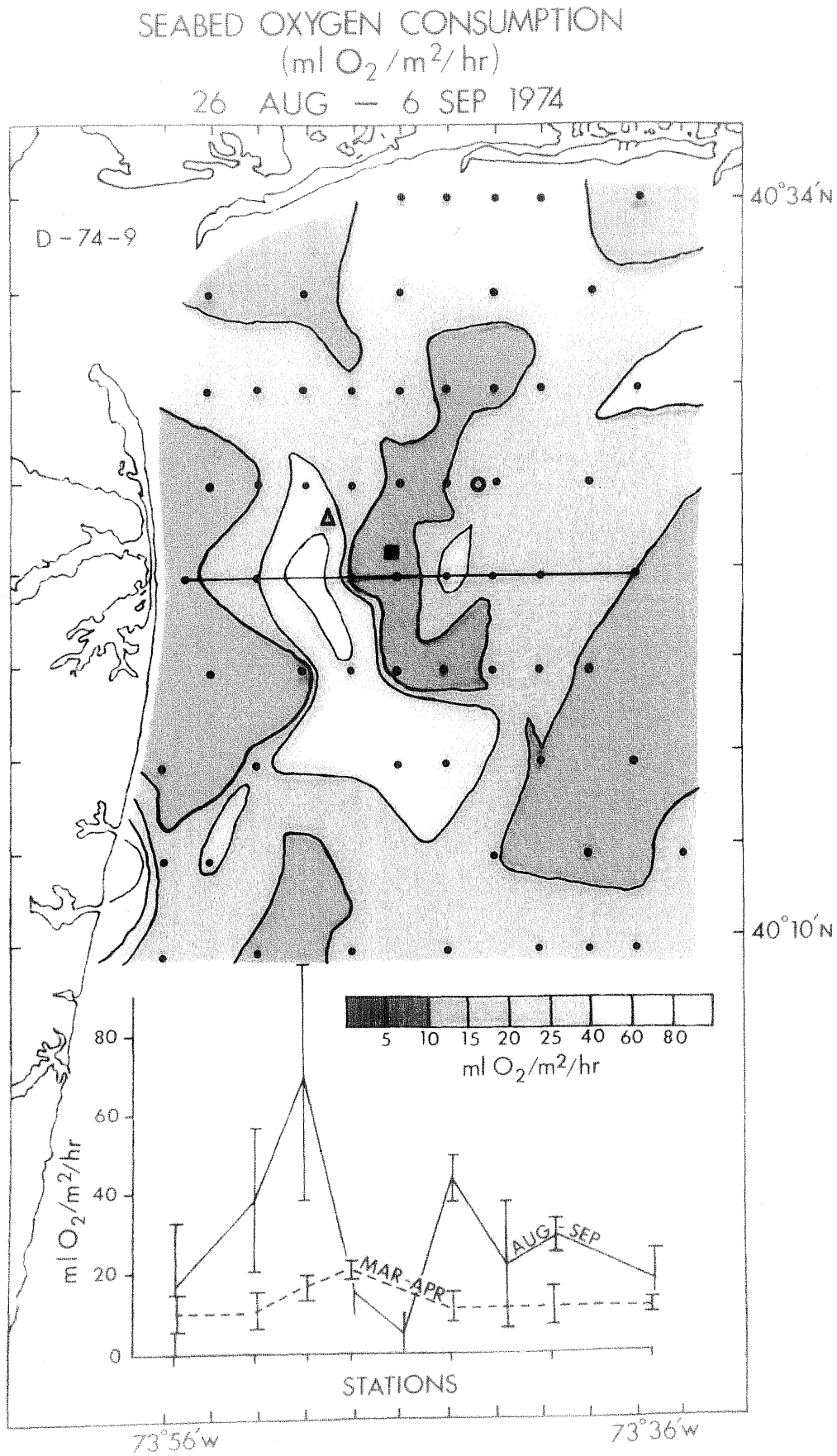
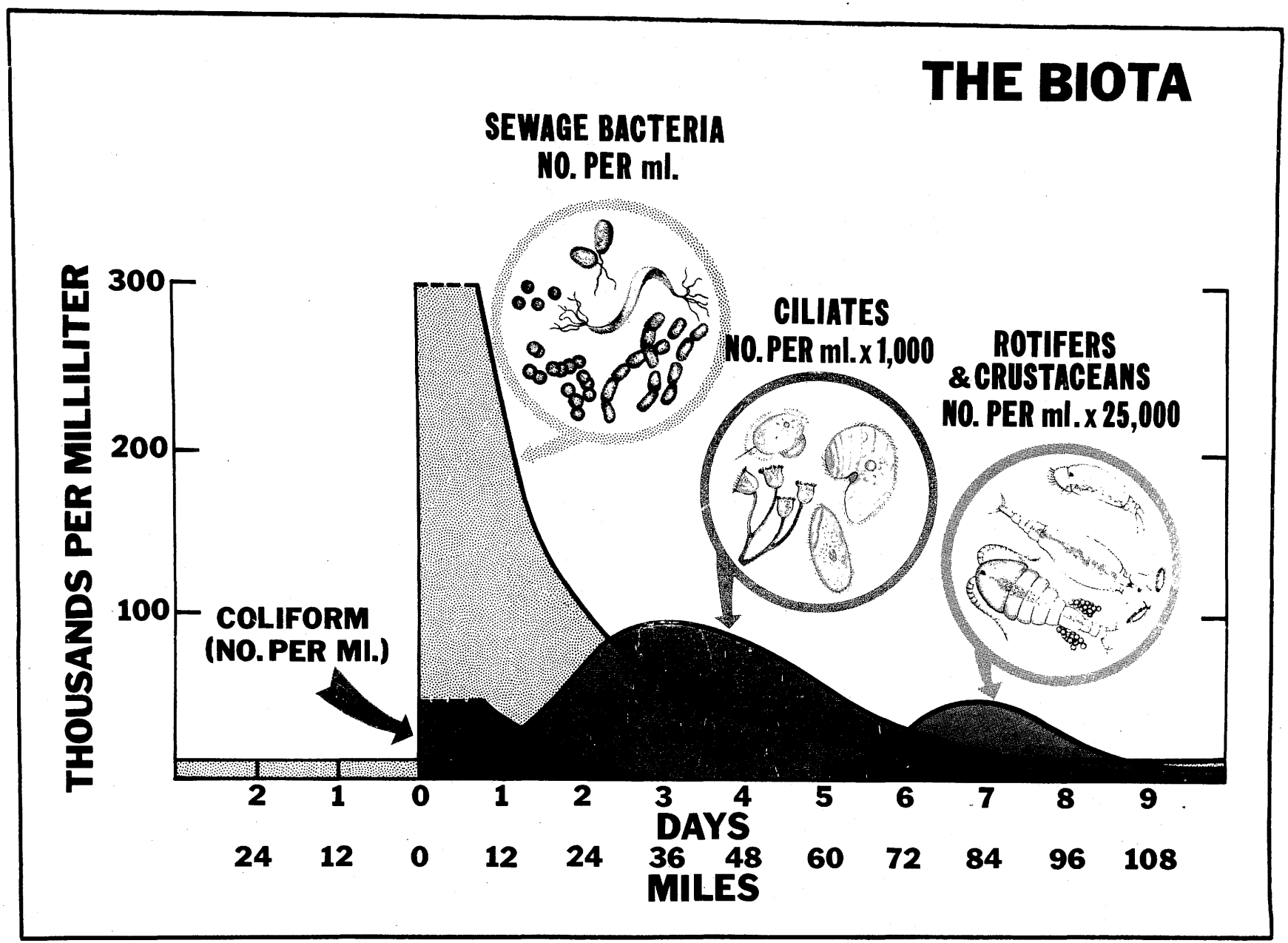

SEABED OXYGEN CONSUMPTION
(ml O2/m2/hr)
26 AUG — 6 SEP 1974
D-74-9
40°34′N
40°10′N
5 10 15 20 25 40 60 80
ml O2/m2/hr
80
60
40
20
0
ml O2/m2/hr
MAR-APR
AUG-SEP
STATIONS
73°56′W
73°36′W

Fig. 10



● FIGURE 6. Bacteria thrive and finally become prey of the ciliates, which in turn are food for the rotifers and crustaceans.

Ciliates in the vicinity of the dump sites seem to respond in a manner that is similar to the classical model described above. Dr. Eugene Small of the University of Maryland, a contractor, has found essentially no ciliates associated with sediments at the dump sites but he has observed large populations of bactivorous ciliates in the water column just above the dump sites, depicted diagrammatically in Fig. 12. He theorizes that they form a lens of ciliates that seems to envelope concentrations of sludge, as diagrammed in Fig. 13.

In their 1959 paper, Bartsch and Ingram also conceptualized the relation of macroorganisms to sewage. In a river where active decomposition is taking place, a few sewage-tolerant benthic macroinvertebrates flourish, but most organisms including fish are absent (Fig. 14). We are finding interesting similarities to and differences from the classical riverine model. Based only on a preliminary analysis of numbers of individuals and of numbers of species of benthic macroinvertebrates, we find very few individuals near the sewage sludge dump site but enormous numbers of individuals a few miles northwest of the dump site (Fig. 15). This response reflects inhibitory effects of overabundance of organic materials and, possibly, of toxicants in the dump area, and stimulatory effects "downstream".

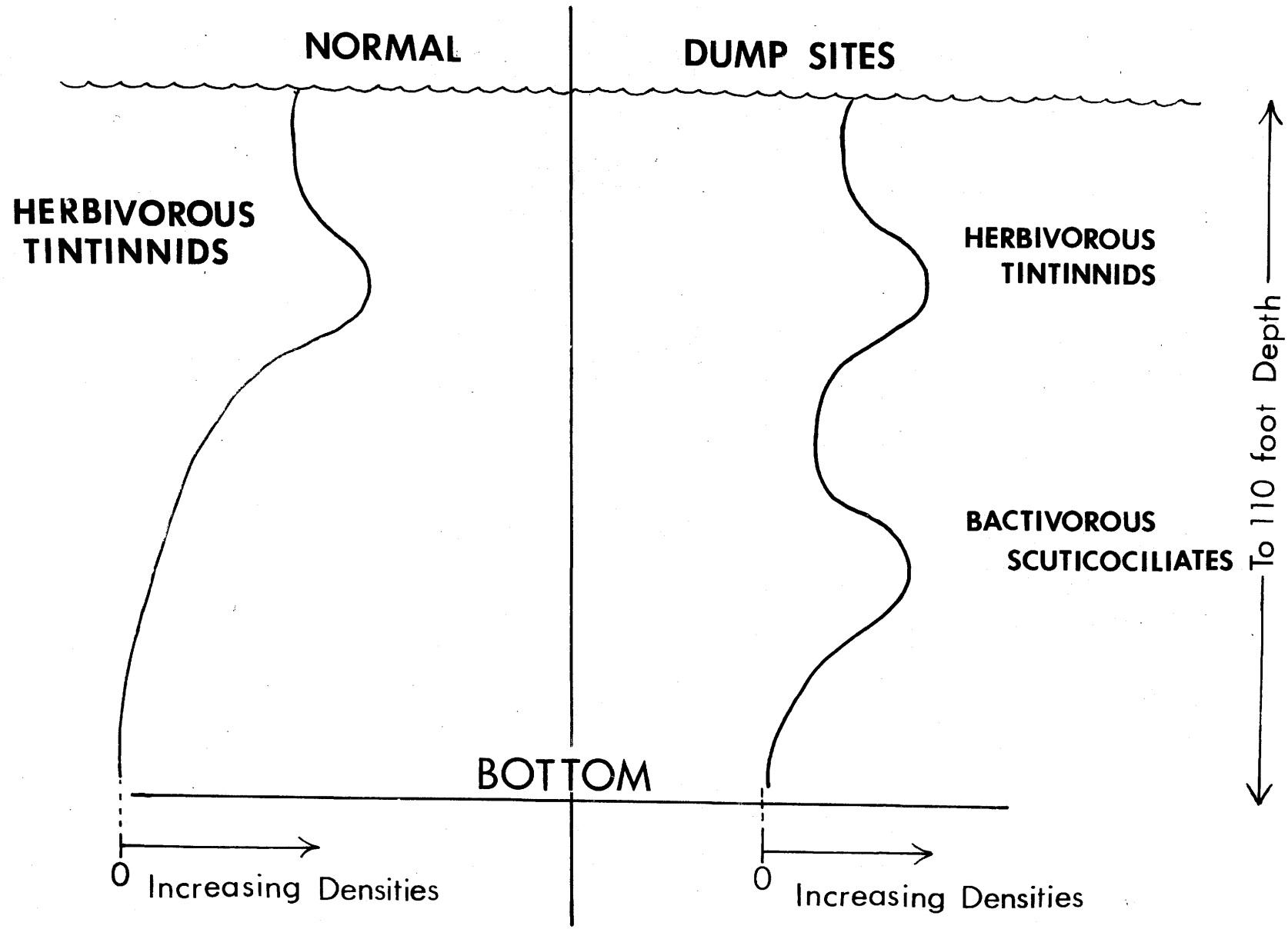

NORMAL
DUMP SITES
HERBIVOROUS TINTINNIDS
HERBIVOROUS TINTINNIDS
BACTIVOROUS SCUTICOCILIATES
To 110 foot Depth
BOTTOM
0
Increasing Densities
0
Increasing Densities

Fig. 12

LENS OF

BACTIVOROUS SCUTICOCILIATES

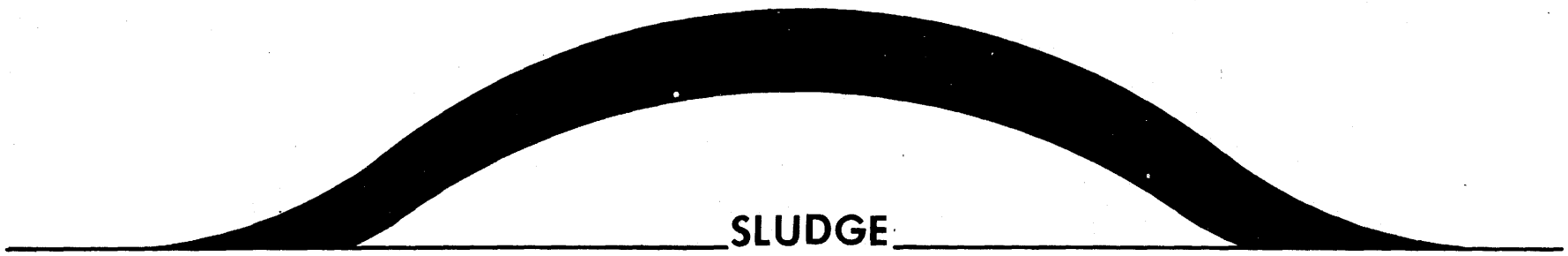
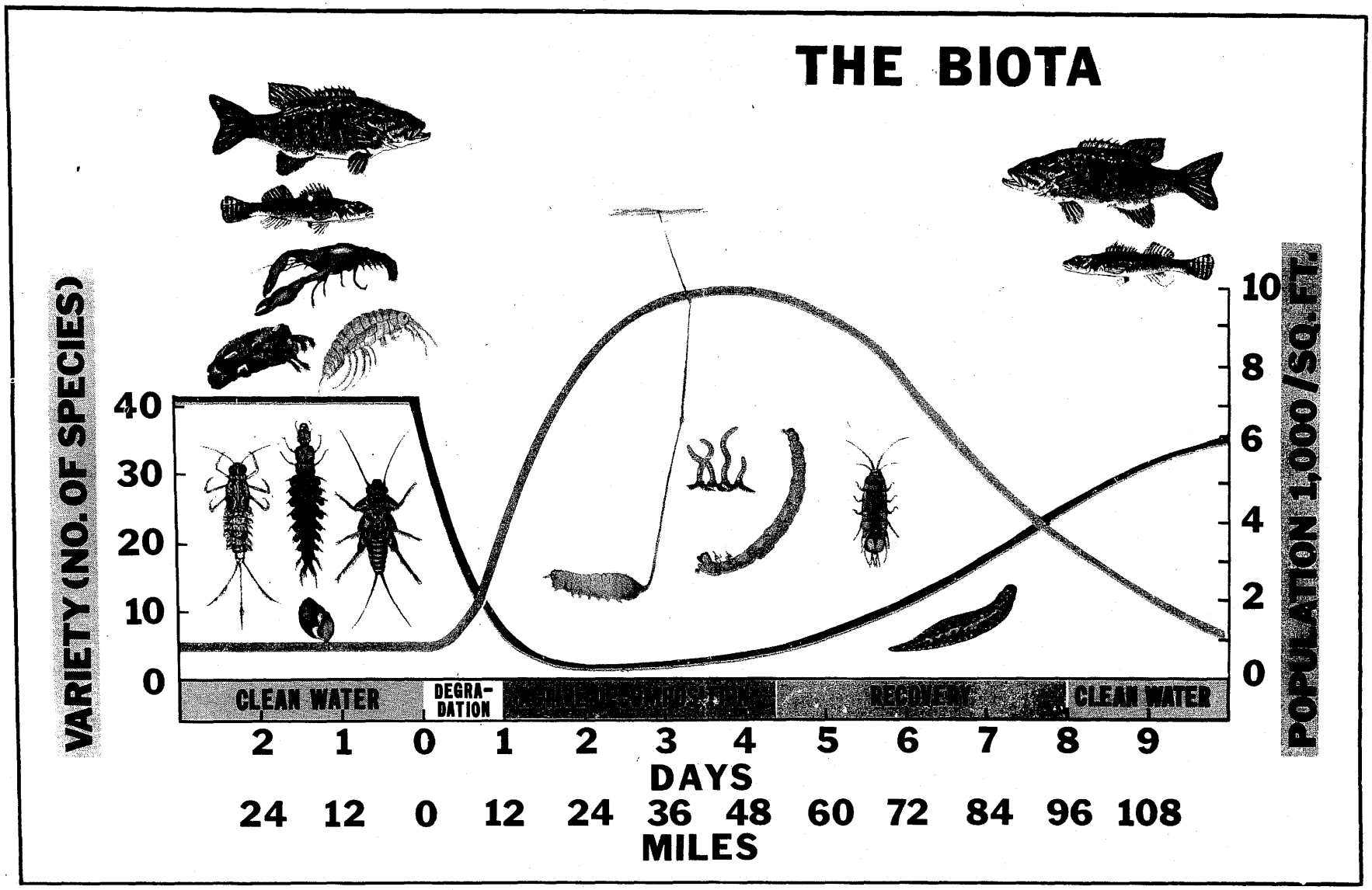


Fig. 13



● FIGURE 7. The green curve shows the fluctuations in numbers of species; the orange, the variations in numbers of each.

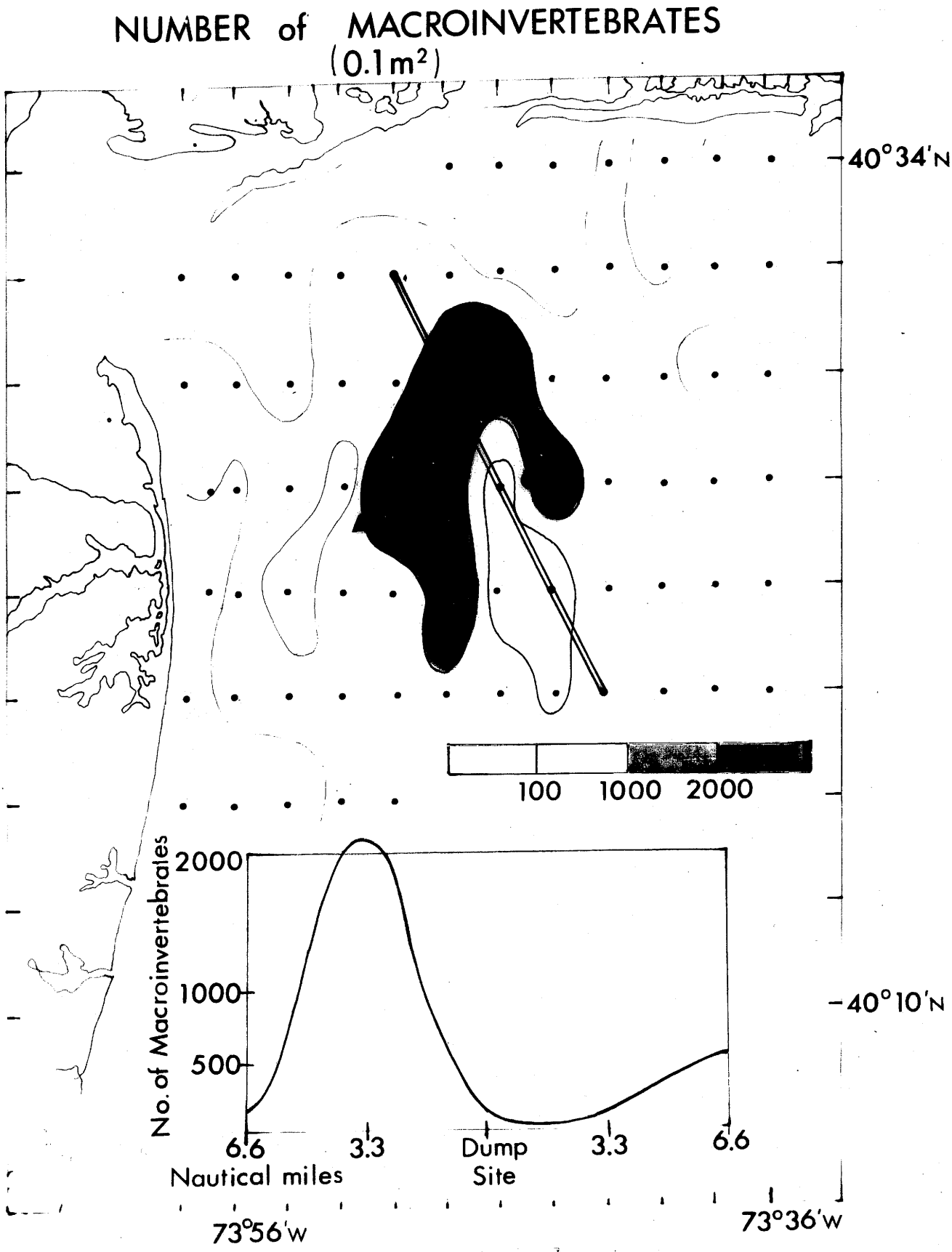

NUMBER of MACROINVERTEBRATES
(0.1m²)
40°34'N
40°10'N
100
1000
2000
No. of Macroinvertebrates
2000
1000
500
6.6
3.3
Dump
Site
3.3
6.6
Nautical miles
73°56'W
73°36'W

Fig. 15

The direction of bottom water movement is generally northwesterly at the sewage dump site. The trend of number of species of macroinvertebrates is similar but not as pronounced as number of individuals (Fig. 16). Preliminary comparison of the classical riverine model with our results indicates that the curves depicting number of species (taxa) and number of individuals diverge sharply in the riverine environment but tend to run parallel in the apex of the Bight. The differences appear to be rather fundamental and they probably reflect the greater freedom of water movement in the oceanic environment compared with the confinement of riverine water between two banks.

Fin rot disease of fishes is known from several polluted areas worldwide including the New York Bight. We are investigating the prevalence of the disease in the field and its etiology based on laboratory experiments. We find the disease in several valuable commercial and recreational species including the fluke (*Paralichthys dentatus*), shown undiseased in Fig. 17. The diseased fish shown in Fig. 18 exhibits a completely missing caudal fin (Fig. 19), partially eroded dorsal and anal fins (dorsal -- Fig. 20), and eye damage (Fig. 21). Although bacterial etiology of the disease has been reported in other investigations, and association with cadmium is implicated

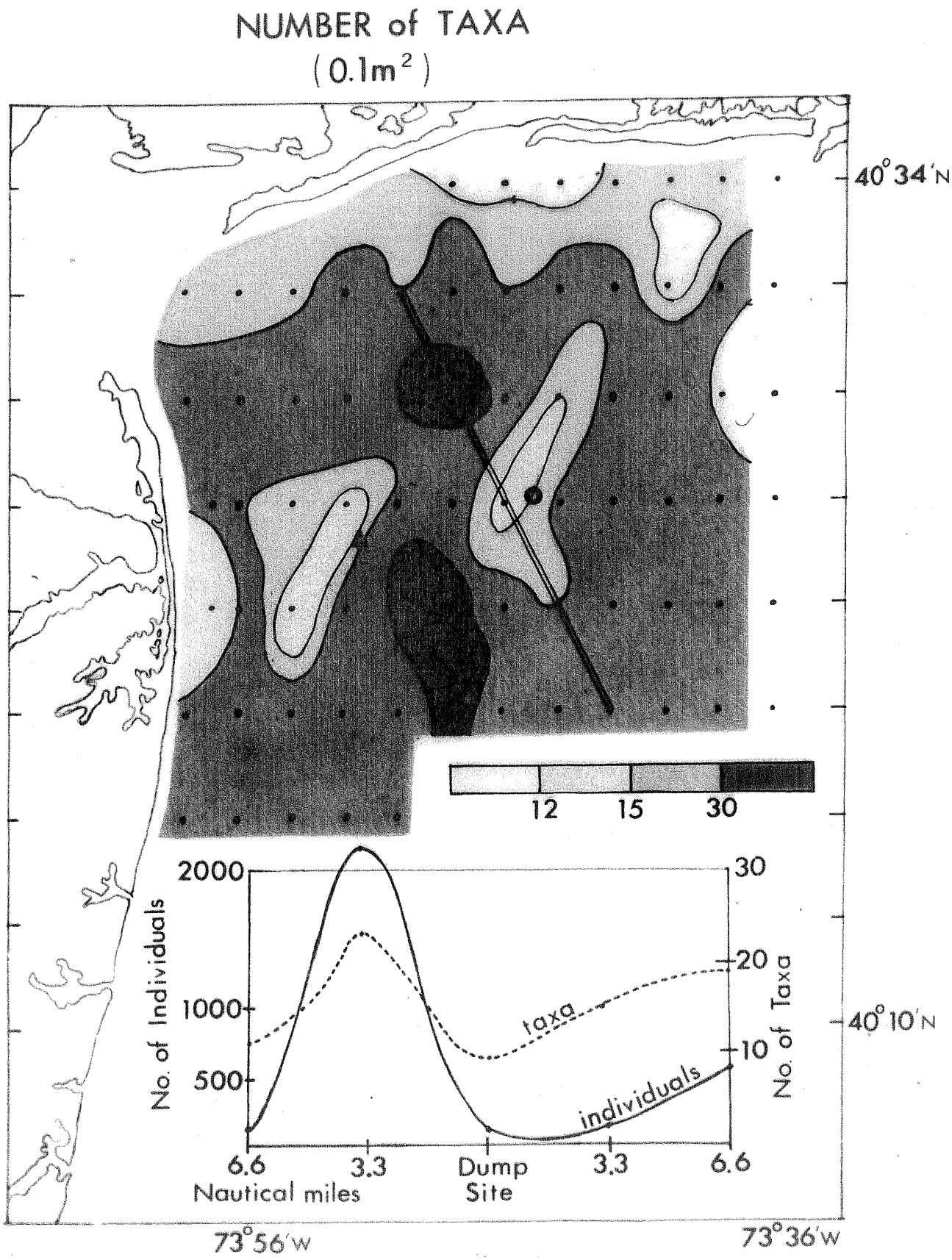

NUMBER of TAXA
(0.1m²)
40°34'N
40°10'N
73°56'W
73°36'W
12
15
30
2000
1000
500
No. of Individuals
30
20
10
No. of Taxa
taxa
individuals
6.6
3.3
Dump
Site
3.3
6.6
Nautical miles

Fig. 16

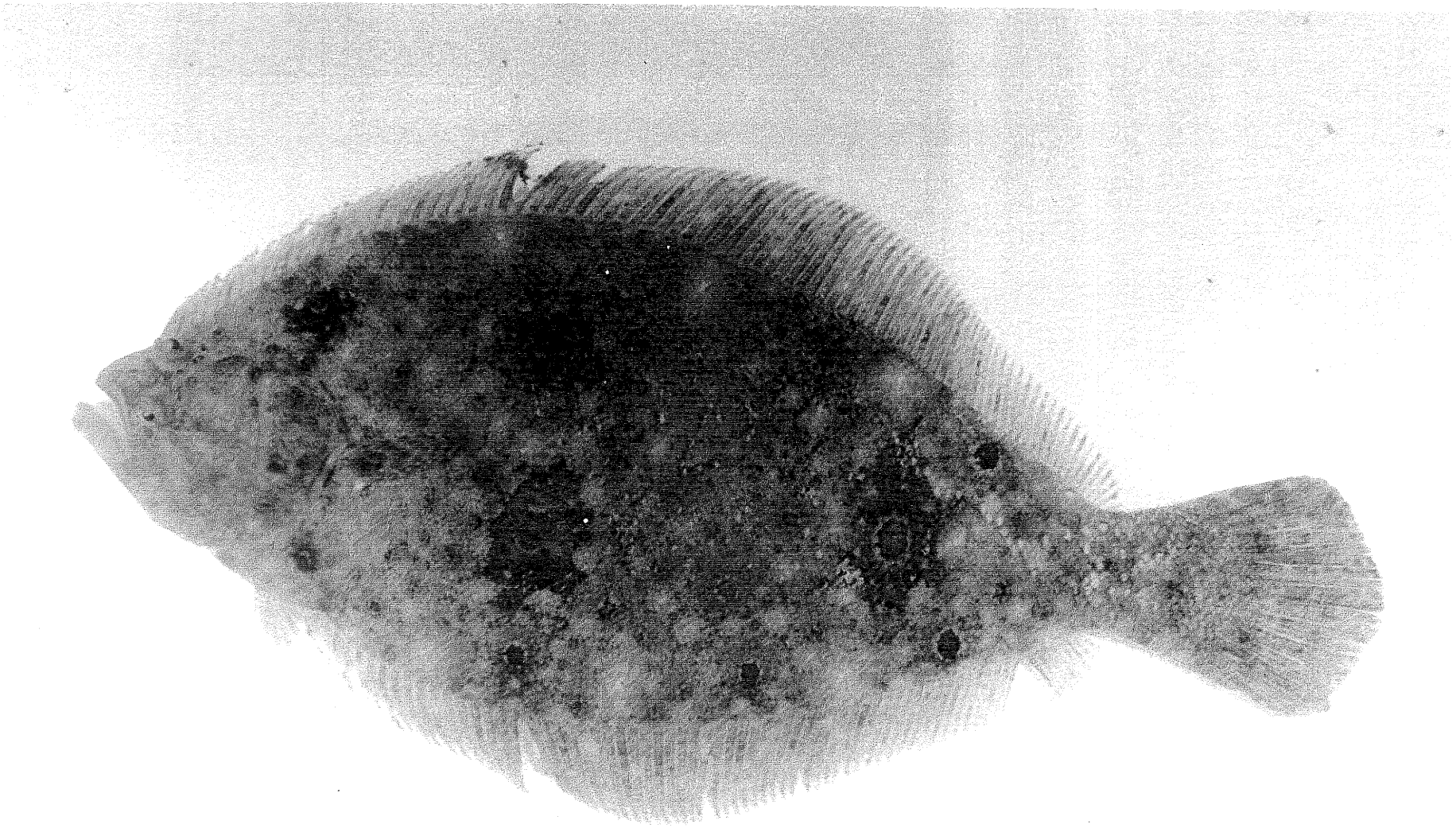


Fig. 17

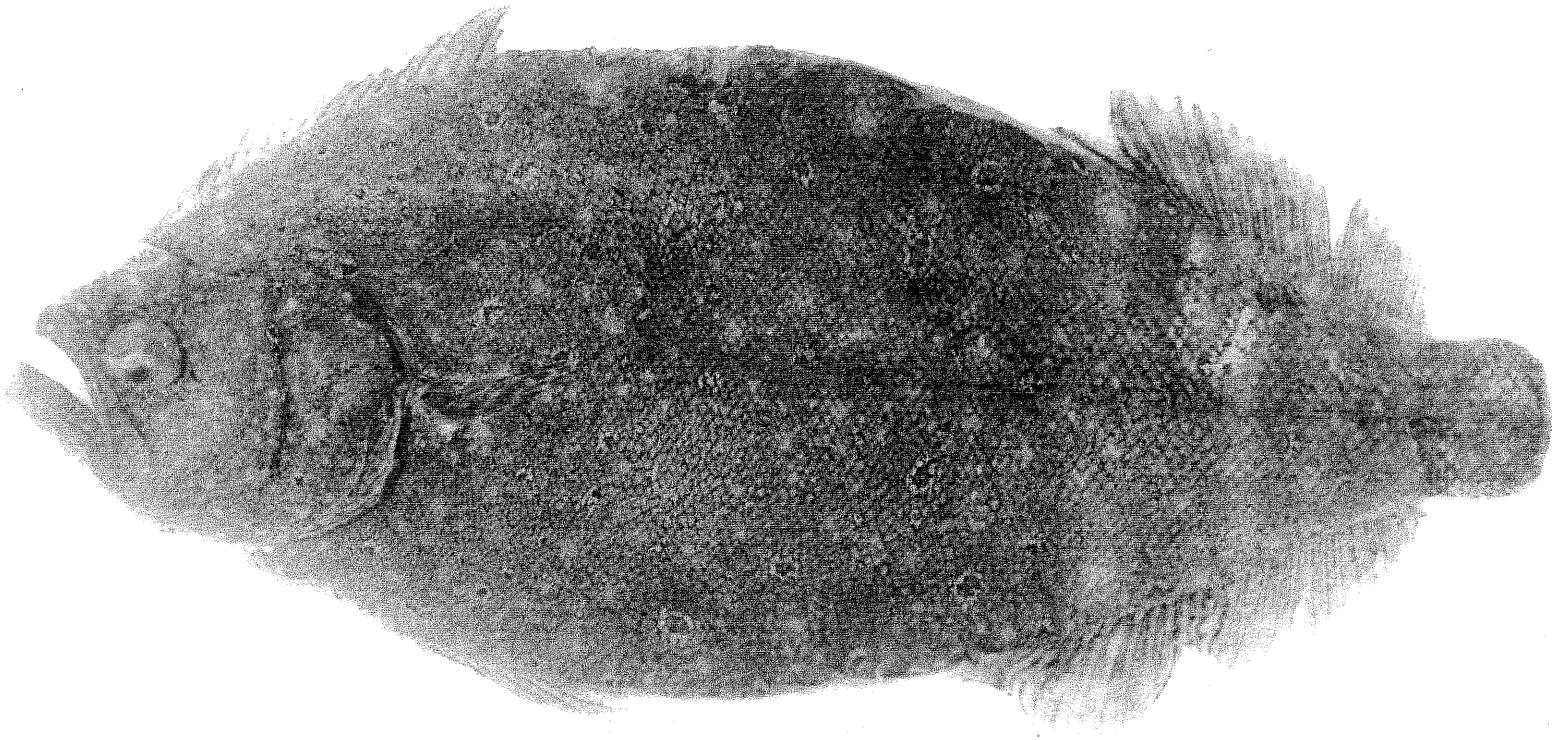


Fig. 18

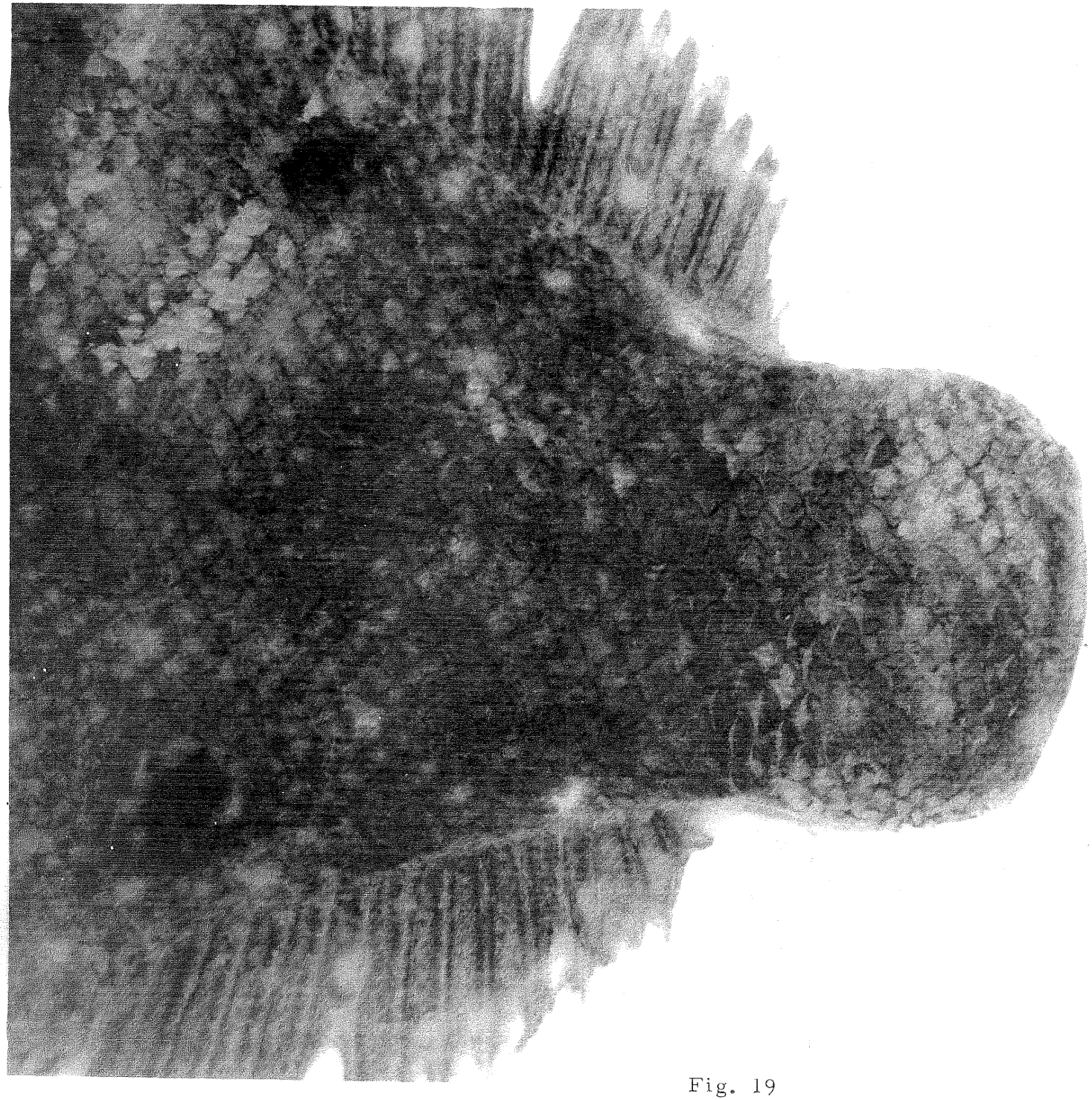


Fig. 19

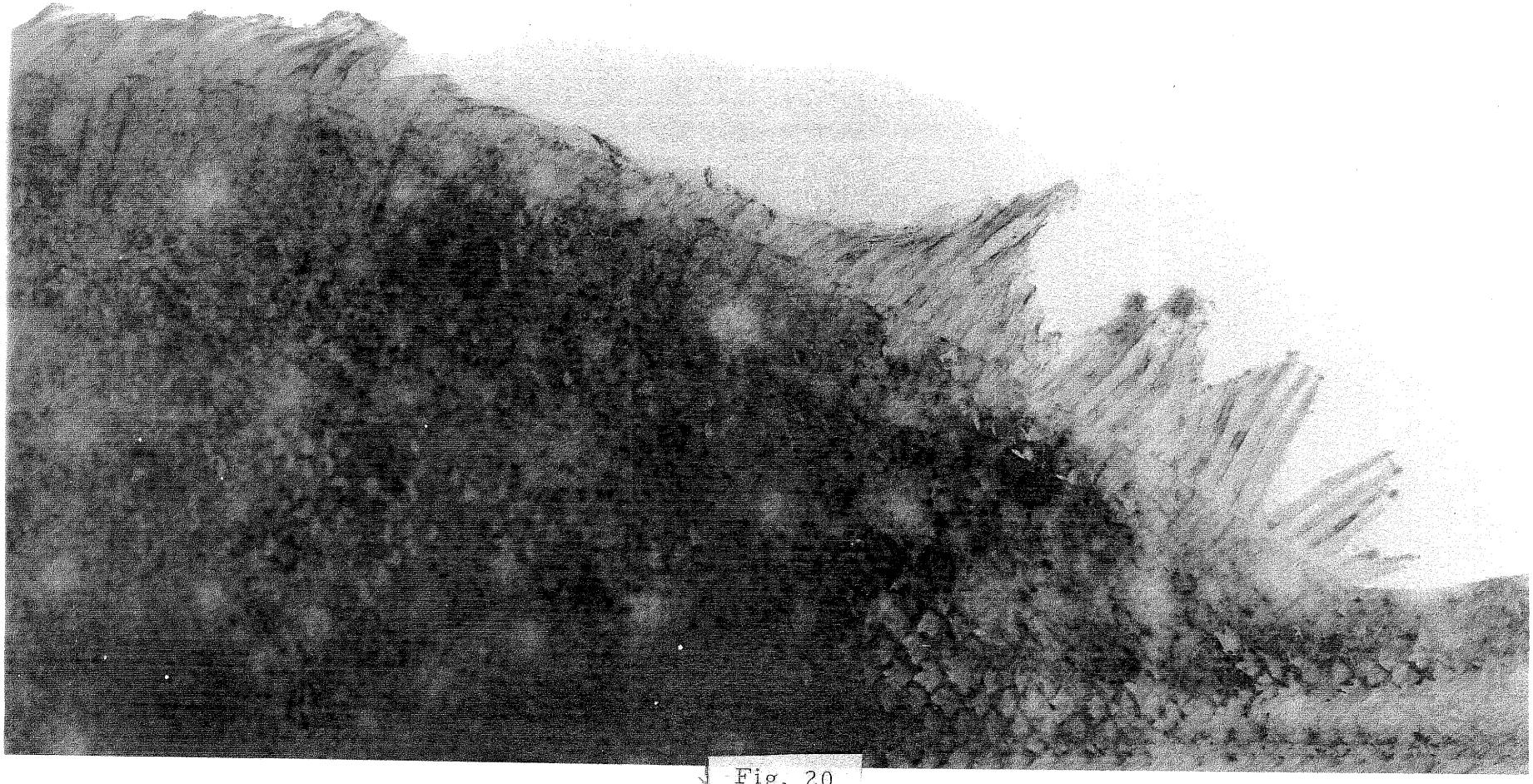


Fig. 20

Fig. 21

in still other studies, we have as yet not demonstrated its cause or causes. Based on field sampling from Block Island to Cape Hatteras, the association of the disease with the apex of the Bight is quantitatively demonstrated for the first time (Fig. 22). In addition, prevalence of the disease is much greater in the Sandy Hook-Raritan Bays complex than in Great Bay, which is relatively unpolluted (Fig. 23).

As part of the NMFS-MARMAP resource assessment survey, we sample groundfish extensively at least twice a year from Block Island to Cape Hatteras, and we find that the catch of bony fish on high carbon areas of the apex of the Bight is considerably lower, at least seasonally, than the catch in normal low-carbon areas (Figs. 24 and 25). This finding plus the other biological findings summarized above constitute a growing body of evidence that pollution in the New York Bight, including ocean dumping, is indeed affecting living resources adversely.

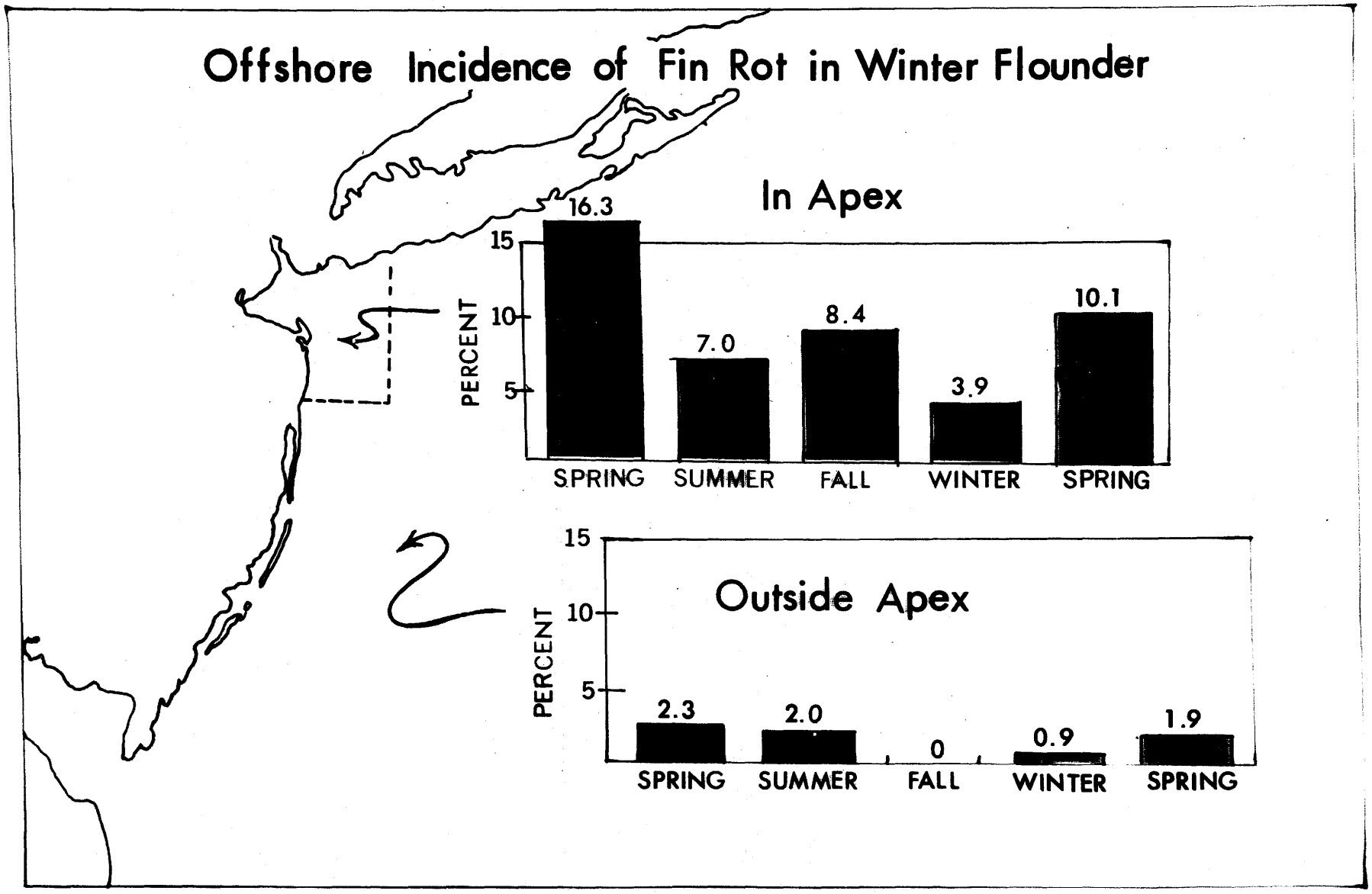

Offshore Incidence of Fin Rot in Winter Flounder
In Apex
PERCENT
15
10
5
16.3
7.0
8.4
3.9
10.1
SPRING
SUMMER
FALL
WINTER
SPRING
Outside Apex
PERCENT
15
10
5
2.3
2.0
0
0.9
1.9
SPRING
SUMMER
FALL
WINTER
SPRING

Fig. 22

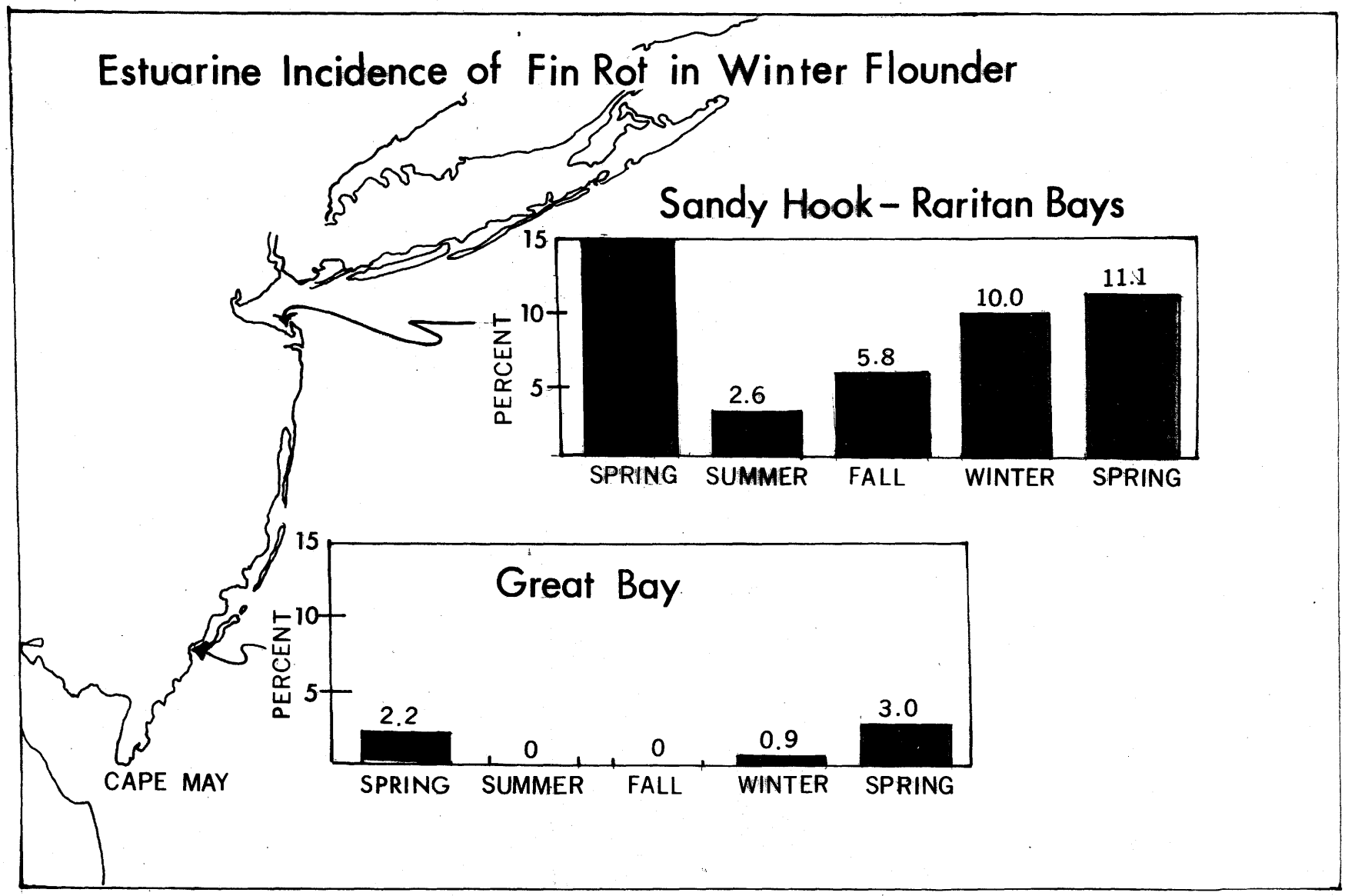

Estuarine Incidence of Fin Rot in Winter Flounder
Sandy Hook – Raritan Bays
PERCENT
15
10
5
2.6
5.8
10.0
11.1
SPRING
SUMMER
FALL
WINTER
SPRING
Great Bay
PERCENT
15
10
5
2.2
0
0
0.9
3.0
SPRING
SUMMER
FALL
WINTER
SPRING
CAPE MAY

Fig. 23

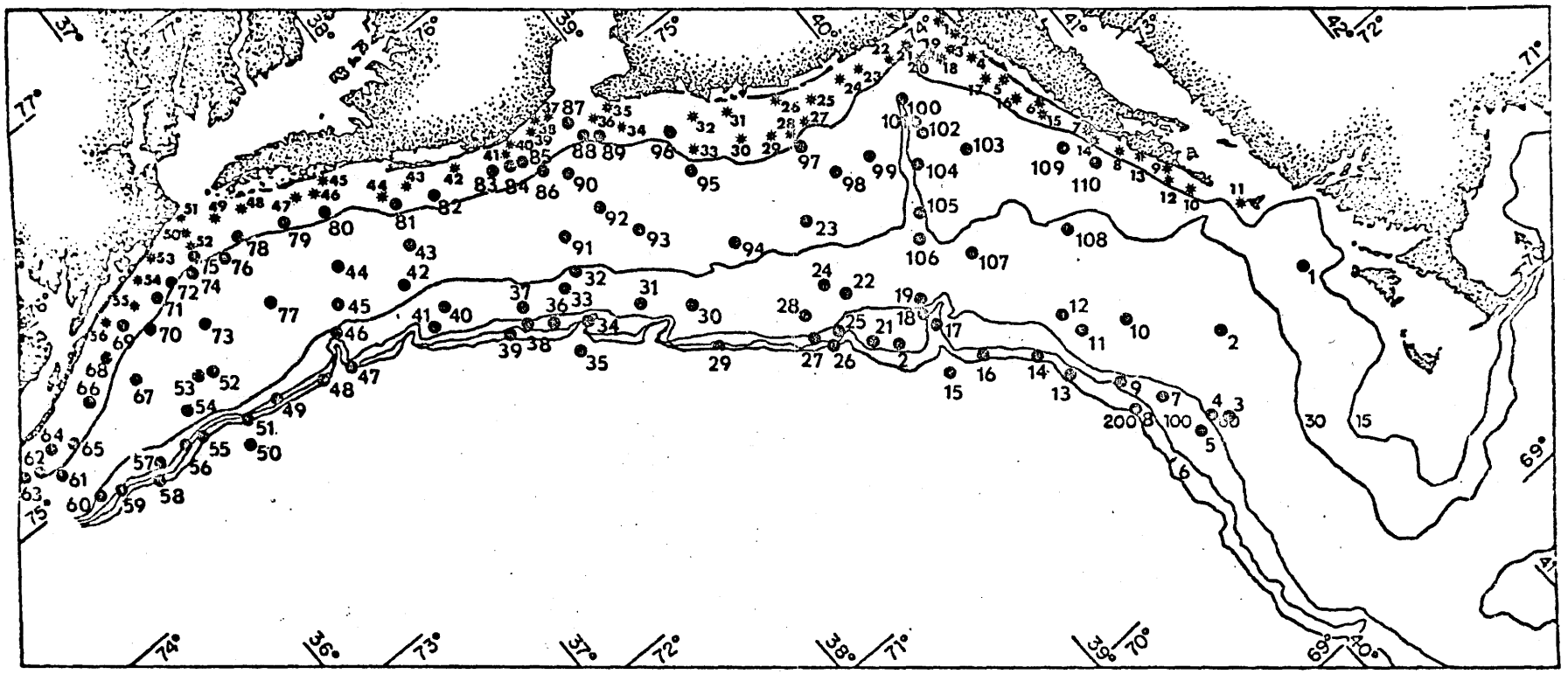


Fig. 24

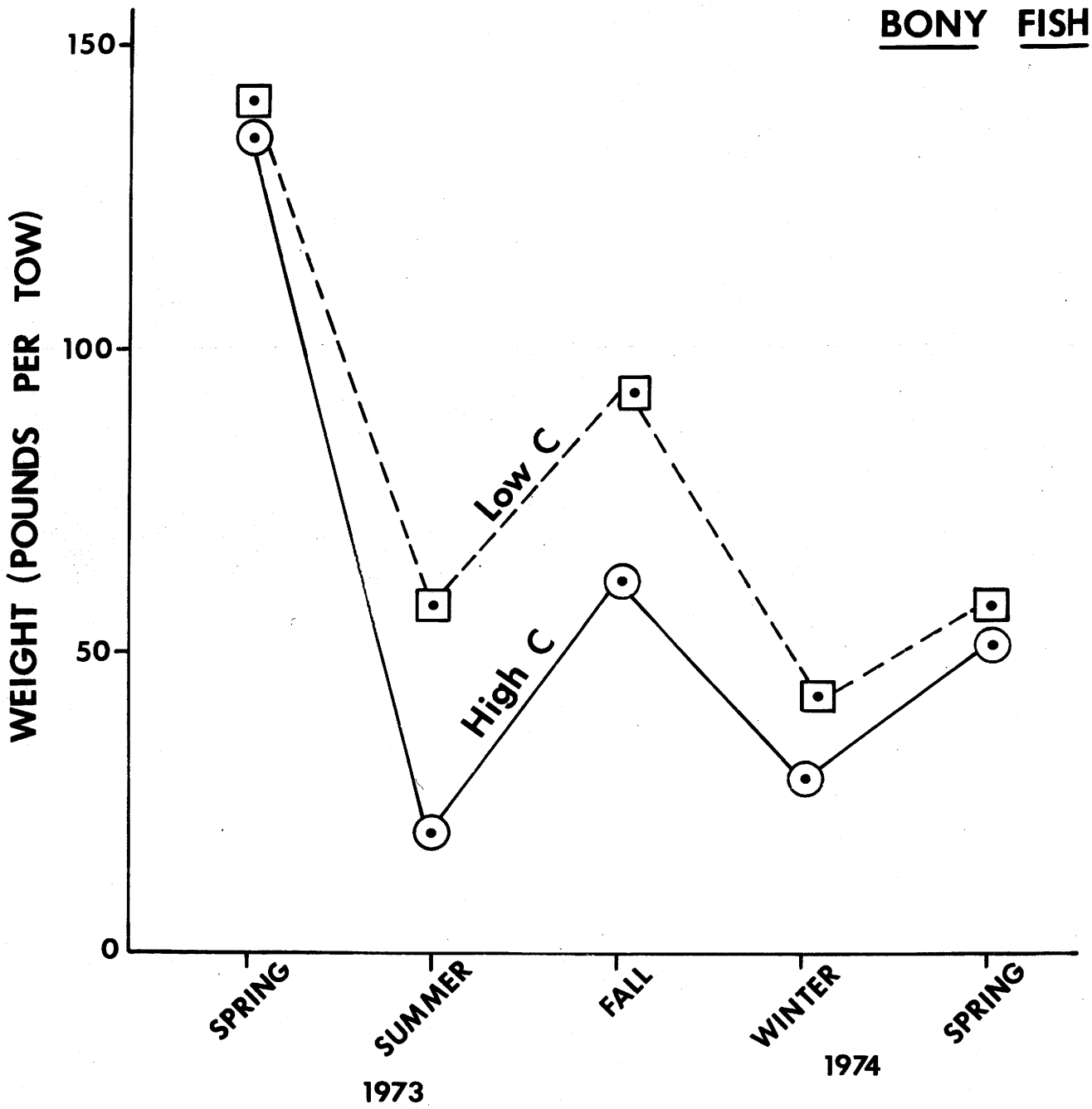

BONY FISH
WEIGHT (POUNDS PER TOW)
150
100
50
0
Low C
High C
SPRING
SUMMER
FALL
WINTER
SPRING
1973
1974

Fig. 25