

Contaminant Effects on Biota of the New York Bight

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ABSTRACT

The Marine EcoSystems Analysis (MESA) Project of NOAA was initiated in 1973 to assess the impacts of man's activities and the natural influences on the New York Bight. Several examples of contaminant impacts on marine resources have been identified rather quickly: (1) high prevalence of diseases in several species of finfish and shellfish, (2) major alterations in the distribution and abundance of bottom living organisms, (3) widespread distribution in exceptionally high numbers of coliform and fecal coliform bacteria, indicative of pathogenic bacteria (which findings have led to closure of clam fishing operations in extensive areas around and landward of ocean dumping sites), (4) presence of transfer-resistant (R^+) bacteria which are resistant to broad spectra of heavy metals and antibiotics, and (5) noxious concentrations of suspended particulate material, flotsam and surface slicks, particularly on beaches used very intensively for bathing and sportfishing.

INTRODUCTION

Even the most optimistic marine scientists now affirm that the wastes of dense human populations often degrade adjacent coastal ecosystems in some respects. The degree of degradation is typically debatable, and varies with many factors from location to location. In this paper I summarize some of the biotic degradation observed in the New York Bight (Fig. 1), a coastal indentation containing one of the most man-dominated coastal ecosystems in the world. The combined effects of 18 million people and their energy-intensive activities adjacent to the New York Bight have disturbed the Bight ecosystem in several readily perceptible ways. I have chosen to summarize only those impacts which are already documented convincingly.

Some of the ecological effects were noted years ago by several investigators. Partial summaries of these earlier observations are in National Marine Fisheries Service (1972), Pararas-Carayannis (1973), and Buzas, et al. (1972). However, for the effects summarized below, most of the documentation has been done during the first 2 years of the Marine EcoSystems Analysis (MESA) Project by MESA-associated investigators. Additional ecological effects, beyond those described in this paper, will undoubtedly become evident with continuing investigation.

The annual quantities of contaminants now reaching the New York Bight are impressive: sewage sludge, 3 to $4.3 \times 10^6 \text{ m}^3/\text{yr}$; dredge spoils, $> 7 \times 10^6 \text{ m}^3/\text{yr}$; acid wastes, $> 2 \times 10^6 \text{ m}^3/\text{yr}$; construction debris and cellar dirt, $4.5 \times 10^5 \text{ m}^3/\text{yr}$; atmospheric fallout of: Cd, Cr, Cu, Fe, Pb, and Zn, 3940 to 32,000 metric tons/yr; plus suspended solids, 49,000 to 500,000 metric tons/yr; and total nitrogen,

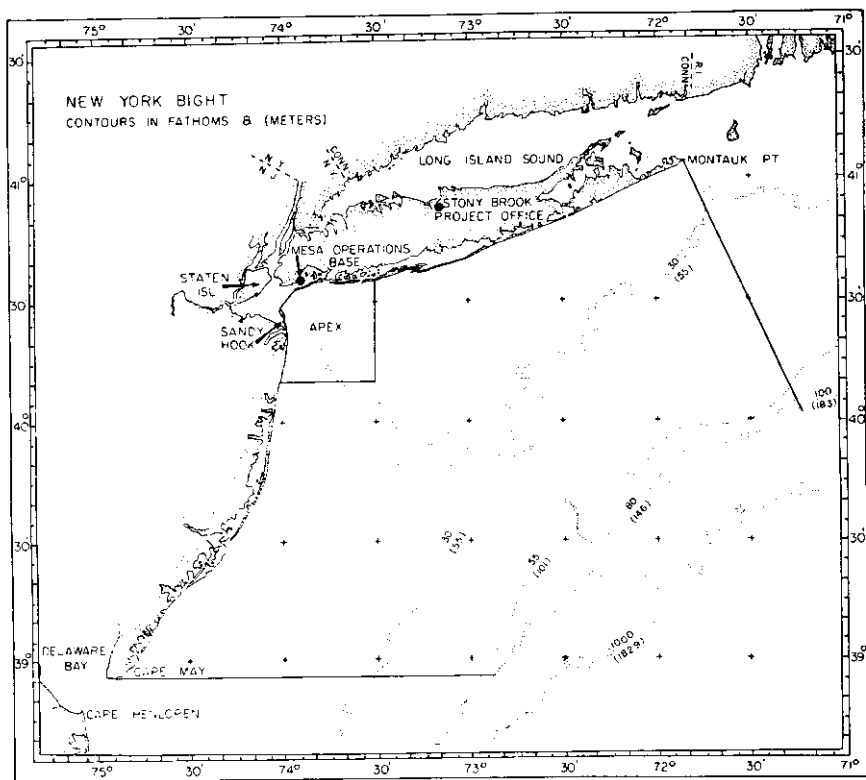


Fig. 1. New York Bight, with MESA-defined limits, and innermost portion of the Bight termed the Apex.

24,000 metric tons/yr; municipal and industrial wastewater containing: oil and grease, 72,000 metric tons/yr; and total nitrogen, 79,000 tons/yr; runoff and groundwater influx containing: oil and grease, 124,000 metric tons/yr; and total nitrogen, 55,000 metric tons/yr.

A detailed and useful summary of the sources and quantities of contaminant inputs to the Bight is given by Mueller, et al. (in press), from which most of the above figures are derived.

Given these enormous volumes of contaminated inputs, and their concentration near the apex of the New Jersey-Long Island shores, one would expect most contaminant effects to appear in the Apex. As will be shown, most effects do seem to be so "localized" although the locale is much larger than most degraded coastal ecosystems.

Fin Rot Disease

Trawl hauls from the Bight since spring 1973 have yielded five species of flatfishes: yellowtail flounder (*Limanda ferruginea*), summer flounder (*Paralichthys dentatus*), fourspot flounder (*Paralichthys oblongus*), winter flounder

(*Pseudopleuronectes americanus*), and windowpane (*Scophthalmus aquosus*) with eroded fin tissue. In addition to these flatfishes, several other fish species have exhibited fin rot disease in the New York Bight area for several years (Mahoney, Midlge, and Deuel, 1973). At least superficially similarly diseased fishes have been observed in the Irish Sea; Puget Sound, Washington, USA; Sandy Hook Bay, New Jersey, USA; southern California coastal waters, USA; and the Gulf of Maine, USA (Ziskowski and Murchelano, 1975) and Narragansett Bay, Rhode Island, USA, (Levin, Wolke, and Cabelli, 1972).

The causes of fin rot disease in the Bight are still uncertain. Its histopathology in winter flounder has been studied by Murchelano (1975) who characterizes fin rot grossly as a progressive necrosis of the anal and dorsal fins and, less frequently, of caudal fins. The fin and fin rays are eroded, with congestion and hemorrhage of blood vessels in the fin remnant (Fig. 2). While the causes of fin rot remain unknown for Bight fishes, Murchelano (1975) seems to have ruled out a primarily bacterial etiology. However, Levin, et al. (1972) have defined the bacterial etiology of (another ?) fin rot disease in winter flounder of Narragansett Bay, Rhode Island.

Since 1973, winter flounder seem to have the highest incidence of fin rot in the Bight. The seasonal incidence in this species, illustrated in Figure 3, is significantly greater inside the Apex than outside during the spring of both 1973 and 1974 ($P < 0.01$ using the t test on arc-sine square root transformed data). The same test indicates significantly more diseased winter flounder in the Apex ($P < 0.01$) over all seasons combined (Ziskowski and Murchelano, 1975). The reason for higher incidence in spring (Fig. 3) is unknown.

Diseases of Crustacea

Some species of crustacea also contract pathologies of their gills and exoskeletons. The exoskeletal "shell disease" of lobsters (*Homarus americanus*) and rock crabs (*Cancer irroratus*) appears to occur primarily in specimens on and near the benthic deposits of dumped sewage sludge and dredge spoils (NMFS, 1972, Sect. 2). Further, the areas of skeletal erosion were primarily on the appendages where contaminated sediments would be expected to accumulate (Young and Pearce, 1975). Equal numbers of crabs and lobsters from relatively uncontaminated areas were exposed, in aquaria, to organic deposits taken near the sewage sludge and dredge spoil dump sites, and to clean sand substrates by Young and Pearce (1975). Skeletal erosion appeared in all crabs and lobsters exposed to both of these contaminated sediments, but none of the crustacea held on clean sands developed any pathology. Histological sections of the diseased animals revealed "pitting and cracking away of the [exoskeletal] laminae" and, in advanced stages, the exoskeleton was replaced by an external blood clot. The lobsters exposed to sewage sludge also exhibit gills fouled with granular material; their chitinous covering is often eroded and the underlying

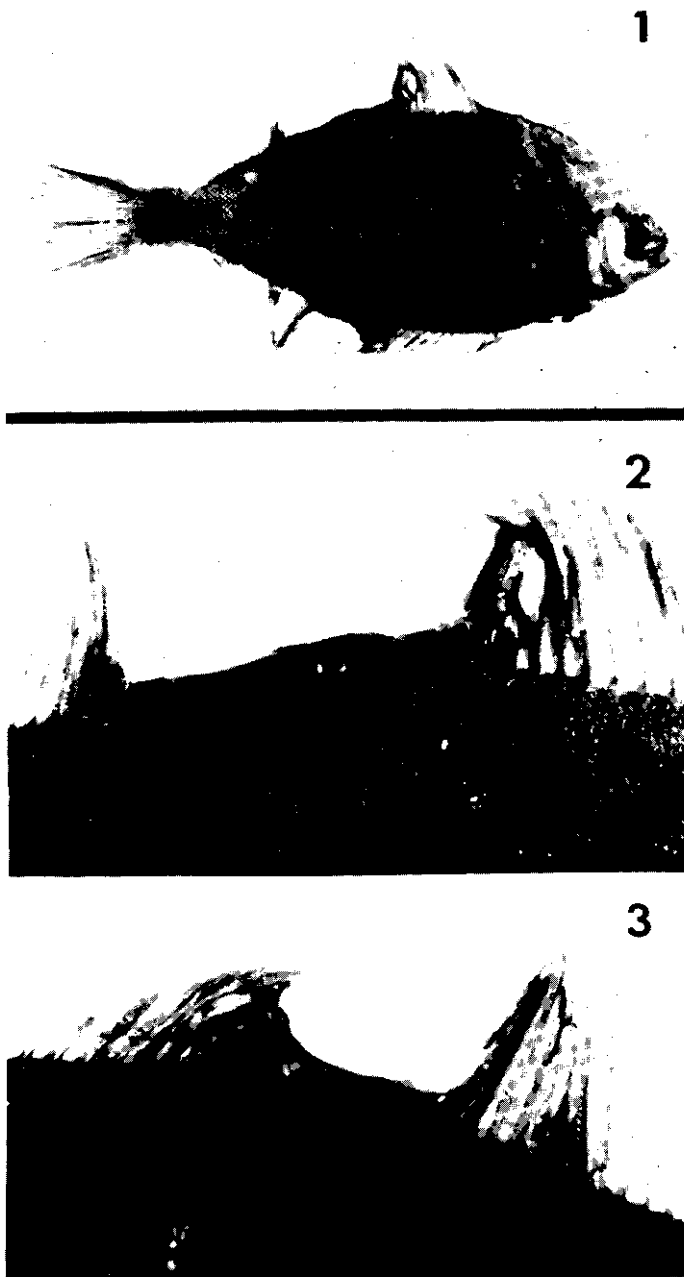


Fig. 2. (1) Winter flounder with fin rot disease of dorsal and anal fins. (2) Dorsal fin. (3) Anal fin. (Photos courtesy of J. O'Reilly, NOAA, NMFS, Middle Atlantic Coastal Fisheries Center, Sandy Hook, N.J.).

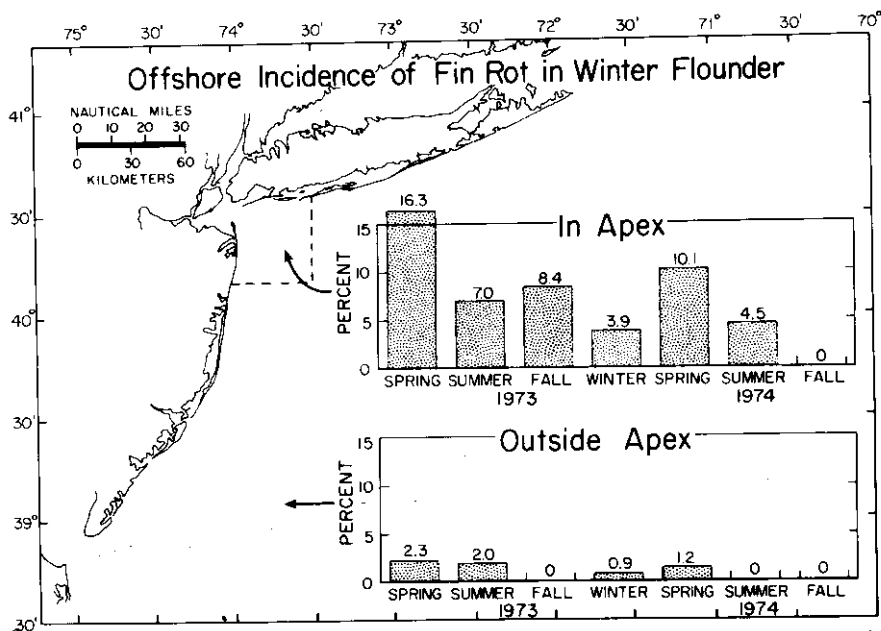


Fig. 3. Seasonal incidence of fin rot in winter flounder (*Pseudopleuronectes americanus*) in the New York Bight.

tissue is killed (Young and Pearve, 1975).

A similar shell disease of the caridean shrimp, *Crangon septemspinosa*, was found to be common in the inner Bight and Raritan and Sandy Hook bays (Gopalan and Young, 1975).

The percentage incidence of these diseases in crustacea of the Bight is not known. However, Young and Pearce (1975) have pointed out that potentially significant mortalities might occur from the effects of gill fouling and necrosis combined with low oxygen concentrations over wide areas of the Apex. The latter phenomenon has since been documented even more precisely by Segar, Berberian, and Hatcher (in press).

Degradation of Benthic Invertebrate Assemblages

Essentially all students of coastal ecological impacts of contaminants agree that benthic invertebrates typically show marked local changes in community composition. Such impacts were documented around sewage outfalls in Biscayne Bay, Florida, by McNulty (1961), off California by Greene and Smith (1975), Smith and Greene (in press), and around the dredge spoil and sewage sludge dump sites of the Bight by NMFS (1972). Commercial-size surf clams (*Spisula solidissima*) (larger than 3 in. or 7.6 cm) are unusually rare in an area of about 520 nautical mi² (1,550 km²) surrounding the Apex dump sites (MESA, 1975). Based upon recent intensive sampling, MESA investigators have begun to

quantify the degree of reduction in species diversity and abundance of benthic macrofauna in the harbors south of New York City and the Bight Apex where sediments are most heavily contaminated. McGrath (1974) has summarized the benthic ecology of Raritan and Lower bays, noting especially the unusually low densities of macrofauna relative to comparable unpolluted areas. Pearce and Radosh (in press) have summarized the historical work on benthic macrofauna of the Bight and preliminary results of some MESA cruises. Figure 4 illustrates the unusually low densities of macrofauna in Raritan and Lower bays, and in some sediments of the Apex most modified by solid waste dumping. Some of these most contaminated areas also have unusually little diversity in species composition (Fig. 5). The high contaminant levels and extended flushing time of the bays south of New York City cause greatly depressed macrofaunal densities and species diversity throughout these bays. However, despite the great volumes of dumped and waterborne materials settling in the Apex, average and high densities of macrofauna are widespread, often with species diversities typical of unstressed areas.

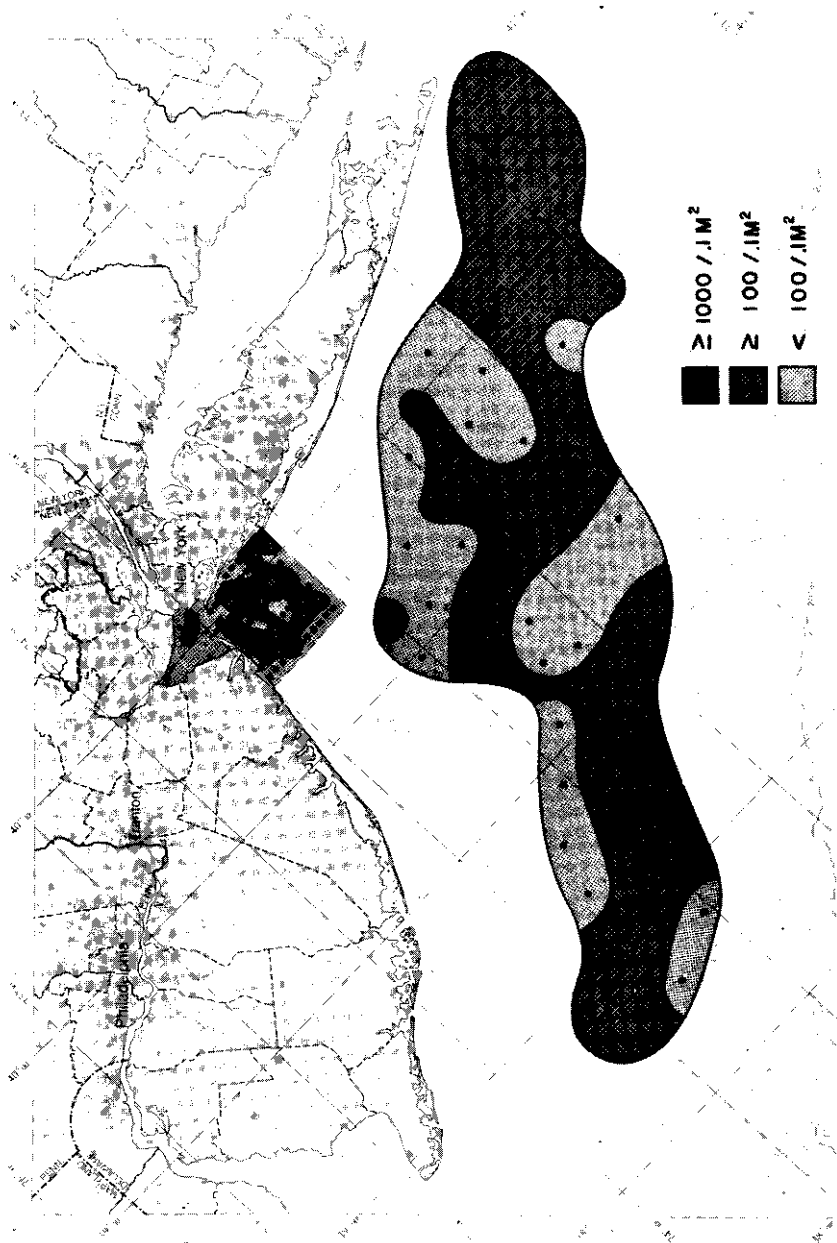
Another illustration of contaminant effects from sewage sludge dumping is given in Figure 6. This figure shows the human artifacts taken from the stomach of one white hake (*Urophycis tenuis*) caught near the sewage sludge dump site. This and other fish species clearly eat injurious artifacts if presented along with their normal diet of benthic fauna.

Bacterial Contamination

It has been known for some time that shellfish near the sewage sludge site may contain unacceptably high concentrations of coliform bacteria (Buelow, Pringle, and Verber, 1968). A circular area of 6 nautical mi (11 km) radius around the sewage sludge dump site was closed to shellfishing in 1970 by the U.S. Food and Drug Administration (FDA). In 1974 the FDA expanded this closure area as shown in Figure 7 because of bacterial contamination from ocean sewage outfalls and seaward flow of contaminated waters from Lower Bay and other bays (Meyer, 1974, personal communication).

A recent study has provided significant insight into the correlation between bacterial concentrations of bathing waters and associated illnesses. This epidemiological study compared beaches at Coney Island and Riis Park of the Rockaways. Given data from 2 years, the rate of gastrointestinal symptoms (vomiting, diarrhea, nausea, or stomach ache) among swimmers at Coney Island was significantly higher than that of non-swimmers. A significant difference between swimmers and non-swimmers was not found at the "relatively unpolluted" Rockaways beach (Cabelli, et al., in press). These workers also found that, while even carefully defined coliform bacterial concentrations were not the best indicator of disease rate, waters with coliform concentrations of 200 MPN/100 ml resulted in gastrointestinal (GI) disease rates of 3-4% of the bathers, and 1-2% of "severe attack" GI rates (Cabelli, et al., in press). Thus it is clear that, at least in the "barely acceptable" bathing waters studied on Coney Island, fecal contamination of bathing waters continues to be a public health problem.

Fig. 4. Numbers of benthic macrofauna per 0.1 m^2 as estimated from Smith McIntyre grab samples. Grab locations are denoted by dots, with two grabs per location in the Apex. The sampling density (78 stations) in the bays south of New York City does not permit indication of sampling locations. (From Pearce and Radosh, in press.)



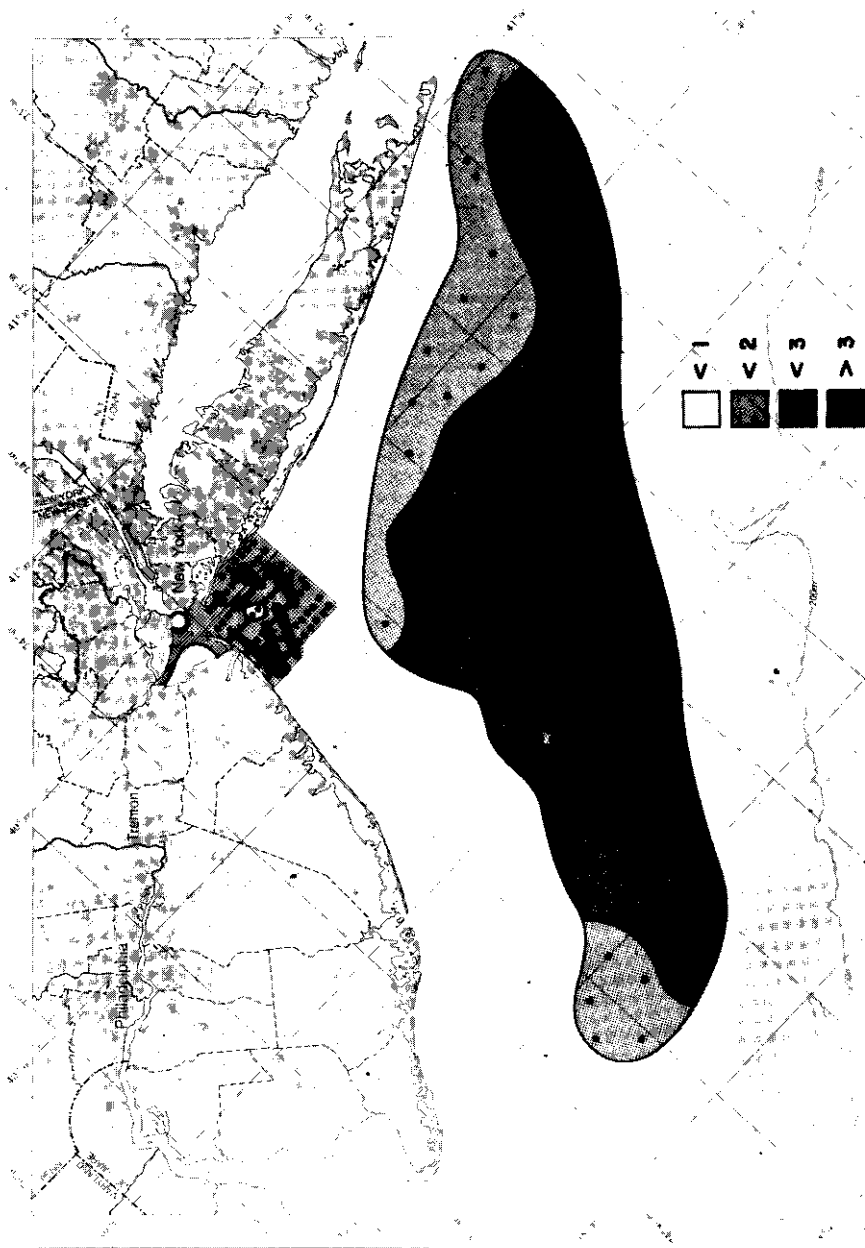


Fig. 5. Species diversity (H') of benthic macrofauna as estimated from Smith McIntyre grab samples. Grab locations are denoted by dots, with two grabs per location in the Apex. The sampling density (78 stations) in the bays south of New York City does not permit indication of sampling locations. (From Pearce and Radosh, in press.)

Widespread usage of antibiotics has contributed immensely to the cure of disease throughout the world over the past 30 years. However, this widespread usage has resulted in strains of pathogenic and coliform bacteria which are resistant to relatively high concentrations of the antibiotics. Resistance to normally toxic heavy metals has also evolved in some bacteria. One form of resistance, called the R factor, can be transmitted among several genera of bacteria. Coliform bacteria, for example, have been found not only to transmit the R factor, but also to serve as a reservoir through which pathogens, for example, *Salmonella*, will become resistant to antibiotics (Anderson, 1968; and Grabow, Prozesky, and Smith, 1974). Coliform bacteria from the Bight have the transfer resistance factor (plasmid) for heavy metals and broad spectra of antibiotics (Koditschek and Guyre, 1974). A portion of the protocol used to determine the incidence of multiple antibiotic and metal resistance in coliforms is illustrated in Figure 8.

The presence of multiple antibiotic and metal resistance in coliform (and perhaps other) bacteria in the New York Bight is not viewed by public health experts as a public health hazard. However, this rapid evolutionary response of bacteria to contaminant concentrations is now worldwide, and constitutes a serious public health problem under some circumstances (Grabow, et al., 1974).

Aesthetic Impacts

Among the most significant contaminant impacts in the Bight, and elsewhere, are those which disappoint man's expectations about his piece of ocean and coast; about the marine areas which are readily accessible. While aesthetic impacts may not pose public health hazards or degrade biological communities, large numbers of people feel strongly about these unpleasant visual, auditory, tactile, or olfactory attributes of their forseen-as-natural environment.

For instance, despite the lack of turbidity measurements in bathing waters, superficial observations can verify that the waters south of Fire Island become much more turbid as one approaches New York Harbor from the east. The Fire Island beaches of Hempstead Town and others further west, including New Jersey, are at times seriously fouled with debris ranging in size from cigarette filters to large planks. The intertidal beaches of the Apex are commonly fouled with large numbers of "tar balls" which are viewed as noxious by beach users. That essentially no effort has gone into the documentation of these contaminant effects does not diminish their significance. These aesthetic kinds of environmental degradation as perceived by the public seem to be fully as significant as some of the more conventionally measured impacts.

DISCUSSION

Several biotic effects clearly arising from human contamination of the inner New York Bight have been summarized. These indicators of marine environmental degradation are of the sorts summarized by Sindermann (1972).



Fig. 6. Stomach contents of a white hake (*Urophycis tenuis*) caught near the sewage sludge dump site. The coin is to illustrate scale. (The figure is courtesy of Dr. John B. Pearce, NOAA, NMFS, Middle Atlantic Coastal Fisheries Center, Highlands, New Jersey.)

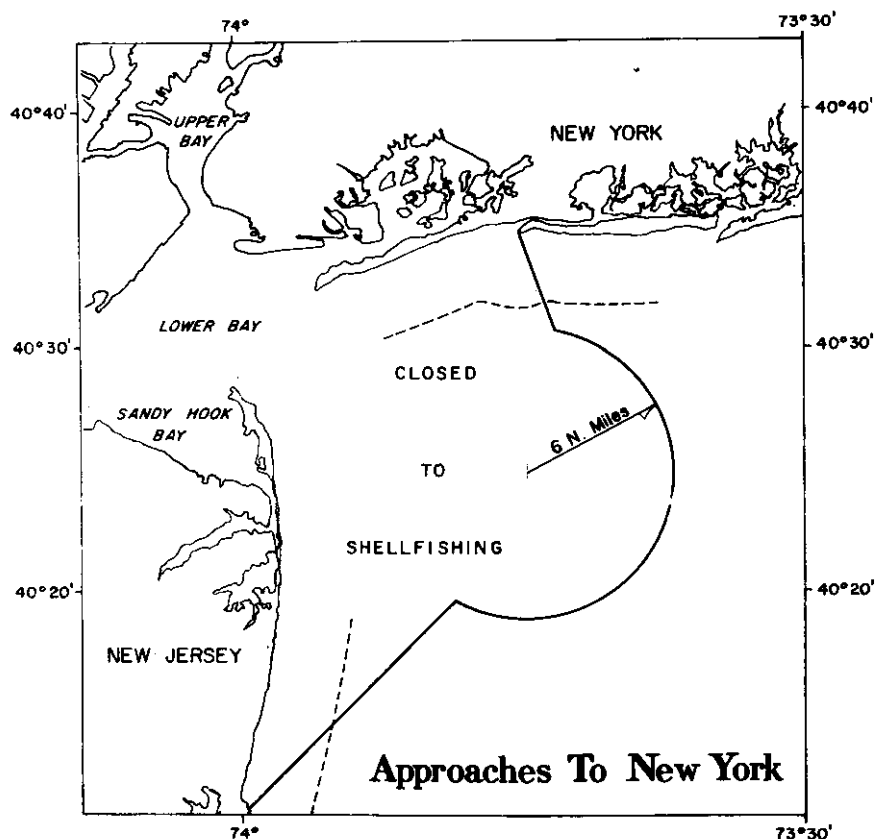


Fig. 7. Shellfish closure areas in the New York Bight as of May 1974.

Investigators are commonly cautioned, and appropriately so, about attributing to contaminants the major changes in abundance, distribution, or attributes of marine organisms which arise so frequently from natural causes. Because these natural fluctuations are commonly so great in comparison with contaminant effects, reasonably sophisticated and time consuming experimental designs are often necessary to clearly distinguish contaminant effects from natural effects. Thus, the presence of so many marked biotic effects which are unequivocally due to artificial contamination of Bight waters and sediments, based upon studies of only 2 years or less, emphasizes the unusual degree to which man has come to modify this area of seacoast. The natural benthic communities have been drastically modified over at least 150 nautical mi² (514 km²), and 244 nautical mi² (838 km²) of open ocean bottom have been closed to shellfishing. Ocean dumping appears to be the principal cause of these effects and most of the others summarized, although other sources of contamination are contributory.

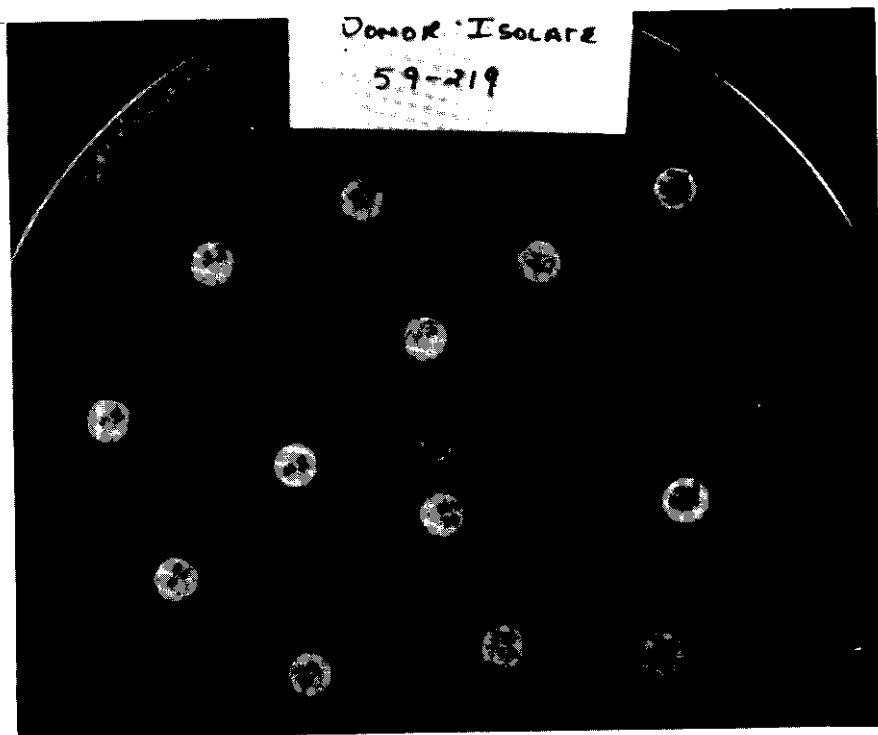


Fig. 8. Bacterial culture and discs saturated with heavy metals and antibiotics. The dark zones (zones of inhibition) around some discs indicate effective toxicity. Bacterial growth up to some discs indicates bacterial resistance to the normally bacteriostatic compound on the disc. This culture is resistant to five antibiotics. (The figure is courtesy of Dr. Leah Koditschek, Montclair State College, Upper Montclair, N.J.)

The most obvious, readily documented contaminant impacts in the Bight are all associated with bottom deposits of dumped material, except for the fouling of surface waters and beaches. Yet, most of the contaminants entering the Bight are from non-dumping sources. These more diffuse sources of contamination (riverine transport, surface runoff, and atmospheric fallout) result in more subtle biotic effects than those of the more concentrated dumped materials. Thus, additional biotic indications of artificial contamination may become obvious after more lengthy observations.

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LITERATURE CITED

- Anderson, E.S.
1968. The ecology of transferable drug-resistance factors in the Enterobacteria. *Ann. Rev. Microbiol.* 22:131-180.
- Buelow, R.W., B.H. Pringle, and J.L. Verber.
1968. Preliminary Investigation of Waste Disposal in the New York Bight. U.S. Department of Health, Education and Welfare, Northeast Marine Health Sciences Lab., Narragansett, R.I. 34 p.
- Buzas, M.A., J.H. Carpenter, B.H. Ketcham, J.H. McHugh, V.J. Norton, D.J. O'Connor, J.L. Simon, and D.K. Young.
1972. Smithsonian Advisory Committee Report on Studies of the Effects of Waste Disposal in the New York Bight. 59 p. (Available from NTIS AD-746 960).
- Cabelli, V.J., A.P. Dufour, M.A. Levin, and P.W. Habermann.
(in press). The impact of pollution on marine bathing beaches: An epidemiological study. *Proc. Special Symposium on the Middle Atlantic Continental Shelf and New York Bight*. ASLO Special Publication No. 2.
- Gopalan, U.K. and J.S. Young.
1975. Incidence of shell disease in shrimp in the New York Bight. *Mar. Poll. Bull.* 6 (10):149-153.
- Grabow, W.O.K., O.W. Prozesky, and L.S. Smith.
1974. Drug resistant coliforms call for review of water quality standards. *Water Res.* 8:1-9.
- Greene, C.S. and R.W. Smith.
1975. Numerical analysis of data on a benthic community. pp. 69-83 In: *Annual Report for the Year Ended 30 June 1975, Southern California Coastal Water Research Project*. El Segundo, California.
- Koditschek, L. and P. Guyre.
1974. Antimicrobial-resistant coliforms in New York Bight. *Mar. Poll. Bull.* 5(5):71-74.
- Levin, M.A., R.E. Wolke, and V.J. Cabelli.
1972. *Vibrio anguillarum* as a cause of disease in winter flounder (*Pseudopleuronectes americanus*). *Canad. J. Microbiol.* 18:1585-1592.
- Mahoney, B., F.H. Midlge, and D.G. Deuel.
1973. A fin rot disease of marine and euryhaline fishes in the New York Bight. *Trans. Amer. Fish. Soc.* 102:596-605.
- Marine Ecosystems Analysis Project (MESA).
1975. Ocean Dumping in the New York Bight. NOAA, Marine Ecosystems Analysis Project, U.S. Government Printing Office, Washington, D.C. 78p.
- McGrath, R.A.
1974. Benthic macrofaunal census of Raritan Bay - Preliminary results. Paper No. 24, *Proc. Third Sympos. on Hudson River Ecology*, March 22-23, 1973. Bear Mountain, N.Y. Hudson River Environmental Society, Bronx, N.Y.
- McNulty, J.K.
1961. Ecological effects of sewage pollution in Biscayne Bay, Florida: Sediments and the distribution of benthic and fouling organisms. *Bull. Mar. Sci. Gulf Carib.* 11(3): 393-447.
- Mueller, J.A., J.S. Jeris, A.R. Anderson, and C.F. Hughes.
(in press). Contaminant Inputs to the New York Bight. NOAA, Environmental Research Laboratories, Boulder Colorado. MESA Technical Memorandum.
- Murchelano, R.
1975. The histopathology of fin rot disease in winter flounder from the New York Bight. *J. Wildl. Diseases.* 11:263-268.

- National Marine Fisheries Service (NMFS).
 1972. The Effects of Waste Disposal in the New York Bight. NOAA, National Marine Fisheries Service, Middle Atlantic Coastal Fisheries Center, Highlands, New Jersey, Vol. 1-9. 749p. (Avail. from NTIS, AD730531 through AD730539.)
- Pararas-Carayannis, G.
 1973. Ocean Dumping in the New York Bight: An Assessment of Environmental Studies. Coastal Engineering Research Center. U.S. Army Corps of Engineers, Tech. Memo, No. 39. 159p.
- Pearce, J.B. and D. Radosh.
 (in press). Benthic Fauna of the New York Bight. MESA New York Bight Atlas Monograph No. 14. (Avail. from New York Sea Grant Institute, Albany, New York at \$4.00.)
- Segar, D.A., G.A. Berberian, and P.G. Hatcher.
 (in press). Oxygen depletion in the New York Bight Apex - Causes and consequences. Proc. Special Symposium on the Middle Atlantic Continental Shelf and New York Bight. ASLO Special Pub. No. 2.
- Sindermann, C.J.
 1972. Some biological indicators of marine environmental degradation. J. Wash. Acad. Sci. 62:184-189.
- Smith, R.W. and C.S. Greene.
 (in press). Patterns in biological communities in an area of wastewater discharge. J. Water Poll. Control Fed.
- Young, J.S. and J.B. Pearce.
 1975. Shell disease in crabs and lobsters from New York Bight. Mar. Poll. Bull. 6(7):101-105.
- Ziskowski, J. And R. Murchelano.
 1975. Fin erosion in winter flounder. Marine Poll. Bull. 6(2):26-29.