NOAA Technical Memorandum NMFS-F/NEC-74

Shell Disease of Crustaceans in the New York Bight

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Center
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Shell Disease of Crustaceans in the New York Bight

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PREFACE

Early in 1988 reports were received from fishermen about high prevalences of shell erosion and blackened lesions on the carapace or appendages of lobsters and crabs from waters of the New York Bight. Although shell disease had been reported previously in the vicinity of nearshore ocean waste disposal sites, reports in 1988 concerned shellfish populations from deeper waters of the submarine canyons near the Deepwater Municipal Sludge Dump Site (DMSDS) -- hereafter called the 106 Mile Site. Questions were immediately voiced about possible relationships between shell disease and sludge dumping at that site. Immediate concerns focused on economic losses due to the unsightly appearance of diseased shells and claws, and possible impacts of unfavorable publicity on seafood markets.

In response to these reports, EPA Region 2 established a Scientific Working Group to analyze shell disease of crustaceans in the New York Bight and elsewhere in the Northeast. The Working Group consisted of federal, state, and university scientists who reviewed available information about the abundance and condition of populations of lobsters and crabs, as well as information on the cause and extent of shell disease.

The primary purpose of the Working Group was to analyze and summarize available data on whether the condition was pollution-related, and whether the disease could cause mortality in economically important species at the 106 Mile Site. The Working Group met in November and December 1988, and again in January and February 1989 to review and analyze published and unpublished data on the status of disease and mortality in commercially important crustacean resources, including those from areas beyond the New York Bight. In February an additional meeting was convened by New Jersey Sea Grant to gain information from commercial fishermen and representatives of other organizations.

Data on crustaceans from the continental shelf break, and the 106 Mile Site, were found to be extremely limited. Nevertheless, in order to assess the possible impacts of pollution on commercial species, the Working Group reviewed the available data on lobster, red crab, rock crab, Jonah crab, and blue crab regardless of the geographic source of the data.

Despite the paucity of information on crustacean health in offshore waters, some tentative conclusions were reached and recommendations proposed, as outlined in the body of this report. As with any group effort of this kind, minor differences of opinion were expressed, but there was general agreement with the principal conclusions and recommendations included here.

The charge given to the Working Group contained six specific topics to be addressed:

(a) Review and evaluate information on shell disease of crustaceans with particular attention to possible relationships with environmental factors in the New York Bight.

(b) Determine whether it is possible to estimate increased mortality rates in crustaceans as a consequence of shell disease.

(c) Review current trends of abundance and condition of stocks of red crab, lobster, rock crab, Jonah crab, and blue crab in the New York Bight, and the factors influencing such trends.

(d) Determine, if possible, from recent data, the present frequency of shell disease in crustacean resources of the New York Bight.

(e) Prepare a report to EPA on shell disease in the New York Bight by April 1, 1989, as part of the New York Bight Restoration Plan.

(f) Outline a proposed short- and long-term research program to augment existing information.

SUMMARY

A detailed examination has been made of the available information on shell disease of crustaceans, especially in those from the New York Bight, but including data from other areas as well. The study addressed three key questions:

(1) Does shell disease constitute a serious problem in crustacean populations of the New York Bight, including continental shelf canyons near the Deepwater Municipal Sludge Dump Site?

(2) Is shell disease related to pollution?

(3) Does shell disease result in mortalities of crustaceans?

Principal findings of the study are these:

- Shell disease is a natural phenomenon, but it may occur with higher prevalence and greater severity in polluted areas than in those not degraded by man's activities. Shell disease represents a stage in the natural relationship between crustaceans and chitin-utilizing microorganisms. The balance between metabolic processes associated with new shell formation, and infection by microbes capable of utilizing chitin, may be disturbed by environmental changes affecting normal shell formation or favoring the growth of chitin-utilizing microbes. Such disturbances may be consequences of pollution.

- Evidence exists for an association of shell disease with habitat degradation. Prevalences have been found to be high in crustaceans from polluted sites; prevalences show trends similar to those of the black gill syndrome, which also has a statistical association with extent of pollution. Experimental exposures of crustaceans to contaminated sediments, heavy metals, biocides, petroleum, and petroleum derivatives can result in the appearance of the black gill syndrome, often accompanied by shell disease. Studies in the New York Bight apex have disclosed the presence of shell disease in lobsters, crabs, and shrimp (*Crangon*). Reference sites sampled for shrimp showed the prevalence of shell disease to be much lower there than in apex samples, but similar data for crabs and lobsters from reference sites should be collected.

- Our analyses suggest that prevalences of less than 5% may represent expected background levels of shell disease in inshore populations, probably related to mechanical damage or wound healing. Prevalences of over 15%, as noted in some inshore samples of lobsters and rock crabs, may reflect pollution-related disease superimposed on the natural occurrence of shell disease. Direct observations on gross signs of disease enable us to determine the prevalence of shell disease, but laboratory studies are needed to determine whether microbial agents or toxic wastes (or both) are responsible for the incidence noted in New York Bight apex populations.

- Shell disease has been reported in offshore (>200 m) crustacean populations, including those in shelf canyons, but data are limited, and there is no conclusive evidence that would associate shell disease in such populations with pollution of offshore habitats.

- Mortalities from shell disease have been observed, occasionally at high levels, in impounded crustacean populations. Destruction of gills and adhesions of the shell which prevent molting have been considered to be responsible factors, as have secondary systemic infections which develop after perforation of the chitinous integument. There is no specific evidence, however, that would link crustacean population fluctuations in the New York Bight with the presence or severity of shell disease. This does not imply that such a relationship could not exist -- but only that data are not available for evaluation. Shell disease may predispose crustaceans to mortality, but there is little evidence for a direct cause and effect relationship. Furthermore, there is no currently available method to separate disease-caused mortality from that caused by other influences.

CONTENTS

1.0 INTRODUCTION

Shell disease in the broad sense of the term, includes a diverse array of shell abnormalities ranging from unsightly black discoloration to open or perforating lesions. The condition may affect the carapace or shell as well as the legs or claws, and has been reported in numerous freshwater and marine species of economic importance, i.e., lobsters, crabs, shrimp, crayfish and prawns (Sindermann, 1989). Shell disease may result from mechanical damage due to wounds or abrasions that permit invasion by chitin destroying bacteria or fungi, or from overcrowding and contact with infectious organims that may gain access to the shell through surface pores. The disease in natural or "wild" populations usually occurs at low levels, but may be enhanced by (1) overcrowding in traps or discard handling during commercial fishing operations, which increase the likelihood of shell damage, (2) stresses from unhealthy environments, or (3) high organic loading of containment waters which contributes to the multiplication of microorganisms, some of which may be pathogenic to crustaceans.

Shell disease has been observed in shrimp, crabs, and lobsters from badly degraded coastal/estuarine waters, often in association with black discoloration of the gills. Erosion of the exoskeleton and odors of hydrogen sulfide or petroleum have been noted in animals taken with contaminated sea bottom sediments. Experimental exposure of crustaceans held in aquaria with sediments from sewage sludge or contaminated dredge material sites leads to mortality and/or enlargement of areas affected by black discoloration or shell erosion. Shell disease therefore, is a particular problem in impoundments, aquaculture facilities, and in degraded habitats. It is complex, contagious, and may be caused by a diverse group of microorganisms and environmental stressors. The condition may contribute to mortality, principally by providing a route of entry for facultative pathogens; severe disease may damage gill tissue and interfere with respiration and may also interfere with molting. Sick or weakened animals may die prematurely, or be consumed by predators. Advanced signs of shell disease are of concern to the fishing industry because of unsightly conditions that affect the marketability of whole animals, legs, or claws.

Shell disease and/or gill blackening has been recognized in crabs, lobsters, and shrimp caught in waters of the New York Bight apex near New York and New Jersey. Present concerns are focused on reports of shell disease affecting commercial catches of crabs and lobsters from waters in proximity to the 106 Mile Site. The 106 Mile Site, located off the continental shelf, is south of the Hudson Canyon, approximately 187 km from the entrance of New York Harbor (see Figs. 1 and 2). Water depths range from 1700 to 2750 m and average about 2200 m. Industrial wastes, sewage sludge, and fly ash have been deposited in the area in the past and it now receives over 8 million wet tons of sludge annually (see Appendix 3).

Recent estimates of the status of crustacean stocks in the Middle Atlantic are summarized in the following sections. (The Working Group is grateful to Dr. Marvin Grosslein and the Resource Assessment Staff of the Woods Hole Laboratory, National Marine Fisheries Service for providing these quantitative summaries).

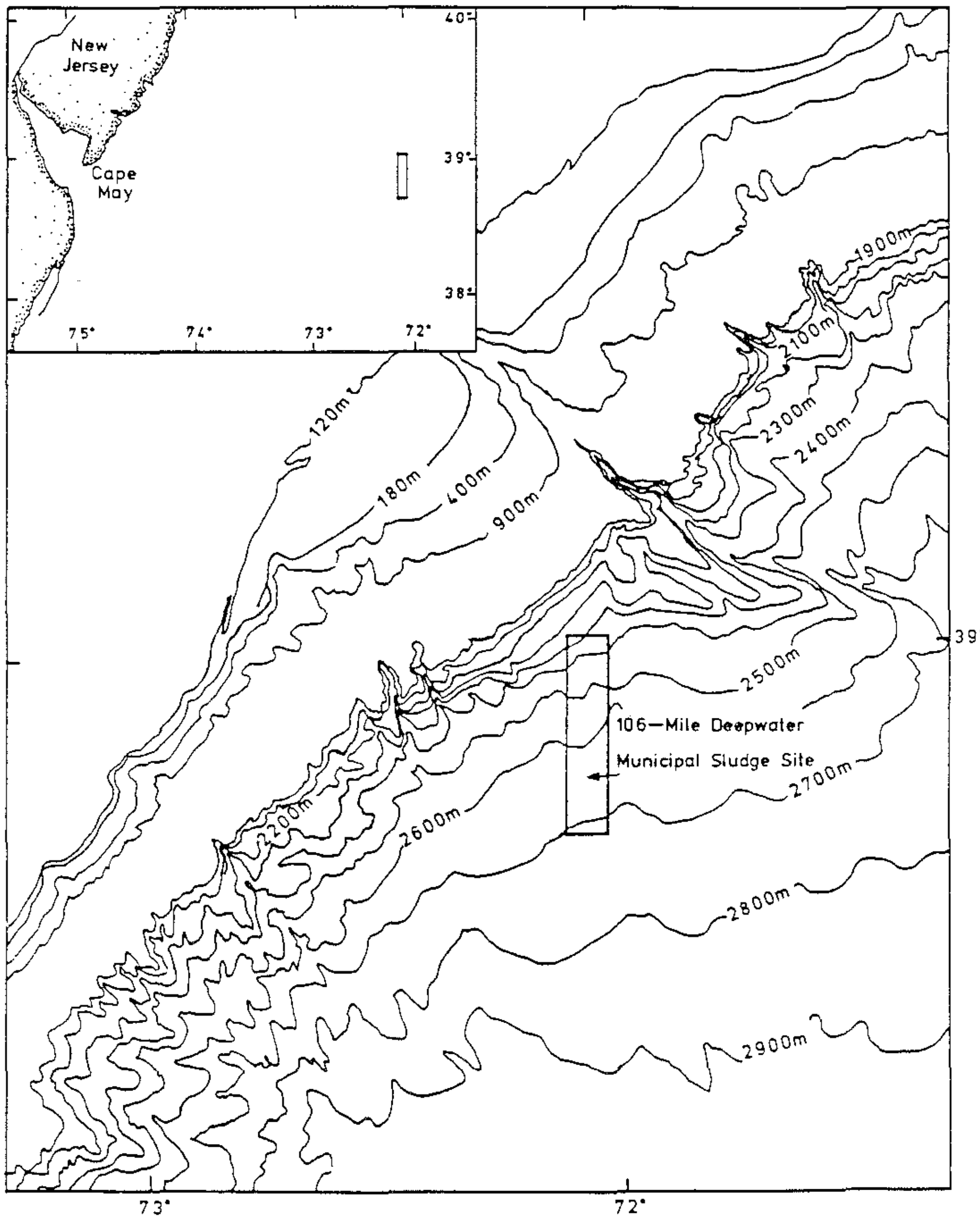

Figure 1. Map of the continental shelf and canyons in the vicinity of the 106 Mile Site.

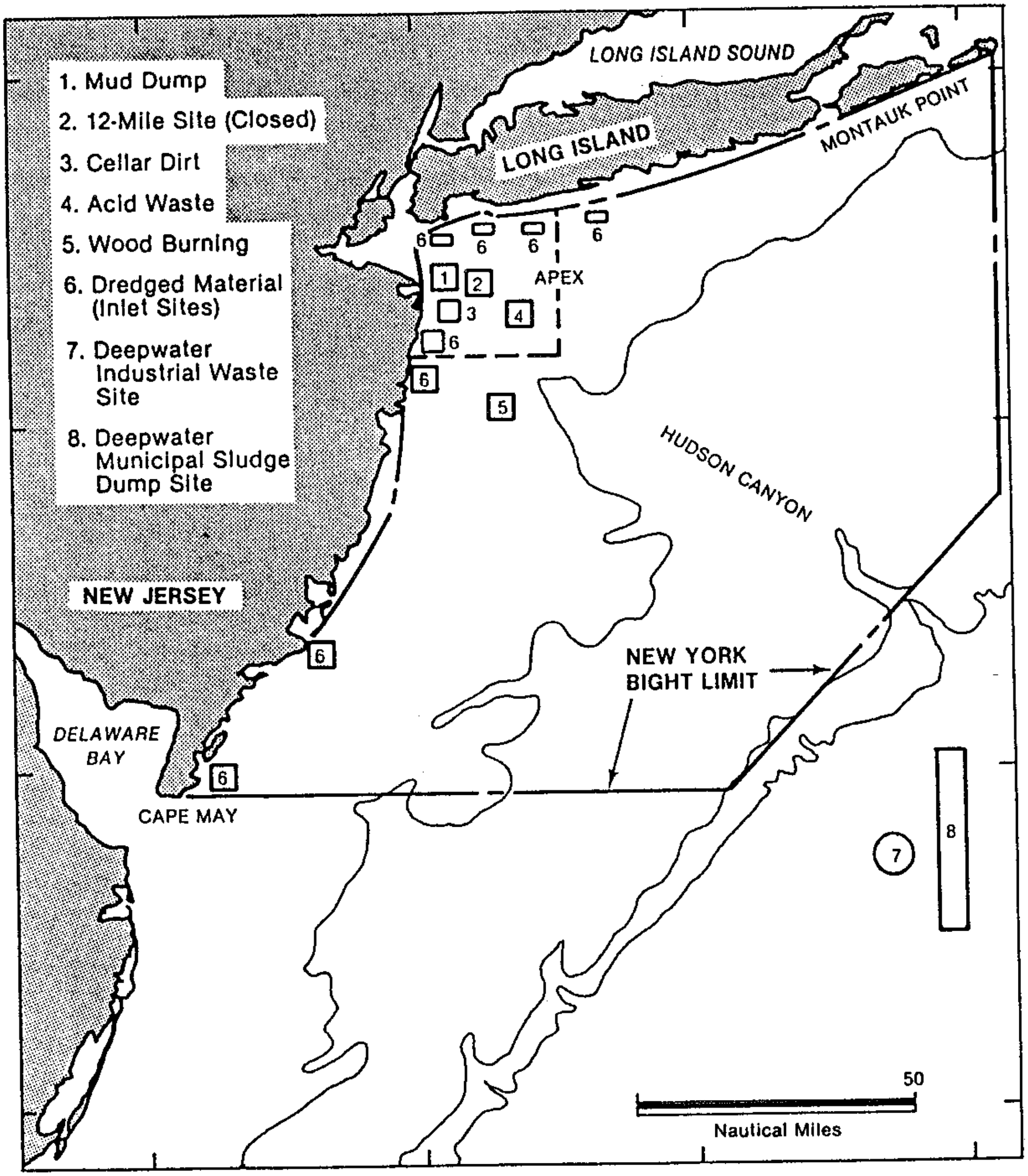

Figure 2. Map of the New York Bight, showing locations of disposal sites.

1.1 American Lobster, Homarus americanus

The American lobster is distributed in waters of the northwestern Atlantic from Labrador to Cape Hatteras. It is fished commercially from inshore to depths of 380 fathoms (700 meters). Although lobsters are concentrated in rocky areas, large numbers of marketable animals occur in the submarine canyons of the continental shelf and constitute an important offshore fishery. Inshore catches in 1987 were approximately 17,300 metric tons. Offshore trap catches averaged about 3,000 metric tons during 1983-1987, while trawl catches were approximately 200-300 metric tons. Lobster behavior patterns are important to the fishery, since larger animals are known to exhibit migratory activity in spring, returning to deeper waters in autumn. They have been found to travel as far as 300 km (186 miles).

Inshore landings of American lobster in the New York Bight and adjacent waters increased during the period 1978-1987. Combined inshore (0-3 mi.) (0-4.8 km) landings from Delaware to Connecticut increased from an average of 1.21 million pounds (550 metric tons) during 1978-80 to 3.08 million pounds (1400 metric tons) during 1985-87. Some of the increase may be attributable to an increase in reported landings for Connecticut, which increased markedly following a change in the reporting system starting in 1983, but landings from neighboring states also increased in that year. Lobster landings from offshore waters (3-200 mi.) (4.8-320 km) for the states of Delaware to New York (no offshore landings reported for Connecticut), fluctuated without apparent trend during 1983-87; landings during this period averaged about one million pounds (455 metric tons). Landings for New York state alone for both inshore and offshore fisheries increased slowly throughout the decade. New York landings increased from 0.33 million pounds (150 metric tons) during 1978-80 to an average of 0.95 million pounds (432 metric tons) during 1985-87. Offshore landings have remained relatively stable for New York state, averaging 0.38 million pounds (172 metric tons).

Preliminary information for 1988 from the major lobster producing states indicates that landings have increased in Maine, Massachusetts, and Connecticut by approximately 10% as compared to 1987. Rhode Island landings declined somewhat, but this is thought to result from Rhode Island vessels landing lobsters in New York, where the 1988 landings are projected to be up by more than 20%.

It should be noted that both inshore and offshore fisheries have experienced large-scale increases in numbers of traps fished during the past decade. However, no effort increases have occurred in the Canadian maritimes where trap limits and a license moratorium are in place, yet the landings trend there has similarly increased. At a meeting in Saugus, Massachusetts on February 8, 1988, state fishery administrators and lobster fishery biologists from along the coast reached a consensus that recently increased landings did not result from significant increases in fishing effort, but from higher than expected recruitment, or greater resource availability to gear. It appears that commercial catch per unit effort, i.e., catch of lobster/trap in pounds and number of individuals, generally increased during the 1980's, particularly as evidenced by Massachusetts' research trap data.

NMFS research vessel otter trawl survey indices from the New York Bight and adjacent waters (Delaware-Connecticut) for American lobster during the autumn indicate no clear trends in relative population size. Stratified mean number per tow for pre-recruit lobsters (<80 mm carapace length, CL), averaged 1.22 individuals during 1978-87. A decline in pre-recruits during 1986-87 to a mean level of 0.66 lobsters per tow, however, was noted. The survey index for lobsters >80 mm CL remained relatively stable for the ten year period 1978-87, averaging 0.33 lobsters per tow. The mean level during 1985-87 was 0.29 individuals per tow.

1.2 Red Crab, *Geryon quinquedens*

The red crab, *Geryon quinquedens*, has been reported from the western portions of the north and south Atlantic from Nova Scotia to Cuba, the Gulf of Mexico, and Brazil (Bigford, 1979). It is distributed along the continental slope of the Northwest Atlantic at depths of 100-1500 m (60-800 fathoms). Trawl surveys have shown that the largest numbers of crabs occur on the upper slope of the continental shelf at depths of about 275-1,000 m from George's Bank to off Cape Hatteras. The annual maximum sustainable yield for red crabs between George's Bank and offshore Maryland has been estimated at 2,700 mt (metric tons), or 5.9 million pounds. The 1984 catch statistics reported landings in excess of this estimate. According to Lux *et al* (1982) the catch from the New England fishery in 1980 was about 2,500 metric tons, and the estimated catch off Delaware, Maryland, and Virginia was approximately 65 mt. Photographic studies made in 1974 showed that most of the sediments were olive green in color and made up of silt and clay. More northern stations in the George's Bank region differed by having pebbles, gravel, and occasional large boulders. Bottom features suggest that crabs living in the more northern waters would be subject to abrasions and shell damage to a greater extent than those living on a sand and silt sea bottom.

Recent systematic studies (Manning and Holthuis, 1984) have shown that a related species, *Geryon fenneri*, or golden crab, inhabits the South Atlantic Bight. Wenner *et al* (1987), caught 3,152 crabs at depths ranging from 296-810 m off the coast of South Carolina and Georgia. Luckhurst (in press) captured *G. fenneri* at 786-1,462 m near Bermuda. According to Wenner *et al* (1987) this species constitutes a small but important fishery in South Carolina.

1.3 Rock Crab, *Cancer irroratus* and Jonah Crab, *Cancer borealis*

The rock crab, *Cancer irroratus*, occupies continental shelf and slope waters from Labrador to South Carolina, but may occur southward to Florida. In northern areas the crabs are found in shallow coastal waters where they may be found at all seasons, while in mid-Atlantic regions they may move inshore to molt during winter and then return to deeper waters. In the Middle Atlantic Bight the highest density of rock crabs occurs at 40-60 m during summer months (Bigford, 1979). Water temperature has an important role in the distribution of rock crabs in both inshore and offshore habitats. Haefner (1976) found rock crabs at depths up to 335 m in continental shelf slope waters, and at depths ranging to 296 m in the Norfolk Canyon. The crabs are virtually absent in shallow bays of Virginia, Maryland, Delaware, New Jersey, and New York during summer months, but remain in bays from Massachusetts to Canada throughout the year.

Jonah crabs, *Cancer borealis*, have been found from Newfoundland to Florida and in the Bahamas (Haefner, 1977). They are most abundant off New England and the Middle Atlantic States at depths of 12-300 m. Landing statistics on *Cancer* crabs include both *C. irroratus* and *C. borealis*. Commercial catches from inshore waters (Delaware to Connecticut) varied erratically during the decade 1978 to 1987 from 100,000 to 400,000 pounds (45 to 180 metric tons). Offshore landings for the same period ranged from 300,000 to 390,000 pounds (135 to 175 metric tons). Thus, *Cancer* crabs support a small but commercially valuable fishery.

1.4 Blue Crab, *Callinectes sapidus*

The blue crab supports a valuable fishery along the mid-Atlantic coast and Gulf of Mexico from Cape Cod to Texas. Waters of the Chesapeake Bay and the Louisiana coast produce about 65% of the commercial catch by weight. The blue crab fishery ranked second in volume and fifth in value among all United States crustacean fisheries in 1987. Fishing activities are intense during the summer months but a significant fishery for dredged hibernating crabs takes place from Virginia to New Jersey during winter. Although blue crabs do not represent a major fishery in the New York Bight or New England, studies on shell disease in this species may lead to a better understanding of the onset and progress of this disease in other crustaceans. Furthermore, blue crabs are year-round residents of coastal rivers and bays, often in areas of sewage and industrial outfalls where contaminant concentrations are higher than in near- and off-shore waters. Many of the microorganisms identified from diseased shells and gills were isolated from blue crabs, and provided much of the groundwork for similar studies with other crustacean species.

1.5 Status of Shell Disease

The status and severity of shell disease in offshore waters of the eastern United States has not been assessed on a sound scientific basis, but appears to be of concern to commercial fishermen. Their reports of shell disease in crabs and lobsters from offshore waters refer to those captured in deepwater canyons along the shelf break -- primarily Hudson, Block, and Atlantis Canyons. Although the disease has been documented from shelf canyons, there is a void in our knowledge of the condition at the 106 Mile Site and its surrounding areas. Therefore, our present assessment of the severity of shell disease in commercially valuable crustaceans is based principally on reports of the condition as recorded from waters of the New York Bight apex. Preliminary findings with a deepwater species, the red crab Geryon quinquedens, are included to document the geographical distribution of shell disease in commercial resources of the continental shelf.

The latest data on the maximum prevalence of shell disease in commercially valuable crustaceans from the New York Bight is summarized in the following table:

Species	Maximum Percent Severe Shell Disease
Lobster (near 12 Mile Site)*	14%
Rock Crab (near 12 Mile Site)	22%
Rock Crab (Hudson Shelf Valley - "Mud Hole")	12%
Rock Crab (Sandy Hook Bay)	11%
Red Crab (Hudson, Block and Atlantis Canyons)	30%
Shrimp (Crangon)	30%

*Post-dumping surveys are in progress.

2.0 SEVERITY OF THE SHELL DISEASE PROBLEM IN THE NEW YORK BIGHT

Data on the effects of ocean pollution on waters, sediments, and infaunal biota of the New York Bight have been accumulating for almost two decades. Microbiological studies have shown that antibiotic resistant bacteria and enteric viruses are readily identified from water and sediments. Commercially valuable shellfish beds have been closed because of sewage-related pollution. Sewage and other pollutants, including heavy metals, PCB's, and PAH's have affected sediments of the Bight, changing some of them from clean sands and muds to foul "black mayonnaise." Altered silty sediments no longer support populations of clams and oysters, and crabs and lobsters often have odors characteristic of petroleum or hydrogen sulfide. Affected sediments are known to contain heavy metals, PCB's, PAH's, coprostanol, viruses, and pathogenic protozoans of concern to human and animal health. The persistence of enteric viruses in the environment has been documented by Goyal (1989) who recovered them from gills of rock crabs and from sediments at the Philadelphia-Camden disposal site 17 months after the cessation of sludge dumping. Shell disease in rock crabs and lobsters has been noted by biologists and commercial fishermen, and is recognized as affecting marketability because of their unsightly appearance.

A major study of shell disease and its possible association with pollution in the New York Bight was reported by Pearce (1971) and Young and Pearce (1975). Lobsters and rock crabs from grossly polluted areas of the Bight apex were found to be abnormal, with appendage and gill erosion a most common sign. Exoskeletal erosion occurred principally on the tips of the walking legs, ventral sides of chelipeds, exoskeletal spines, gill lamellae, and around areas of skeletal articulation where contaminated sediments could accumulate. Gills of crabs and lobsters were usually clogged with detritus, had a dark brown coating, contained localized thickenings, and displayed areas of erosion and necrosis. Similar disease signs were produced experimentally in animals held for six weeks in aquaria containing sediments from sewage sludge or dredge material disposal sites. Initial discrete areas of erosion became confluent, covering large areas of the exoskeleton, and often parts of appendages were lost. The chitinous covering of the gill filaments was also eroded, and often the underlying tissue became necrotic.

Histological studies on crabs and lobsters have revealed numerous internal lesions in the gill, intestine, and hepatopancreas, and similar lesions have been induced experimentally by both biological agents and chemicals (Greig et al., 1982; Sawyer, unpublished data). Black discoloration of crustacean gills has been found to result from accumulations of black mud and silt that may interfere with respiration. Internal blackening (melanization) of gill tissue denotes areas of cellular death and has been termed "endogenous" to differentiate the condition from external or "exogenous" blackening caused by sediment deposits. Blackened gill cuticle has been observed as a result of mechanical blockage of respiratory surfaces by dense bacterial mats, diatoms, or gill fouling protozoans.

Evidence to support numerical or statistical estimates of pollution effects on morbidity or mortality of fish and crustaceans in the New York Bight is primarily inferential, since weak or diseased animals are subject to predation, or rapid bacterial decomposition after death. Indirect evidence is available, however, since attempts to maintain animals in laboratory tanks or aquaria lead to mortalities or manifestations of disease conditions. Dead and moribund crabs and lobsters in New York Bight apex waters have been reported on several occasions by divers, and dissolved oxygen concentrations near the bottom have often approached zero during summer (Pearce, 1972; Young, 1973). Low oxygen stress, combined with gill disease could probably lead to mortality (Thomas, 1954).

The severity of the problem of pollution in the New York Bight apex is no longer a matter of speculation. Valuable shellfish beds have been replaced and affected by fine silty sediments and muds that smother sessile infauna. Numbers of enteric bacteria are present, some, in sediments, in excess of those considered to be safe for commercial harvests; enteric viruses survive in contaminated sediments; and the prevalence of visible signs of disease in the biota is significantly higher than in specimens captured from areas that are remote from excessive pollution. For those species of economic importance, it appears that reproduction and recruitment of young year classes is sufficient to offset losses due to disease, predation, and commercial fishing activities. Such losses do not appear to have affected annual crustacean commercial landings.

Studies on crustacean populations near the 106 Mile Site, using parameters similar to those employed for nearshore population studies, are needed before the severity of pollution effects in deepwater crustaceans may be assessed.

2.1 Shell Disease in Lobsters

Estimates of the prevalence and severity of shell disease in lobsters in offshore waters have not been made on the basis of sound scientific studies. Most reports on the gross, or visible appearance of animals have been made by commercial fishermen who have expressed concern over the "unappetizing" appearance of lobster catches that would otherwise be marketable as live lobsters (Fig. 3). Estrella (1984), however, has conducted extensive surveys on shell disease in bays and coastal waters of Massachusetts. Shell disease was found to affect large numbers of commercial-sized animals that molt 1-2 times each year, and small and more frequently molting juveniles to a lesser extent (Table 1). Water quality data, and estimates of the numbers of sewage-associated bacteria from bays and harbors, have provided good information about correlations between pollution and the prevalence of shell disease (Table 2).

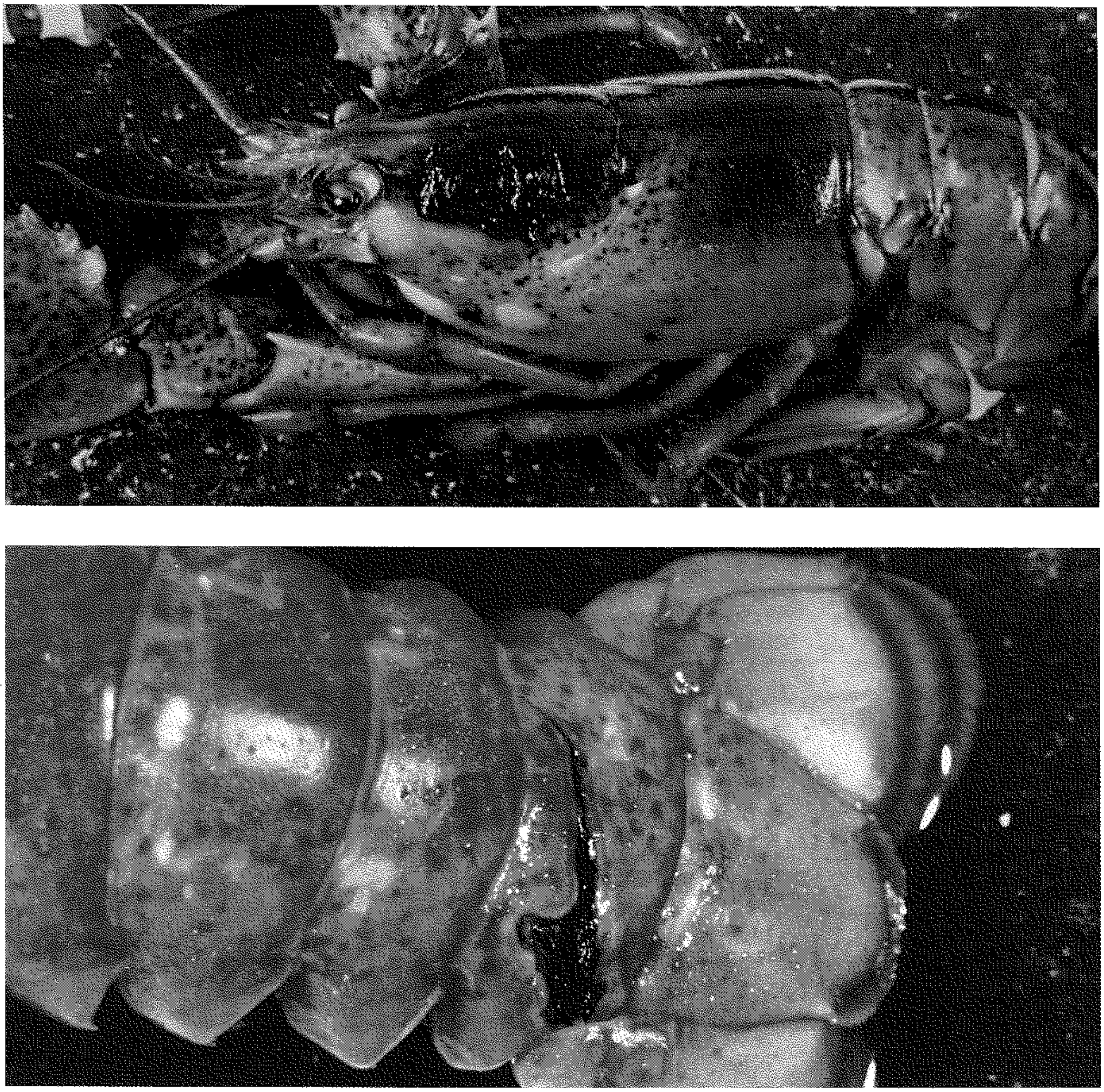

Figure 3. Shell disease in lobsters, *Homarus americanus*. (Photograph supplied by Ms. J. C. Rugg).

Table 1. Prevalence of Shell Disease in Lobster, *Homarus americanus* by Size (mm.) (Estrella, B., unpublished data, 1983-84).

Carapace Length	No. Examined	% Shell Disease
41-50	3	33.3
51-60	17	5.9
61-70	48	6.3
71-80	187	11.2
81-90	13	30.8
91-100	4	50.0

Note: Data does not take molting activity into account. Influence of molting was noted in a November 1988 survey as follows:

Outside Boston Harbor - 16 hard shell (18.8%), 97 paper shell (7.2%).

Buzzards Bay - 91 hard shell (37.4%), 69 paper shell (8.7%).

Table 2. Shell Disease in the American Lobster, *Homarus americanus*. (From Estrella, B.T. - unpublished data, 1984).

Station No.	Location	Number of Lobsters	% Shell Disease	Fecal Coliforms
1	Cape Ann	28	0.0	<36
2	Massachusetts Bay (Broad Sound)	24	12.5	930
3	Cohasset	26	0.0	230
4	Plymouth Bay (Outside)	31	9.7	33
5	Cape Cod Bay	4	0.0	36
6	Cape Cod Bay	26	0.0	36
7	Ocean-Cape Cod	31	0.0	540
8	Buzzards Bay	23	4.3	>1,600
9	Buzzards Bay	8	12.5	>11,000
10	Buzzards Bay	35	22.9	No Data
11	New Bedford	12	33.3	>16,000
12	New Bedford	24	50.0	>1,600

Note: Subsequent sampling of legal sized hard-shelled lobster was undertaken in May 1985 and May 1986:
Inside Boston Harbor - 47% (N-30)
Buzzards Bay - 37% (N-59).

Additional data (Estrella, 1984) provide useful information in terms of shell disease occurring at low levels in apparently healthy lobster populations, but showing significantly increased prevalence in areas of measurable environmental pollution (Figure 3). J. Rugg (1989, unpublished), began a study of perforating lesions of the shell in lobsters of the New York Bight apex in 1986. Her initial sampling disclosed prevalences of shell perforations averaging 14%.

Information currently available suggests that the natural occurrence of shell disease in lobsters may result from scratches, abrasions, or wounds that expose underlying layers of the shell to invasion by chitin digesting bacteria or fungi. It remains to be determined, however, what role, if any, may be attributed to microbial or chemical agents associated with waste disposal.

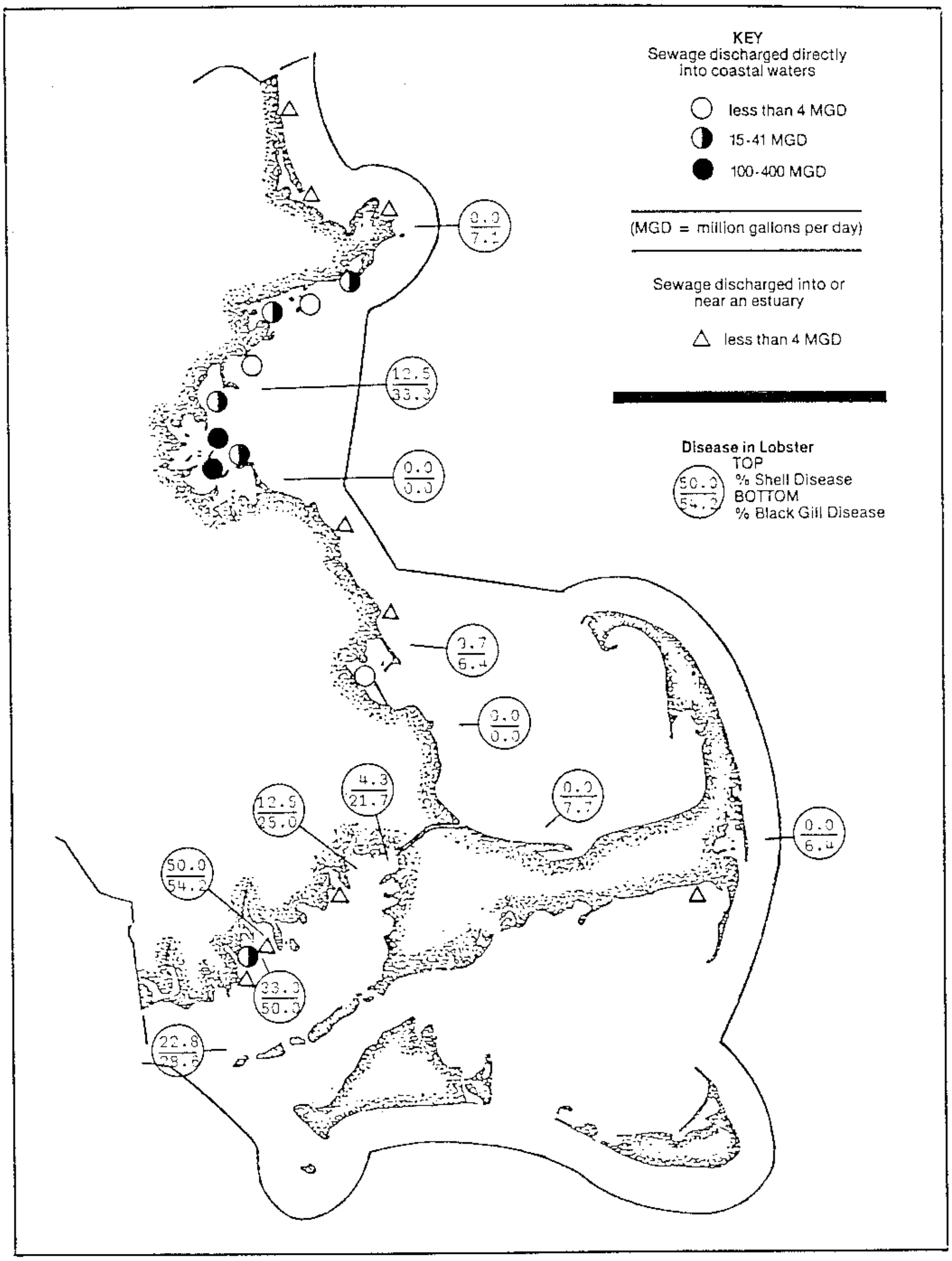

Figure 4. Prevalences of two diseases -- black gill disease and shell disease -- in Massachusetts lobsters - 1983 and 1984. Locations of major sewage discharges are also indicated. (From Estrella, 1984).

2.2 Shell Disease in Red Crabs

Shell disease in red crabs from three continental shelf canyons (Table 3) was studied by Young (1988, in press) (Fig. 5), who proposed a rating scale of 1-5 to estimate the severity of the disease. A rating of "1" was given to crabs without visible evidence of shell disease, "2" to those with up to 10 black spots; "3" to those with >10 black spots or <10% of the body showing shell blackening; "4" to those with large areas affected by blackening of 10-50% of the body, and "5" crabs with blackening of >50% of the body, and/or open lesions present, or with one or more missing appendages. Crabs with missing appendages were often blackened at the site of the break(s). Ratings of moderate to severe ("4" or "5") were assigned to 13% (27/202) of the specimens from the Hudson Canyon, 30% (23/77) from Block Canyon, and 19% (21/110) from Atlantic Canyon. The prevalance of shell disease in crabs from the canyons appears to be significant, especially since video films of the sea bottom showed soft to silty sediments and the absence of rocks or crags associated with physical causes of shell damage (National Underwater Research Program, Univ. of Conn.). R. R. Young (unpublished data) also found shell disease in a small collection of red crabs from the Middle Atlantic Bight deposited in the Smithsonian Institution, Washington, DC, over a century ago (1884). Preliminary microbiological studies (Bullis, et al., 1988) on eroded shell lesions in red crabs identified several species of bacteria (*Vibrio* spp. and *Flavobacter* spp.) as well as several fungi that deserve further investigation.

Table 3. Shell Disease in the Deep Sea Red Crab, <u>Geryon quinquedens</u> (Young, R. - 1988, in press).

		Rating*				
Location	No. Crabs	1(%)	2(%)	3(%)	4(%)	5(%)
Hudson Canyon	202	17(8.4)	77(38)	81(40)	16(7.9)	11(5.4)
Block Canyon	77	6(7.8)	15(19.5)	33(43)	13(17)	10(13)
Atlantis Canyon	<u>110</u>	<u>10</u>(<u>9</u>)	<u>31</u>(<u>28</u>)	<u>48</u>(<u>41</u>)	<u>16</u>(<u>14.5</u>)	<u>5</u>(<u>4.5</u>)
TOTALS	389	33	123	162	45	26
PREVALENCE (%)		(8.5)	(31.6)	(41.6)	(11.6)	(6.7)

*Rating:
1 - absence of visible spots
2 - very slight, <10 small spots
3 - slight, >10 spots; <10% of body blackened
4 - moderate, blackening over 10-50% of body
5 - severe, blackening >50% of body; open lesions; missing appendages with blackening at point of break

Note: Moderate to severe blackening noted in 13-30% of specimens

Figure 5. Shell disease in the red crab, *Geryon quinquedens*. (Photograph supplied by Dr. R. A. Bullis)

Commercial catches of red crab reported in 1973 ranged up to 3,500 pounds (1600 kg) per towing hour (Meade & Gray, 1973) showed that the fishery was small but of significant market value. The impact of shell disease on the marketability of commercial catches has not been determined. Commercial fishermen, however, have voiced concern over the visible appearance of shell diseased individuals and its effect on market value.

The golden crab Geryon fenneri, although not found in the New York Bight apex, is also affected by shell disease. Wenner et al, 1987, examined 3,183 specimens from the South Atlantic Bight and found that 95% had blackened abraded areas on the exoskeleton. Damage to the exoskeleton was noted in 19% of the premolt crabs, and in 75% of those in intermolt. One or more appendages were missing from 2.4%, and pereopods were missing from 9.6% of the specimens.

2.3 Shell Disease in Rock Crabs and Jonah Crabs

Molting behavior, male:female ratios, carapace width, and geographical distribution have been found to influence surveys on the prevalence of shell disease in rock crabs, C. irroratus (Table 4). Shell disease in nearshore waters of New York and New Jersey was found to occur in <5% of the specimens examined during molting periods, but up to 20% during intermolt periods (Fig. 6). Other studies at the now closed Philadelphia-Camden sewage sludge disposal site 40 miles offshore, showed that shell disease was present in 16% (91/580) of the specimens examined during intermolt periods, and in 8% (33/426) of a second group when 102 of them had undergone a recent molt. Data from the New York Bight apex showed that inshore females mated in late fall followed by shoreward migration and molting of males in shallow rivers and bays. Mating periods showed a male:female ratio of approximately 1M:1F, while post-mating and subsequent molting by males showed a ratio of up to 100M:1F. In the deeper offshore waters newly molted females and males often were captured at the same time and ratios rarely exceeded 5M:1F.

The prevalence of shell disease among offshore decapod crustaceans from clean or unimpacted habitats has not been studied extensively. The lack of such data is due to the fact that very few, if any, coastal environments from Canada to Florida have been completely spared the effects of pollution. Studies on rock crabs and lobsters in the New York Bight apex have shown that when migratory behavior, molt cycles, and sewage polluted sediments are taken into account, prevalences of up to 20-30% in intermolt specimens are not unusual. Prevalences of 5-6% or less, in locations where contaminant levels are low, suggest that this range may be "expected" while the higher figures represent levels of disease that may be superimposed as a consequence of contaminant inputs and sea bottom degradation.

Figure 6. Shell disease in the rock crab, Cancer irroratus. (Photograph supplied by Ms. J. C. Rugg)

Table 4. Shell Disease in Rock Crabs, *Cancer irroratus* in Nearshore Waters (Sawyer et al, 1979 - 1984, unpublished data)

Location	No. Crabs	% Shell Disease*
Sandy Hook, NJ	609	18.8
12 Mile Site, NY	472	21.8
Hudson Valley Shelf	1,020	12.0
Philadelphia-Camden Disposal Site	1,016	15.7

*Maximum prevalence noted during intermolt period - prevalence may decrease to <5% during molting periods.

Small collections of rock crabs were made in Maine (Portland and Boothbay Harbor) where shell blackening was not recorded but 15% (30/206) had perforating shell lesions (4 with perforation of the appendages and 26 with perforations of the carapace). Other collections near Ocean City, Maryland, and in proximity to the closed Philadelphia-Camden sewage sludge disposal site showed that 39% (39/99) of the large crabs caught in traps 16 miles offshore had shell disease. In contrast, none of 103 recently molted specimens caught inshore during January through March had evidence of shell disease.

In conclusion, studies on the rock crab, C. irroratus, are more extensive than on other decapod species examined in the New York Bight. Background information has shown that migratory behavior and molting by some crustaceans may vary seasonally between inshore, near shore, and offshore populations. Male:female ratios approaching 1:1 are indicative of seasonal mating activity by C. irroratus. The peak prevalence of shell disease occurs during intermolt periods since blackening and non-perforating lesions may be cast off with the old shell. Limited data indicate that the more northern population may serve as an indicator of perforating shell disease associated with chitinoclastic bacteria, while mid-Atlantic coastal and shelf populations may also be affected by shell blackening as well as perforating lesions due to bacteria and/or other unknown causes.

Perforations and/or shell blackening have been seen in Jonah crabs, but the number of specimens studied has been too small to support estimates of disease prevalence in this species. Furthermore, molting data for C. borealis are insufficient to define seasonal patterns (Haeffner, 1977).

2.4 Shell Disease in Blue Crabs

Information on causes of shell disease and damage in blue crabs from the Pamlico River, North Carolina has been provided by S. McKenna and co-workers (unpublished report). Portions of the river have experienced numerous fish kills, algal blooms, anoxic events, and outbreaks of fish disease associated with poor water quality. Trawl catches of 1,459 crabs showed that 5% had severe lesions on the dorsal surface of the carapace, and pot catches had prevalences as high as 10%. Bacteriological studies on the lesions yielded species of Pseudomonas, Vibrio, and Proteus.

D. Engel and co-workers (unpublished data) have stated that chitinoclastic disease normally associated with blue crabs produces lesions on the ventral surface of the animals, and is usually a coalescence of individual small lesions. However, the disease observed in the Pamlico River affects the dorsal surface of the crabs and appears to be an extremely aggressive form of chitinoclastic disease. Vibrio and Pseudomonas, as well as other bacteria and fungi, have been isolated from the lesions. It is not known why the disease in Pamlico River crabs affects different portions of the exoskeleton, or whether more than one type of disease is involved. Although the etiology of the disease has not been established, the data and observations suggest that some environmental factor or combination of factors predispose the crabs to this particularly aggressive form of shell disease.

The descriptions of shell disease in the blue crab population in the Pamlico River are preliminary. It has been established, however, that the disease is not unique to the Pamlico River since crabs with shell disease have also been collected in the Alligator River and southern Albemarle Sound. Reports also have been made of similar types of disease in blue crabs from the St. Johns River in Florida, and from Freeport, Texas. These studies of blue crabs in North Carolina suggest that there may be chemical as well as biological factors involved in the development of shell disease in crustaceans (Fig. 7); chemicals (or stress related to chemical contaminants) may have a role in shell disease in some situations, even where chitin-digesting bacteria have not been culturable from shell lesions. This research area needs to be expanded, in both microbiological studies and chemical analyses of tissues from diseased crabs.

PROPOSED PATHWAYS OF SHELL DISEASE

Natural

↓

Cuticular abrasion or mechanical disruption.

↓

Invasion and proliferation by chitinoclastic organisms.

↓

Pitting and erosion of cuticle and perforation of shell in advanced cases.

↓

Secondary infection of underlying tissues.

Stress-Induced

↓

Immunosuppression and physiological/biochemical disturbances in chitin synthesis and mineral deposition, especially in areas of setal pores.

↓

Invasion by chitinolytic organisms, often with bilateral configuration.

↓

Host responses include formation of hemocytic plug, deposition of melanin and increased chitin formation.

↓

Calcified areas may become friable and eventually perforate, forming the so-called "ulcerative" stage.

Figure 7. Dual pathway of shell disease, based on a proposal by R.A. Bullis (unpublished).

Shell disease, therefore, is found in crustaceans of many species, including those discussed in this section. The disease occurs along the entire Atlantic coast of United States, as well as in many other geographic locations -- inshore and offshore, polluted and non-polluted. It appears in a variety of forms, including surface pitting, blackening of the shell, and areas of shell perforation which may be extensive.

3.0 RELATIONSHIP OF SHELL DISEASE TO POLLUTION

Most of the visible signs of shell disease in crustaceans, and the variety of microorganisms isolated from lesions, were reported long before environmental pollution was considered as a possible predisposing factor. Much has been learned during the last two decades, however, as a result of extensive studies in contaminated waters of both the east and west coasts of the United States. Most studies, however, have dealt with surveys on visible signs of disease, the geographical distribution of disease, and pathological conditions noted in tissues and organs. Very few observations have been made on different year classes, temporal and spatial effects, and seasonal influences related to differences in animal behavior, feeding habits, and population density.

Observations on lobsters sampled on the Massachusetts coast (Estrella, 1984), showed a higher prevalence of shell disease in specimens taken from polluted sites (Boston Harbor and Buzzards Bay) than in those taken from open and deeper stations near Cape Ann, Cape Cod Bay, and outer Cape Cod. Studies with rock crabs (Sawyer et al, 1984) conducted on a multi-year basis, and taking size and molting stage into account, also suggested that the prevalence of shell disease is higher in stressed environments than in those further from known sources of pollution. It is important to note, however, that sewage sludge dumpsites are rarely fished intensively, and therefore might be expected to have more larger and older animals which molt infrequently, and hence, may have higher prevalences of shell disease. It is also important to keep in mind that temperature effects, seasons, molt stages, and differing migratory patterns have profound effects on prevalences of gill blackening and shell condition (Sawyer, 1982; Sawyer et al, 1985).

Studies that support an association of pollution and shell disease have been published, and gross effects documented. Statistical analyses have shown that the types of shell lesions of concern occur naturally, but are numerically more frequent and severe in specimens collected from polluted waters. Gopalan and Young (1973) examined "shell disease" in the caridean shrimp, Crangon septemspinosa, an estuarine and coastal food chain organism extremely important in the diet of bluefish, weakfish, flounders, sea bass, and other commercial and recreational species. Samples of shrimp from the New York Bight apex showed that up to 15% of them had eroded appendages and blackened erosions of the exoskeleton. Similar signs of disease were only rarely observed in shrimp examined from waters of the Beaufort, North Carolina and the Woods Hole, Massachusetts region. All layers of the exoskeleton in affected shrimp were eroded, affected portions were brittle and easily fragmented; cracking and pitting were noted in calcified layers, and underlying tissues were often necrotic. Laboratory experiments using sea water from the highly polluted inner New York Bight resulted in shell disease in 50% of the test animals. Erosion was progressive, crippled individuals were cannibalized, and eroded segments of the appendages did not regenerate after molting. Disease signs did not develop in control animals held in artificial seawater. Other evidence for a relationship between shell disease and pollution was presented by Pearce (1971, 1972) and Young and Pearce, (1975). Based on field collections and experimental studies, they concluded that "crabs and lobsters collected from the vicinity of sewage sludge and dredge spoil disposal areas within the New York Bight apex most frequently showed skeletal erosions . . ." Furthermore, they reported that normal animals exposed to sewage sludge from disposal sites developed exoskeletal lesions within six weeks, and that eroded gills were of particular note.

In contrast to existing knowledge, where specific causes of shell disease have been documented, it is apparent that multiple causes of disease should be investigated in animals residing in both clean and stressed environments. One of the most immediate concerns, with regard to pollution-related causes of shell disease, should focus on whether or not chemical pollutants compromise chitin deposition and shell mineralization, rendering the exoskeleton more susceptible to chemical degradation and/or destruction by lytic microorganisms. Current knowledge suggests that there is a definite, though unquantified, relationship between environmental pollution and the prevalence of shell disease. With few exceptions, existing sampling techniques have not been applied to the biota of the 106 Mile Site and canyons of the continental shelf.

Concerns expressed by commercial fishermen suggest that crabs and lobsters may now have unusually severe signs of shell disease. However, data are not available to support or deny recent increases in this form of the disease. Specific indicators of sewage pollution such as viruses, bacteria, protozoa, and coprostanol are present in sediments of the New York Bight apex, and high prevalences of shell disease have been reported. Only limited studies of similar contaminants have been made on deepwater offshore sediments. No direct evidence exists to support claims that pollution is associated with shell disease in offshore crustacean populations.

4.0 RELATIONSHIP OF SHELL DISEASE TO INCREASED MORTALITY

Mortality due to shell disease in natural populations of crustaceans has not been determined with any degree of certainty. In contrast to marine fish kills where floating fish may be seen on the surface, dead crustaceans generally remain on the sea bottom or are consumed by scavengers, only occasionally showing up in traps or trawls. Evidence for disease or stress leading to mortality has been noted; deaths often occur soon after newly caught diseased specimens are placed in holding tanks. In other instances, it has been noted that blackened spots or shell lesions may increase in size and severity during captivity. Periods of high water temperature and low oxygen tension (anoxia) have been associated with mortalitites noted by divers and commercial fishermen. It is likely that stressed crabs and lobsters are less motile and defensive than healthy ones and are slow to move out of anoxic zones. Divers have noted that weakened animals are less aggressive than healthy ones, and are slow to assume a defensive posture or seek shelter when threatened. Blue crabs, Callinectes sapidus, known to be infected by parasitic amoebae, may die in less than one hour after being taken out of water, and have been observed to fail to turn over when placed on their backs. Weakened or diseased crustaceans may remain alive when bathed by oxygenated water, but suffer respiratory stress and die when oxygen levels are low. Evidence for stress-related conditions affecting rock crabs, Cancer irroratus, has been observed visually among transient subpopulations caught in Sandy Hook and Lower Bays, New York and New Jersey. Large numbers of male crabs entering the bays to molt during winter months begin their return to the ocean in late winter or early spring. Crabs captured near the end of the annual migration are often afflicted by severe gill blackening, shell discoloration, or shell lesions, and have been referred to as the "stragglers", i.e., that portion of the population suffering from physiological stress. Cancer crabs, red crabs, and lobsters "walk" rather than "swim" and are known to move considerable distances during periods of migration and molting. Disease or stress, whether biological, nutritional, or chemical, all are known to weaken affected animals and contribute to morbidity or mortality.

Evidence for degraded sea bottoms affecting crustacean health has been obtained from studies on "black gill disease" in rock crabs captured in the New York Bight apex (Sawyer, 1982); Bodammer and Sawyer, 1981, Sawyer et al, 1979, 1983, 1984). High prevalences were associated with sewage sludge and/or contaminated dredge material disposal sites where environmental degradation was severe. Prevalences of gill disease ranged up to 30% in intermolt crabs. The etiology of the disease is complex, but it involves accumulations of black silt between gill lamellae, and the presence of fouling organisms on gill surfaces. Localized "black spots" associated with melanized gill tissue were often noted in stained sections of gill tissue (Sawyer, 1983). An association of gill blackening with shell erosion was also noted (Sawyer, 1982), i.e., "Specimens with gills judged to be 100% black often had external blackening and shell erosion. Black gills were often melanized extensively with necrosis of gill cuticle or entire gill filaments."

Mortalities attributed to effects of shell disease have been observed and reported, occasionally at high levels, in impounded populations of crustaceans. In lobsters, death has been associated with progressive erosion and destruction of gill membranes, with resultant reduced oxygen uptake, especially in hypoxic situations. Estrella (personal communication) observed one episode of natural mortality from undetermined causes among small lobsters at Racing Beach, Falmouth, Massachusetts in 1983, where the numbers of dead lobsters went from 0% in May and June to 3.78% in July, 2.3% in August, and then declined to <1% in the autumn. In shrimp, failure to complete molting because of shell adhesions has been identified as a cause of mortality. Death may also result from secondary systemic infections after the exoskeletal barrier has been breached, especially in the presence of high populations of facultative pathogens. Additionally, it is quite likely that severely affected animals would be more vulnerable to predation.

Some limited information exists about possible association of shell disease, environmental degradation and mortalities of crustaceans. Pearce (1971) reported field observations of high mortality of crabs and lobsters in and around sewage sludge and contaminated dredge material disposal areas of the New York Bight, and attributed the deaths to observed "fouling and necrosis of gill tissue, which decrease respiratory surface area, together with the low oxygen concentrations in the bottom water of the waste disposal areas."

In addition to <u>direct</u> mortality, it is reasonable to expect that damaged or crippled crustaceans would be more subject to predation or cannibalism than healthy ones -- and there is some limited information to support this. In a study of caridean shrimp (<u>Crangon</u> <u>septemspinosa</u>) from the New York Bight, Gopalan and Young (1973) observed in aquarium studies that individuals with advanced shell disease were attacked and eaten by the healthy cannibalistic survivors.

Reductions in crustacean populations may be brought about by many factors, including predation, disease, and overfishing. Some of the best estimates of mortality have been obtained by studying the feeding habits and gut contents of predatory species. For example, juvenile and adult rock crabs are known to make up a large portion of the diet of predatory fish such as cod, skate, smooth dogfish, and striped bass, while juveniles are known to be fed upon extensively by lobsters (Bigford, 1979). Reilly (1975) estimated that 75-85% of second-year class rock crabs, and 68-80% of the third-year class are consumed by predators in coastal waters. There are no comparable estimates for similar losses in offshore or continental shelf habitats.

A considerable body of knowledge exists about crustacean mortalities, and estimates have been made of the prevalence of shell and gill disease in several commercial species. Information derived from experimental studies and observations on laboratory-held animals, have suggested that several diseases undoubtedly have a role in naturally-occurring mortalities. Recent studies indicate, however, that ocean pollution and other conditions that impact on healthy environments lead to increases in the prevalence of visible signs of disease. Crustacean landings suggest that in spite of disease and mortality, reproduction and recruitment are sufficient to compensate for population losses. There is increasing concern, however, about the numbers of animals exhibiting external signs of disease that render them unsuitable for marketing.

The overall opinion of the Shell Disease Working Group is that crustacean mortalities, although difficult to assess visibly, are higher under conditions of poor water quality than in ecosystems without measurable contaminant impacts. There is, however, no published information on mortalities in wild populations from unimpacted areas that could be attributed directly to shell disease. This does not imply that deaths do not occur -- simply that observations of them in natural populations would be difficult to make. By inference from observations of captive or experimental populations, it seems likely that highly stressed individuals may die from the effects of advanced shell disease, secondary infections, and/or predation.

5.0 CONCLUSIONS

Based on examination of available published and unpublished information, and on extensive discussion, the Working Group has reached these conclusions:

- Shell disease represents a stage in the natural relationship of crustaceans with chitin-utilizing bacteria and fungi. An uneasy balance is usually maintained by the metabolic processes associated with new shell formation at molting, and subsequent shell maintenance and repair -- and the growth, metabolism, and reproduction of microbes capable of degrading chitin. The balance may be disturbed by environmental changes that reduce the crustacean's capabilities (metabolic and defensive) to maintain an intact shell, or that encourage multiplication of marine microorganisms with chitinolytic capabilities.

- Mortalities from shell disease have been observed in laboratory-held and impounded populations, occasionally in large numbers. Systemic infections which may develop after perforation of the chitinous integument, as well as destruction of the gills, and adhesions which prevent molting, have been considered to cause mortalities. Shell disease may predispose crustaceans to predation or disease-related mortality, but there is little evidence from wild populations for a direct cause and effect relationship. There is no conclusive evidence that shell disease causes fluctuations in crustacean populations in the New York Bight apex.

- Evidence has been published that shows an association between habitat degradation and shell disease. High prevalences of both shell disease and the black gill syndrome have been found in crustaceans from polluted sites. Black gill and shell disease have also been noted after experimental exposure of crustaceans to heavy metals such as cadmium, and to biocides, petroleum, and petroleum derivatives. Both diseases have been reported from the New York Bight apex.

The only conclusion that can be made about the situation near the 106 Mile Site is that shell disease may be a problem insofar as the marketability of diseased crabs and lobsters is concerned. However, there is no conclusive evidence to associate shell disease in offshore populations with sludge dumping activities at the 106 Mile Site.

6.0 RECOMMENDATIONS

To extend and verify the conclusions reached by the Working Group, the following actions are recommended:

- Since shell disease in crustaceans may be influenced by a number of environmental factors -- natural and man-induced -- a continuing monitoring effort is necessary to determine prevalences and severity of disease in species of economic importance. This effort should take into account seasonal, behavioral, and physiological changes in the hosts. The sampling pattern should include polluted and reference sites, and should be stratified by data on salinity, depth, and extent of pollution, as measured by levels of contaminants and presence of specific indicators in sediments, bottom water, and host tissues. As part of the monitoring plan, criteria should be developed to rank severity and type of disease for each species studied.

- Critical to a full understanding of shell disease are further experimental studies, particularly those concerned with identification of specific microorganisms capable of pathogenesis, experimental manipulation of possible predisposing environmental factors, and the immunologic response of hosts to shell disruption.

To accomplish these general objectives, the Working Group proposes a short- and long-term research program oriented toward understanding shell disease in crustaceans of the New York Bight:

Proposed Short-term Activities include the following:

- Examine status of stocks of crustaceans (lobsters, red crabs, blue crabs, rock crabs) in the New York Bight, and review factors (including diseases) which may affect abundance.

- Sample crustaceans from the New York Bight (including 12 Mile and 106 Mile Sites), as well as from appropriate reference sites, on a monthly or seasonal basis for prevalences and intensities of shell disease noting temperature, depth, sex, size, molting stage, and gill abnormalities. Molting stages for each species must be determined.

- Examine data and design a statistically valid sampling scheme to determine relationships, if any, between shell disease and contaminant levels (inorganic and organic), in tissues, in sediments, and in the water column.

- Carry out tagging studies of diseased crabs and lobsters to determine disease progression and to provide information about possible differential mortality in natural populations.

- Conduct microbiological studies to determine causative agents of shell disease in New York Bight crustaceans and in those from reference sites, to determine if there are differences among areas or host species.

- Conduct experimental studies of disease progression and effects on survival, using microbial isolates from diseased animals. Variables to be examined include salinity, temperature, pressure, presence of specific contaminants, availability of oxygen, trauma, and numbers of pathogens present.

Proposed Long-term Activities include the following:

- Continue sampling activities and stock assessment activities. Long-term sampling program to be developed with aid of fishermen, and with possible assistance of Sea Grant Extension Service staff.

- Examine the relationship between black gill disease, shell disease, and associated microorganisms in crustaceans.

- Carry out physiological/biochemical studies of the process of chitin formation and maintenance in crustaceans, particularly as it may be affected by pollutants.

- Carry out immunological studies of defenses of crustaceans against microbial infections, particularly those modifications that may be induced by pollutants.

- Analyze inshore and deep water sediments for specific indicators of sewage wastes (bacteria, viruses, protozoans, etc.).

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9.0 APPENDICES

Though not necessarily integral to the report itself, additional information is here supplied in four categories:

9.1 Participants in the Working Group discussions
9.2 EPA and NOAA roles and responsibilities
9.3 106 Mile Site Fact Sheet
9.4 Questions and answers about shell disease

9.1 Appendix 1. Participants in the Working Group Discussions

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9.2 Appendix 2. EPA and NOAA Roles and Responsibilities

The New York Bight is an ocean area extending over 100 miles into the Atlantic Ocean from the mouth of the Hudson River Estuary to the limit of the Continental Shelf. Roughly 240 miles of sandy shoreline from Cape May, New Jersey to Montauk Point, Long Island from its landside border. The Bight is a resource of great public importance. It provides water-based recreation to a resident population of over 20 million people. The Bight and its adjoining estuaries support an extensive commercial and recreational fishery. It is also the site of a major world shipping port. It has also become a repository for an outpouring of wastes from a vast metropolitan area which is impacting or jeopardizing many of these water-based uses.

Pollution has resulted in various water use impairments in the New York Bight. Some of these impacts have been direct and immediate, such as the beach closures resulting from wash-up of floating refuse and noxious waste materials that have become particularly troublesome in recent years, or the closure of shellfish beds as a result of bacterial contamination. In addition to such obvious problems, there is a deeper concern that the Bight's overall capacity to function as a healthy, productive ecosystem is declining as a result of the cumulative effects of human activities in this densely populated area.

Both EPA and NOAA have had and still have research and monitoring programs in the New York Bight.

NOAA

NOAA, through its National Marine Fisheries Service and Office of Marine Assessment, is concerned with abundance of living marine resources and the status of their habitats -- thus activities such as fishery management and pollution monitoring logically fall within the agency's purview. Legislative authorities are derived from the Fisheries Conservation and Management Act and the Marine Protection Research and Sanctuaries Act. The resource-oriented responsibilities thus can integrate well with the water quality-oriented responsibilities of EPA when questions arise about possible effects of environmental degradation on living resources. NOAA has had a long history of data acquisition in the New York Bight, beginning in the early 1970's with a detailed study funded in part by the U. S. Corps of Engineers. The long term NOAA-MESA Project for the New York Bight provided a much larger data base, which has been augmented by continuing research and monitoring by the NOAA-NMFS Sandy Hook Laboratory.

In FY 1984, the Ocean Assessments Division of NOAA initiated a new program called the National Status and Trends (NS&T) Program, within which a series of activities were undertaken to quantify the current status and long-term, temporal and spatial trends of key contaminant concentrations and biological indicators of effects in the nation's coastal and estuarine environments. The program's purposes were to provide highly reliable data on concentrations of toxic chemicals in marine fish, shellfish, and sediments, to measure biologic parameters that accurately reflect anthropogenic stress, and to assess marine environmental quality and recommend Federal actions needed to maintain or improve it. Key questions the program intends to answer are (1) what are the current environmental quality conditions of the nation's coastal zone and (2) are these conditions getting better or worse? A nationally uniform set of measurement techniques is employed to determine marine environmental quality parameters. In conducting the program, NOAA cooperates with, and acquires data from, other existing monitoring programs to enhance its assessment capabilities.

Samples have been collected since 1984 at about 50 Benthic Surveillance sites and since 1986 at about 150 Mussel Watch sites. Sediment samples are collected at all sites. At Benthic Surveillance sites, benthic fishes are collected and their lives excised and stored for subsequent chemical analysis. At Mussel Watch sites bivalve molluscs are collected for analysis. The first NS&T report (NOAA, 1987a), based on data from analyses of sediments and fish livers collected in 1984, was issued in January 1987. The second report (NOAA, 1987b) was issued in December of 1987 and was a summary of tissue contaminant data for fish collected in 1984 and 1985 and bivalves collected in 1986.

Information from the NS&T Program will provide a basis for setting priorities for management action and for documenting changes that may occur because of such actions. One objective of the program is to quantify general, depositional areas of contamination and not to define "hot spots." Sites are selected deliberately away from major point sources of contamination. Management action taken on any individual point source will probably not be seen in the NS&T data unless that source exerts a dominant influence on environmental quality over a relatively large area. On the other hand, the NS&T Program will identify the combined influence of many point and non-point sources of contamination to an area.

EPA

In response to concerns about the degradation of water quality and marine resources, the U. S. Congress passed legislation in December 1987 requiring the U. S. Environmental Protection Agency (EPA) to prepare a Restoration Plan for the New York Bight. This plan is to be completed by December 1990. Congress required that the restoration plan undertake the following tasks:

(1) identify and assess the impacts of pollutants affecting water quality and marine resources;

(2) identify uses being adversely affected;

(3) determine what is happening to the contaminants and their effect on human health and the marine environment;

(4) identify technologies and management practices necessary to control the pollution;

(5) identify costs of and impediments to implementing such technologies and management programs;

(6) devise an implementation schedule;

(7) develop recommendations for funding and for interagency and intergovernmental coordination; and

(8) assess alternatives to ocean dumping of municipal sludge and timber burning.

The guiding principles for the development of the plan include the following:

a. The plan will provide the overall umbrella for management of Bight water quality. It will provide a Bight-wide ecosystem perspective within which more detailed site-specific solutions developed through ongoing programs and studies can be orchestrated.

b. The plan will place priority on the control of those pollutants most directly associated with important water use impairments.

c. The plan will build upon remedial programs already underway under the requirements of the Clean Water Act, the Marine Protection, Research and Sanctuaries Act, and other related Federal, State, and local legislation. It will assess the extent to which those efforts are adequate to meet water quality and public health goals and will recommend such additional measures as may be required. Impacts resulting in beach closures and impairments, unsafe seafoods, damage to commercial and recreational fisheries, damage to marine mammals, birds, and reptiles, and effects on commercial navigation and recreational boating will be assessed.

Recent attention by legislators and the media has focused on perceived problems with ocean dumping. The 106 Mile Site, for example, has been "held responsible" for 70 percent decreases in offshore fisheries catches, diseases in crabs and lobsters, dolphin deaths, and floating debris washing up on New Jersey beaches. The 106 Mile Site is currently designated for disposal of municipal sludges originating from 9 sewage authorities in the New York metropolitan area. It is the only site designated for municipal sludge disposal in the United States. Are media claims realistic? The U. S. Environmental Protection Agency (EPA) has developed a monitoring plan that is being used to determine whether impacts result from municipal sludge at the 106 Mile Site. It has been developed using an approach based on current Ocean Dumping Regulations and designed to provide for efficient and effective monitoring results that can be used in making management decisions.

9.3 Appendix 3. 106 Mile Site Fact Sheet

Municipal Sludge Disposal: 12 Mile Site and 106 Mile Deepwater Municipal Sludge Dump Site

Historical Perspective

In 1924 New York City began ocean dumping municipal sludge at a site 12 miles outside of New York Harbor, known as the 12 Mile Site. Over the next few decades additional communities in the New York and New Jersey area began to dump municipal sludge at this site. The 12 Mile Site was located in the New York Bight Apex approximately 10.3 nautical miles east of Highlands, New Jersey, and 9.9 nautical miles south of Long Island. The site occupied an area of about 6.6 square nautical miles with a water depth of approximately 27 meters (88 feet).

While more than 200 sewage treatment plants dumped municipal sludge at the 12 Mile Site at one time, by December 1981 only nine municipal sewage authorities from both New York and New Jersey were authorized to use that site. The nine were the New York City Department of Environmental Protection, the Westchester County Department of Environmental Facilities, the Nassau County Department of Public Works, the Passaic Valley Sewerage Commissioners, the Middlesex County Utilities Authority, the Rahway Valley Sewage Authority, the Bergen County Utilities Authority, the Linden/Roselle Sewerage Authority, and the Joint Meeting of Essex and Union Counties.

In 1981, New York City and several other municipalities brought suits against EPA, challenging the Agency's refusal to renew their permits to dispose sludge at the 12 Mile Site after December 31, 1981, when site designation expired. In the case, "City of New York v. EPA," 543 F. Supp. 1084 (S.D.N.Y. 1981), the Judge ruled that EPA could not deny ocean dumping permits without considering the availability and impact of land-based alternatives.

On May 4, 1984, EPA designated the Deepwater Municipal Sludge Dump Site (DMSDS), commonly known as the 106 Mile Site. Beginning with the designation of the 106 Mile Site in 1984, sludge disposal operations at the 12 Mile Site were phased out. The disposal of sludge at the 106 Mile Site began in March 1986; sludge disposal at the 12 Mile Site ended on December 31, 1987. Since then all sludge disposal has taken place at the DMSDS. The DMSDS is located approximately 120 nautical miles southeast of Ambrose Light and 115 nautical miles from Atlantic City, New Jersey, the nearest coastline. Water depths at the site range from 2,250 to 2,750 meters. The site occupies an area of approximately 100 square nautical miles.

EPA's Regulatory Aspects

Ocean dumping was not regulated until 1973, when Congress passed the Marine Protection, Research, and Sanctuaries Act (MPRSA). Under the MPRSA, EPA is required to establish and apply criteria for reviewing and evaluating permit applications in determining whether the proposed dumping "unreasonably degrades". In establishing these criteria, EPA is required by statute to consider, but is not limited to, the following:

- the need for the proposed dumping;
- the effect of such dumping on human health and welfare, economic, aesthetic, and recreational values;
- the effect of such dumping on fisheries resources, plankton, fish and shellfish, wildlife, shorelines and beaches;
- the effect of such dumping on marine ecosystems, particularly with respect to:

  (i) the transfer, concentration, and dispersion of such, or its by-products through biological, physical, and chemical processes;

  (ii) potential changes in marine ecosystem diversity, productivity and stability, and;

  (iii) species and community population dynamics;

- the persistence and permanence of the effects of the dumping;
- the effect of dumping particular volumes and concentrations of such materials;
- appropriate locations and methods of disposal or recycling, including land-based alternatives and the probable impact of requiring use of such alternate locations affecting the public interest;

- the effect on alternate uses of oceans, such as scientific study, fishing, and other living resource exploitation and non-living resource exploitation; and

- in designing recommended sites, shall utilize, where feasible locations beyond the edge of the Continental Shelf.

EPA is also authorized to designate recommended ocean dumping sites or times for dumping, and when necessary to protect critical areas, to designate sites or times within which contaminated materials may not be dumped. Sites are designated after considering the nine (9) statutory factors listed above.

EPA's Regulatory Authority

The Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA) regulates ocean dumping activities (Ocean Dumping Program). Any material which would unreasonably degrade or endanger human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities is prohibited from being disposed in the ocean. To implement this purpose and to control ocean dumping in ocean waters, MPRSA specifies and assigns site designation procedures, permitting procedures, monitoring responsibilities, and enforcement responsibilities to four separate federal agencies.

Title I of MPRSA authorizes the EPA Administrator to designate sites where ocean disposal may be prohibited or permitted. This Title also establishes a permitting program and assigns its administration to EPA and the Army Corps of Engineers. The Coast Guard is given the responsibility for conducting surveillance and other appropriate enforcement activities to prevent unlawful ocean dumping and to ensure that the dumping occurs under a valid permit, at the designated location, and in the manner specified in the permit. Title II of MPRSA requires EPA and the National Oceanic and Atmospheric Administration (NOAA) to conduct a comprehensive and continuing program of research and monitoring regarding the effects of ocean disposal. Title III gives NOAA the authority to establish marine sanctuaries.

The Ocean Dumping Ban Act of 1988, which was signed on November 18, 1988, lends additional enforcement power to the administration of the Ocean Dumping Program. It bans all ocean dumping of municipal sludge and industrial waste after 1991. No permit may be issued under MPRSA which authorizes a person to dump into ocean waters, or to transport for the purpose of dumping into ocean waters, sewage sludge or industrial waste, unless that person was authorized by a permit issued under Section 102 of MPRSA or by court order as of September 1, 1988. Thus, no new entities will be permitted to use those particular ocean disposal sites. In addition, within 9 months of enactment (by August 15, 1989) no previous permittee may dump sewage sludge or industrial waste unless such entity has obtained a permit from EPA and entered into an agreement to phase out and terminate ocean dumping.

Existing Ocean Disposal Activities

The nine sludge dumpers currently utilize the DMSDS for the disposal of municipal sludge. In 1987, over 8.4 million wet tons of sludge were ocean dumped, 47% at the 12 Mile Site and 53% at the DMSDS or 106 Mile Site. Beginning in 1988, all sludge has been discharged at the DMSDS. Sludge disposal is currently authorized by Federal court order, not by EPA permit.

The nine sewerage authorities utilize a combination of private waste transporters and municipally owned and operated vessels to dispose of the sludge. New York City owns and operates its own fleet of sludge barges; Westchester County, Nassau County, and the six New Jersey authorities (Passaic Valley Sewerage Commissioners, Middlesex County Utilities Authority, Rahway Valley Sewage Authority, Bergen County Utilities Authority, Linden/Roselle Sewerage Authority, and Joint Meeting of Essex and Union Counties) contract private waste transporters to dispose of their sludge.

Site Designation

As stated previously, the 12 Mile Site had been in use since 1924 for the ocean disposal of municipal sludge. In 1973, EPA designated the site as an "interim" disposal site. On May 18, 1979, EPA designated it as an approved municipal sludge disposal site.

Based on the results of the monitoring on the 12 Mile Site, EPA decided not to redesignate the site when its designation expired in 1981. EPA determined that in order to minimize environmental impacts, a new deepwater site should be designated off the Continental Shelf.

EPA's decision to designate a deepwater site was based upon the results of studies at the interim 106 Mile Site as well as at the 12 Mile Site. Previous monitoring activities at the interim 106 Mile Site indicated that wastes disposed at a deepwater site undergo rapid initial dilution followed by extensive dispersion. Thus, after temporary perturbations, water quality could be expected to return to ambient conditions before reaching any beach, shoreline, or known geographically limited fishery or shellfishery.

On May 4, 1984, EPA designated the DMSDS as an approved municipal sludge dump site. This site was located within the previously interim designated 106 Mile Site. Site designation expires on March 17, 1991.

Permitting

As noted above, the nine municipal sludge dumpers have no current EPA permits to ocean dispose sludge. Since the 1981 court decision discussed under "Historical Perspective", all nine of the sludge dumpers have been operating under court orders. In July 1986 EPA notified the nine sludge dumpers that, in order to continue to utilize the DMSDS, they must submit permit applications consistent with the criteria specified in MPRSA. MPRSA specified that ocean dumping permits may not be issued unless the applicant can demonstrate that there are no alternative land-based disposal methods available that are technically feasible, economically reasonable, and likely to have less adverse impacts on the total environment and human health than ocean disposal. EPA requested that these applications be submitted by January 1987.

EPA received applications from three New York sludge generators in January 1987. The six New Jersey authorities, however, requested an additional six months to submit their applications. In August 1987, one application was submitted on behalf of all six New Jersey dumpers. In November 1987, EPA completed its review of the permit applications and determined that all of the applications were incomplete because they did not contain a current or viable analysis of land-based alternative disposal methods and technologies. EPA sent letters to the applicants informing them that additional information was required in order for the applications to be considered complete. The applicants submitted additional information on incineration, landfilling and/or composting in January 1988. EPA has completed its review of this additional information, but must engage in further negotiations with the applicants to conclude compliance/enforcement agreements to end the ocean dumping of municipal sludge in compliance with the Ocean Dumping Ban Act. These matters must be resolved before EPA can make its final determination regarding permit issuance.

Site Management

EPA has site management responsibilities at all ocean disposal sites. As part of these responsibilities, EPA has developed a monitoring plan for the DMSDS with the objective of assessing actual and potential impacts of sludge disposal on the marine environment, both at the site and in adjacent areas. Data collected is being used to make decisions regarding both the issuance of permits in compliance with the Ocean Dumping Ban Act and the design of future monitoring programs.

Information on baseline conditions at the site, including chemical and physical characteristics, exists from recently completed studies. Between 1984 and 1986, EPA conducted 5 baseline studies at the site. The data that were collected were used to develop an updated monitoring plan and were used as the baseline for comparison of more recently gathered data at the DMSDS.

Since 1986, when sludge dumpers first began utilizing the DMSDS, EPA has conducted semiannual surveys at the site to determine the fate and effect of the sludge being dumped. In addition to field observations of sludge plume behavior, waste characterizations have been performed on sludge samples collected both at the site and at the individual treatment plants.

9.4 Appendix 4. Questions and Answers about Shell Disease

During the Working Group discussions, it became apparent that specific responses to many questions about shell disease could be useful to readers of the report. We have selected some that seem of most concern, and have provided a brief summary of information about each.

- What specific microorganisms are associated with shell disease in New York Bight crustaceans?

Several species of bacteria and fungi have been identified from shell lesions of red crabs taken from deep water canyons (see Section 2.2: Shell Disease in Red Crabs). We are not aware of any other attempts to identify microorganisms from other New York Bight crustacean species. This question needs to be addressed, and is included in our recommendations for further research (Section 6).

- What are the effects of temperature and other variables on molting and shell disease?

The effects of temperature and other variables on chitinoclastic microorganisms, or the size and frequency of shell disease lesions, have not been determined. However, temperature and other environmental factors are related to molting activity and it is during intermolt that the prevalence of shell disease appears to be highest (see Section 2.3).

- What is the effect of molting on shell disease?

Successful molting results in the shedding of gross (visible) signs of shell disease with the discarded old shell. Trawl surveys during molting seasons usually provide data indicating the lowest incidences of shell disease at that time. However, severe shell disease, associated with adhesions of the underlying tissues, may interfere with molting and the successful shedding of the old shell.

- Are any effects of sludge dumping detectable in sediments at the 106 Mile Site and nearby areas as shown by the isolation of microbiological agents (viruses, bacteria, fungi, protozoans, etc.)?

Studies on microbial agents in deepwater sediments at the site should be undertaken. Investigations of this nature are required to provide definitive answers.

- Do microorganisms that cause shell disease differ geographically or by crustacean host species?

Several species of the bacterial genus *Vibrio* have been identified from shell disease lesions of shrimp, crabs, and lobsters and appear to be universally associated with this disease. Other types of bacteria and fungi have been reported from crustaceans but no attempts have been made to determine whether each type of organism can cause disease in more than one species of crustacean. Studies on geographical differences should be done.

- Is there a relationship between contaminants in tissues and shell disease?

There are no data currently available to answer this question.

- Is shell disease a naturally occurring condition or is it related to pollution?

Shell disease is caused by bacteria or fungi as a naturally occurring disease in crustaceans. Laboratory studies have shown, however, that crowding in cages, pens, etc. may increase the severity and prevalence of the disease. Trawl surveys and commercial catches have shown that high prevalences (>15%) occur in polluted or degraded habitats.

- Is there any evidence to support claims by commercial fishermen that there is a recent increase in shell disease, and a decrease in catches?

Whereas there have been no scientific studies or surveys in the past few years that enable the Working Group to confirm or deny these reports from commercial fishermen, there is general agreement among fishermen from Ocean City, Maryland, New Jersey, New York, Connecticut, Massachusetts, and Rhode Island, that shell disease affects the marketability of crabs and lobsters because of unsightly blackened lesions (effects being most noticeable in the last five years). Although the Working Group cannot address increases or decreases in individual catches, available data indicate that the total landings for lobsters have increased during the last decade.

- Are there any human health effects associated with shell disease?

There is no direct evidence for a relationship between shell disease and human health.

- What were some of the concerns expressed by commercial fishermen at the February 1989 Sea Grant Meeting with several members of the Working Group?

Prices are lower when buyers see gross signs of disease; concern for bad publicity associated with reports of "unhealthy" seafood products; increased evidence of shell disease in lobster catches since 1986; and assurance that an objective review of the issues would be reported.

- Is there a relationship between sludge dumping activities at the 106 Mile Site and the occurrence of shell disease in offshore populations?

There is no conclusive evidence for such an association. This question has been addressed in our recommendations for future research (Section 6).

(continued from inside front cover)

55. **A Plan for Study: Response of the Habitat and Biota of the Inner New York Bight to Abatement of Sewage Sludge Dumping.** By Environmental Processes Division, Northeast Fisheries Center. June 1988. iii + 34 p., 5 figs., 3 tables, 4 app. NTIS Access. No. PB89-100903/AS

56. **Characterization of the Middle Atlantic Water Management Unit of the Northeast Regional Action Plan.** By Anthony L. Pacheco, ed. July 1988. v + 322 p., 136 figs., 21 tables. NTIS Access. No. PB89-145262/AS.

57. **An Analysis and Evaluation of Ichthyoplankton Survey Data from the Northeast Continental Shelf Ecosystem.** By Wallace G. Smith, ed. August 1988. xiii + 132 p., 53 figs., 12 tables, 1 app. NTIS Access. No. PB89-122501/AS.

58. **An Indexed Bibliography of Northeast Fisheries Center Publications and Reports for 1987.** By Jon A. Gibson. August 1988. iii + 20 p. NTIS Access. No. PB89-113013/AS.

59. **Surveys of Breeding Penguins and Other Seabirds in the South Shetland Islands, Antarctica, January-February 1987.** By W. David Shuford and Larry B. Spear. September 1988. vii + 27 p., 14 figs., 1 table. NTIS Access. No. PB89-141311/AS.

60. **Survey of Antarctic Fur Seals in the South Shetland Islands, Antarctica, during the 1986-1987 Austral Summer.** By John L. Bengtson, Lisa M. Ferm, Tero J. Harkonen, Everett G. Schaner, and Brent S. Stewart. September 1988. vii + 8 p., 1 fig., 3 tables. NTIS Access. No. PB89-141303/AS.

61. **Fish as Sentinels of Environmental Health.** By Robert A. Murchelano. September 1988. iii + 16 p., 4 figs. NTIS Access. No. PB89-139737/AS.

62. **The Effects of Density Dependent Population Mechanisms on Assessment Advice for the Northwest Atlantic Mackerel Stock.** By W. J. Overholtz, S.A. Murawski, W.L. Michaels, and L.M. Dery. October 1988. v + 49 p., 7 figs., 20 tables. NTIS Access. No. PB89-151948/AS.

63. **Status of the Fishery Resources Off the Northeastern United States for 1988.** By Conservation and Utilization Division. October 1988. iii + 135 p., 51 figs., 52 tables. NTIS Access. No. PB89-130819/AS.

64. **The Shell Disease Syndrome in Marine Crustaceans.** By Carl J. Sindermann. February 1989. v + 43 p., 5 figs., 2 tables. NTIS Access. No. PB89-162523/AS.

65. **Stock Assessment Information for Pollock, *Pollachius virens* (L.), in the Scotian Shelf, Georges Bank, and Gulf of Maine Regions.** By Ralph K. Mayo, Stephen H. Clark, and M. Christina Annand. April 1989. vi + 14 p., 6 figs., 14 tables. NTIS Access. No. PB90-120676/AS.

66. **Guidelines for Estimating Lengths at Age for 18 Northwest Atlantic Finfish and Shellfish Species.** By Judith A. Pentilla, Gary A. Nelson, and John M. Burnett, III. May 1989. iii + 39 p., 18 figs., 19 tables.

67. **Response of the Habitat and Biota of the Inner New York Bight to Abatement of Sewage Sludge Dumping. Second Annual Progress Report -- 1988.** By Environmental Processes Division, Northeast Fisheries Center. July 1989. vii + 47 p., 39 figs., 11 tables, 3 app.

68. **MARMAP Surveys of the Continental Shelf from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia (1984-87). Atlas No. 3. Summary of Operations.** By John D. Sibunka and Myron J. Silverman. July 1989. iv + 197 p., 36 figs., 2 tables. NTIS Access. No. PB90-125444/AS.

69. **The 1988 Experimental Whiting Fishery: A NMFS/Industry Cooperative Program.** By Frank P. Almeida, Thurston S. Burns, and Sukwoo Chang. August 1989. v + 16 p., 9 figs., 11 tables, 1 app.

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PUBLICATIONS AND REPORTS OF THE NORTHEAST FISHERIES CENTER

NOAA's National Marine Fisheries Service (NMFS) seeks to "achieve a continued optimum utilization of living resources for the benefit of the Nation." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Center (NEFC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: (1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and (2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." To provide its data, information, and advice to constituents, the NEFC issues publications and reports in three categories:

Technical Memorandums--Issued irregularly as *NOAA Technical Memorandum NMFS-F/NEC* series. Series includes data reports of long-term or large area studies; synthesis reports for major resources or habitats; annual reports of assessment or monitoring programs; documentary reports of oceanographic conditions or phenomena; manuals describing field and lab techniques; literature surveys of major resource or habitat topics; findings of task forces or working groups; and summary reports of scientific or technical workshops. Issues do not undergo exhaustive technical review and editing, but are reliable sources of information. Limited free copies are available from authors or the Center. Issues are also available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA, 22161.

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