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NEW BEDFORD HARBOR ENDANGERMENT ASSESSMENT

TASK 2.5

EXPOSED SPECIES ANALYSIS

DRAFT LETTER REPORT

Prepared for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Waste Programs Enforcement
Washington, D.C. 20460

Work Assignment No.	:	560
EPA Region	:	1(C)
Site No.	:	TGB811443
Date Prepared	:	December 12, 1986
Contract No.	:	68-01-7037
PRC No.	:	15-5600-78
Prepared By	:	Alliance Technologies Corporation
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IN ANTICIPATION OF LITIGATION

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December 12, 1986

Mr. Frank Ciavettieri
U.S. EPA Region 1
JFK Federal Building
Boston, MA 02203

Dear Mr. Ciavettieri:

PRC Environmental Management, Inc. and its subcontractor, Alliance Technologies Corporation (formerly GCA Corporation, Technology Divisions) are pleased to submit two reports entitled, "New Bedford Harbor Endangerment Assessment, Task 2.5 - Exposed Species Analysis - Draft Letter Report" and "New Bedford Harbor Endangerment, Task 2.6 - Ecotoxicity Assessment - Draft Letter Report", for work assignment no. 560. Please accept my apology for the delayed submittal of these deliverables.

Should you have any questions or wish to discuss these reports or the work assignment in general with me directly, please feel free to do so.

Thank you for your assistance and cooperation.

Sincerely,
PRC Environmental Management, Inc.

Eric S. Morton
Public Health Scientist

cc: Nancy Deck
Bruce Bakaysa (letter only)
Barb Myatt, Alliance Technologies Coprporation

DOCUMENT FORMAT

Although this document is being submitted as a Letter Report, it constitutes part of an Endangerment Assessment and as such, follows a format whereby it can be incorporated into the Endangerment Assessment.

CONTENTS

FIGURES

TABLES

Exposed Species Analysis

The species present in the New Bedford Harbor area represent numerous exposed populations which need characterization as to their abundance, spatial distribution, behavior patterns, size/age distributions, habitat and food requirements, health or status, and bioconcentration/accumulation factors to fully assess the impacts of exposure to PCBs on these organisms. To fully characterize exposure and the population parameters of the hundreds of species which have been identified within the bounds of the New Bedford Harbor study area is not feasible. This section will identify a subset of the species (based on site-specific presence or absence data). A more complete list of species known to occur in New Bedford Harbor can be found in the GCA Endangerment Assessment Work Plan, (GCA 1986a). Macrobenthic and planktonic communities will not be dicussed until more recent data, currently being generated by the Massachusetts Corps of Engineers becomes available. This report focuses on selected finfish, crustaceans and mollusks, characterizing their exposure within the bounds of the site study area (see Appendix A), so that a reasonable picture of the ecosystem can be constructed and organisms can be classified into exposure scenario groups. The following exposure routes will be discussed as part of the biological characterization process:

- Water column,
- Sediments, and
- Food webs.

Although many marine organisms at New Bedford Harbor are being exposed to PCBs via some or all of these exposure routes, organisms were placed in the exposure categories that best reflect their life history characteristics. The organisms used to represent these categories were picked based on their documented existence in New Bedford Harbor and their biological interaction with organisms within the other exposure route categories. Also considered was the availability of useful ecotoxicity data, which exist for a limited number of species present in New Bedford Habor, and the importance of emphasizing the most recent site-specific ecotoxicity data. These selected organisms will serve as examples and representatives of the hundreds of other taxa in the vicinity of New Bedford Harbor, and as such will be discussed in detail.

The following areas of importance in characterizing species exposure to PCBs will be addressed. The range and distribution will be discussed with specific reference to the zones of New Bedford Harbor where each species is known to occur. These data are supplemented by identifying the extent to which the organisms are likely to occur in the zones of New Bedford Harbor based on their tolerance of physical parameters such as salinity, water temperature and depth. Table 1 lists data for these three physical parameters and Figures 1, 2, and 3 map these parameters. Population characteristics of the organism show the sensitivity of each species to exposure based on fecundity, survival rates, and frequency of spawning. The reproduction of each species will be discussed to reflect exposure at spawning grounds and provide information on the factors influencing initiation and duration of spawning. The eggs, larvae and juveniles of each species will be discussed to provide information as to the route(s) of exposure, distribution within the New Bedford Harbor estuary, duration of exposure at each life stage, and expected growth rate. The feeding, predation and disease section will describe the prey and predators of each species in order to characterize exposure via the food chain and the extent to which bioaccumulation is possible. Any disease common to the organism will be discussed and the effect of exposure to PCBs addressed if applicable. Finally, the utilization section will present information on landings of each species in New Bedford Harbor, the commercial importance of the catch, and the implications to public health.

A species profile table for selected additional organisms known to exist in New Bedford Harbor will be provided for each exposure category. This table will provide the reader with a list of organisms and their life history characteristics in relation to New Bedford Harbor. These analyses will develop a characterization of the different organisms at New Bedford Harbor and their interactions within the harbor relative to PCB exposure.

Water Column--

The marine environment can be divided into the open water region (pelagic) and sea-floor (benthic). The larger swimming fish of the open ocean waters are referred to as pelagic (low tide to 200 m depth). Many of the fish

TABLE 1. PHYSICAL CHARACTERISTICS OF NEW BEDFORD HARBOR AND BUZZARDS BAY, ZONES 1 THROUGH 5

Location	Date	Salinity (0/00)	Temperature (°C)	Sample depth (m)	Water depth (m)
Zone 1[a]	11/25/75	23.20	19.5	Surface	2-6
Lat. 41° 39.35'		28.30	12.6	6	2-6
Long. 70° 55.10'		22.00	-	Surface	2-6
		29.10	5.5	4.5	2-6
	3/16/76	25.50	2.5	Surface	2-6
		29.00	5.0	2.9	2-6
Zone 2[a]	9/19/75	32.50	18.5	Surface	7-9
Lat. 41° 38.29'	11/24/75	29.00	10.0	Surface	7-9
Long. 70° 55.09'	1/6/76	23.20	0.5	Surface	7-9
	3/10/76	27.80	2.5	Surface	7-9
		28.75	2.5	5	7-9
	4/27/76	30.60	10.6	Surface	7-9
		30.60	10.0	5	7-9
		29.90	9.9	8.5	7-9
Zone 3[a]	9/19/75	31.50	18.5	Surface	7-9
Lat. 41° 37.65'	11/24/75	28.00	9.7	Surface	7-9
Long. 70° 54.50'	1/5/76	30.05	1.0	Surface	7-9
	3/10/76	26.00	2.7	Surface	7-9
		28.00	2.5	5	7-9
	4/27/76	28.60	10.5	Surface	7-9
		29.90	10.5	5	7-9
		30.10	9.6	8.5	7-9
Zone 4[a]	3/10/76	27.75	2.5	Surface	8-9
Lat. 41° 37.30'		28.40	2.5	5	8-9
Long. 70° 54.28'	4/27/76	28.60	10.1	Surface	8-9
		30.10	10.0	5	8-9
		30.50	9.5	9	8-9
	7/6/76	30.90	22.75	9	8-9

(continued)

TABLE 1. (continued)

Location	Date	Salinity (0/00)	Temperature (°C)	Sample depth (m)	Water depth (m)
Zone 5[b]	7/29/82	30.89	22.4	1	9-11
Lat. 41° 36.8'		30.96	22.0	2	9-11
Long. 70° 53.8'		30.98	22.0	3	9-11
		31.03	21.7	4	9-11
	10/28/82	31.48	12.3	1	9-11
		31.35	12.3	2	9-11
		31.33	12.3	3	9-11
		31.49	12.0	4	9-11
		31.60	11.8	5	9-11
	1/13/83	31.37	4.4	1	9-11
		31.35	4.4	2	9-11
		31.35	4.4	3	9-11
		31.37	4.5	4	9-11
		31.36	4.7	5	9-11
	5/5/83	29.60	12.2	1	9-11
		29.59	12.2	2	9-11
		29.67	12.2	3	9-11
		30.05	11.9	4	9-11
		30.50	11.4	5	9-11

[a]Data file: New Bedford Harber, Massachusetts. Jeffrey P. Ellis, et al. December 1977, WHOI-77-73.

[b]Hydrographic Study of Buzzards Bay, 1982-1983. Leslie K. Rosenfeld, et al., WHOI-84-5.

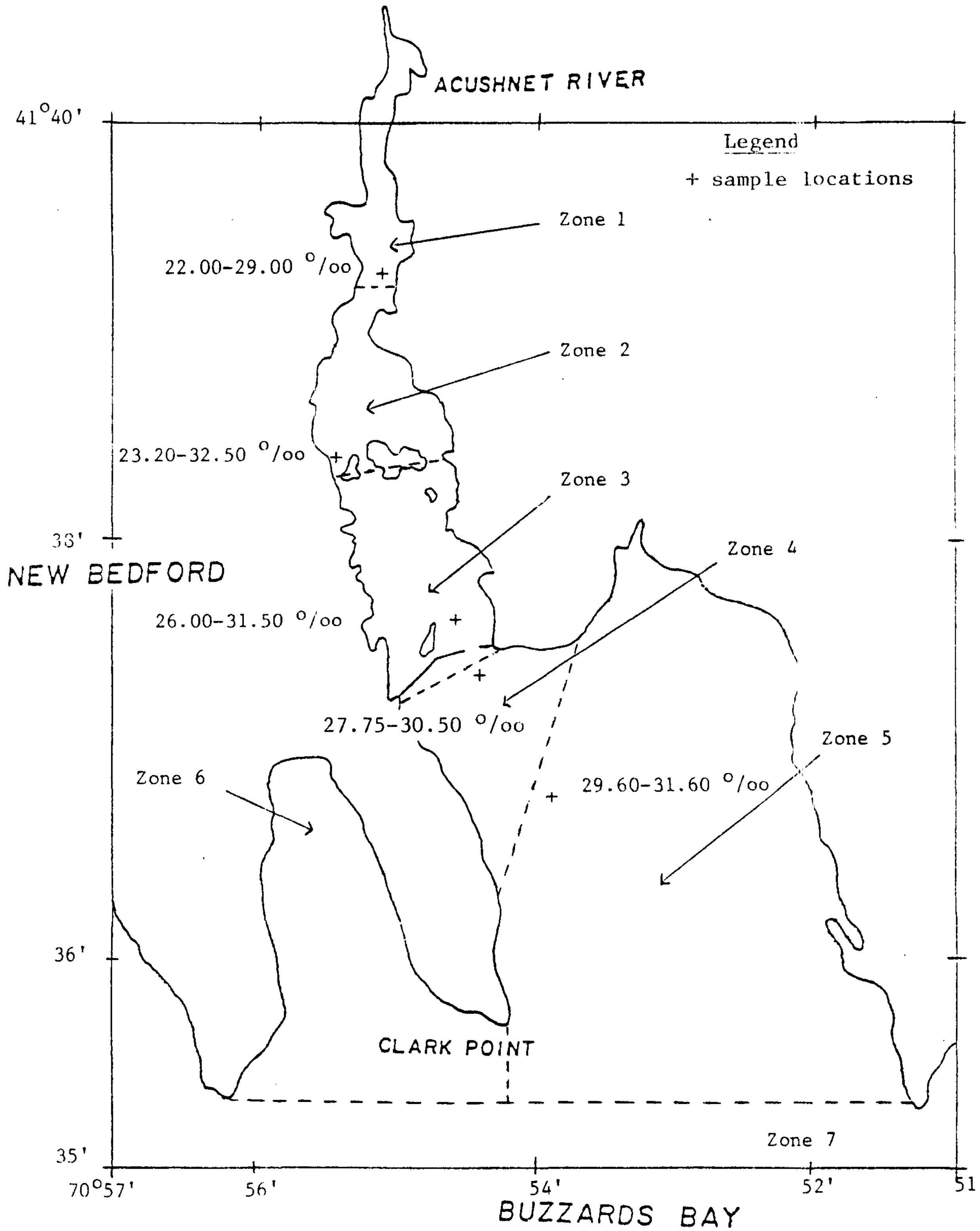


Figure 1. Salinities for New Bedford Harbor, zones 1-5.

Source: Refer to Table 1 .

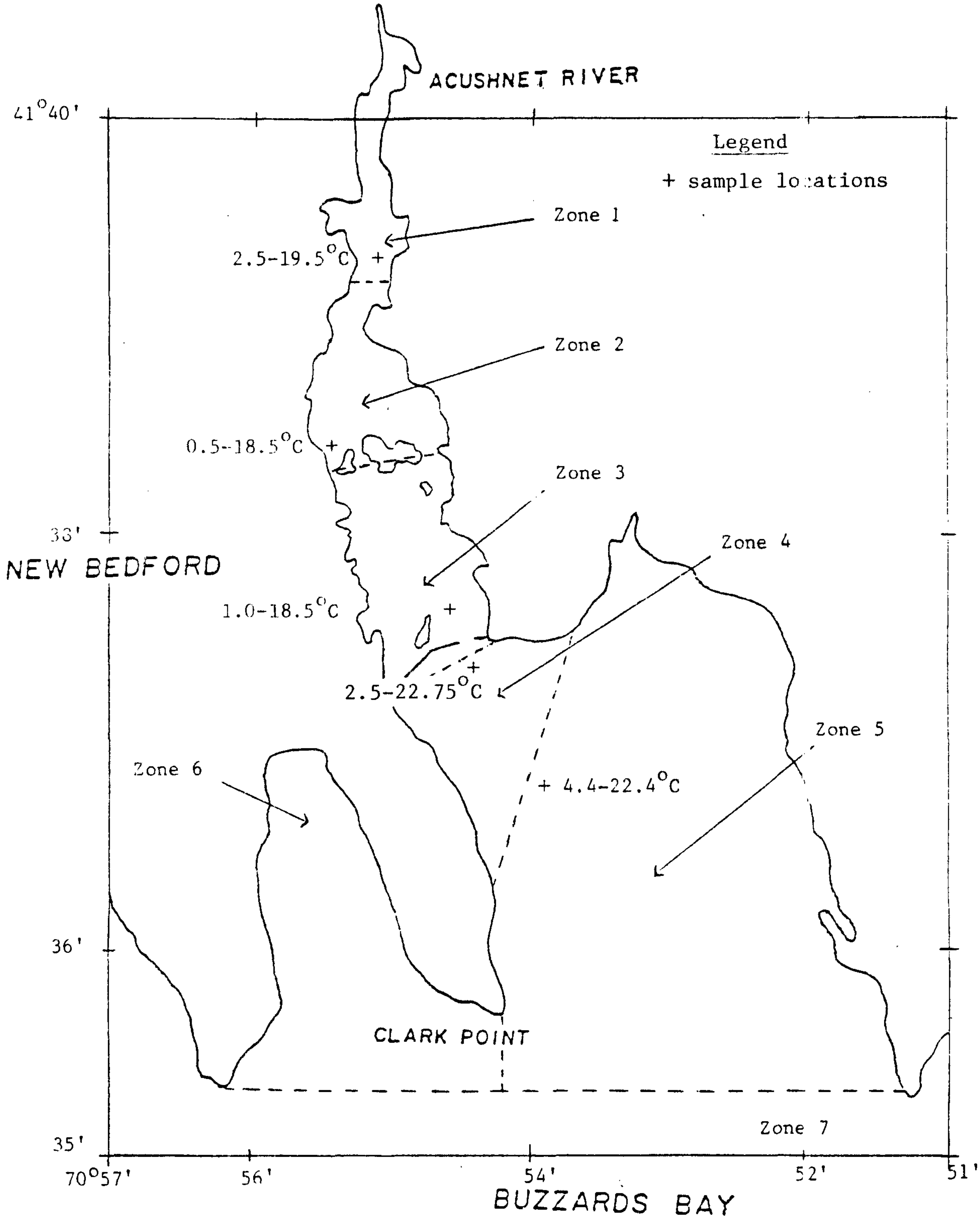


Figure 2. Temperature range in New Bedford Harbor, zones 1-5.

Source: Refer to Table 1 .

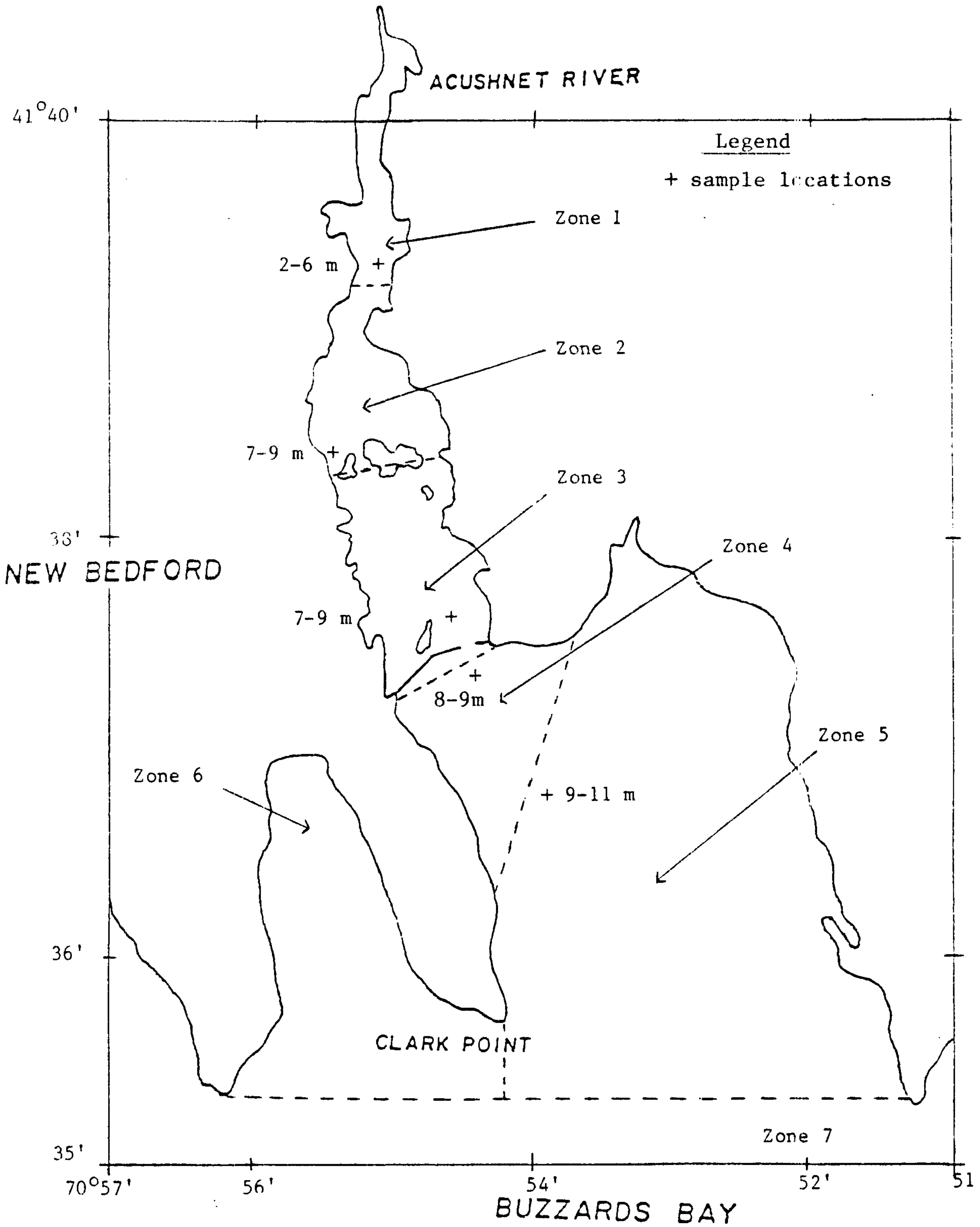
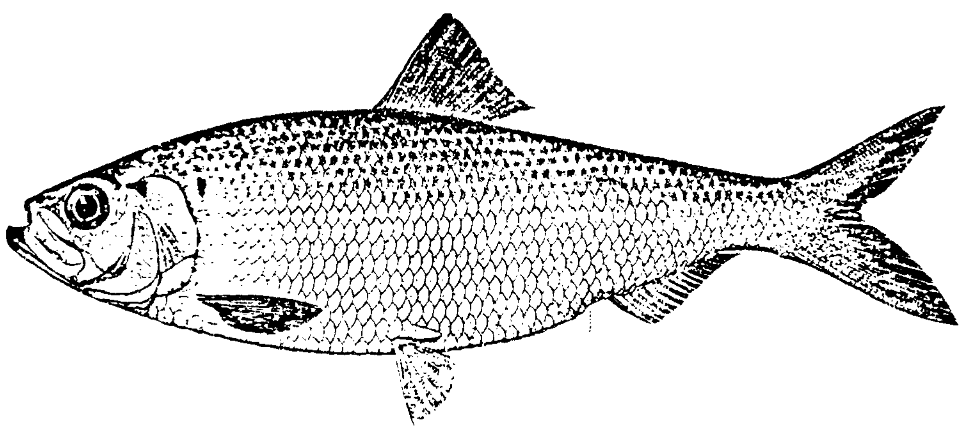


Figure 3. Water depth in New Bedford Harbor, zones 1-5.

Source: Refer to Table 1.

associated with New Bedford Harbor swim between the surface and deeper water and contribute organic matter by egestion, excretion, and death. The following fish from New Bedford Harbor are representative of this pelagic life style: striped bass (Morone saxàtalis), bluefish (Pomatomus saltatrix), blueback herring (Alosa aestivalis), alewife (Alosa pseudoharengus), Atlantic menhaden (Brevoortia tyrannus), and the Atlantic mackerel (Scomber scombrus) (Table 2. is a partial list of pelagic fishes known to inhabit New Bedford Harbor). The uptake and retention of PCBs by these fishes is directly from the water column via such tissues as the gills or epithelial tissues. However, the voracious appetite of these fish can also enhance exposure via the food web. Below is a concise description of these fish and how their life history characteristics reflect potential PCB exposure in New Bedford Harbor.

Alewife (Alosa pseudoharengus)--



Range and distribution--The alewife, Alosa pseudoharengus, is an anadromous fish of eastern North America found from Nova Scotia to South Carolina (Clayton, 1976). Historically, New Bedford Harbor (zones 1 through 8) has been inhabited by this fish (Bourque, 1986). However, anadromous alewife populations have declined sharply. Since colonial times the destruction of spawning areas, the installation of dams, and increased levels of stream pollutants have often been blamed for this decline (Clayton, 1976). Today, alewife runs still occur in a number of places in Massachusetts where coastal stream conditions are suitable, and a small local population is thought to exist in New Bedford Harbor (Bourque, 1986).

TABLE 2. SPECIES PROFILE FOR NEW BEDFORD HARBOR PELAGIC ORGANISMS

Genus and species	Common name	Abundance[a]	Distribution (zones)	Behavior[b]	Age	Habitat & food	Health[a]	[BCF][c]
Alosa pseudoharengus	Alewife	L	1 - 8	Anadromous	Juveniles/Adults	Planktivore	P	270,000
Brevoortia tyrannus	Atlantic Menhaden	L	1 - 8	Anadromous	Juveniles/Adults	Plantivore	P	270,000
Clupea harengus	Atlantic Herring	L	1 - 8	Anadromous	Juveniles/Adults	Plantivore	P	270,000
Osmerus mordax	Rainbow Smelt	L	-	Predatory	Juveniles/Adults	Carnivore	P	48,000
Gadus morhua	Atlantic Cod	L	-	Predatory	-	Carnivore	P	-
Molanogrammus aeglefinus	Haddock	L	-	Predatory	-	Carnivore	P	-
Merluccius bilinearis	Silver Hake	L	5	Predatory	Adults	Carnivore	P	-
Microgadus tomcod	Atlantic Tomcod	L	-	Predatory	-	Carnivore	P	-
Pollachius virens	Pollock	L	-	Predatory	-	Carnivore	P	-
Urophycis chuss	Red Hake	L	3,5,7 and 8	Predatory	Adults	Carnivore	P	-
Morone americana	White Perch	L	3,5 and 8	Predatory	Juveniles/adults	Carnivore	P	-
Morone saxatilis	Striped Bass	M	2 - 8	Predatory	Adults	Carnivore	F	-
Scomber scombrus	Atlantic Mackerel	L	-	Predatory	Adults	Carnivore	P	-
Pomatomus saltatrix	Bluefish	M to H	2 - 8	Predatory	Juveniles/adults	Carnivore	G	-
Alosa aestivalis	Blueback Herring	L to M	1 - 8	Anadramous	Juveniles/adults	Planktivore	F	270,000

P = Poor L = Low
F = Fair M = Moderate
G = Good H = High
E = Excellent

[a]This is a qualitative indicie based on site-specific data.
[b]Characteristics of particular significance in exposure assessment.
[c]EPA Ambient Water Quality Criteria for PCBs (EPA-440/5-80-068).

Source: Bourque, 1986; Clayton, 1976; and GCA, 1986a.

Population characteristics--In the northern part of their range, alewives may return to natal streams as many as three to five times to spawn, whereas in the southern range they spawn only once. Recruitment as adults may occur as early as age 2 in the south and as late as age 5 in the north. Alewives spawning in the Parker River-Plum Island Sound Estuary in Massachusetts mature at ages 3, 4, and 5 with full recruitment at age 6 (Clayton, 1976). The Parker River Estuary has similar physical and biological characteristics to the Acushnet River Estuary (see Table 3.). Therefore, predictions on the fisheries of the Acushnet River Estuary can be inferred on the basis of these similarities. Males dominate first-time spawning at age 3 but decline in overall percentage at 4 and 5. There appears to be a higher mortality rate among those that spawned at an early age resulting in older age groups being dominated by alewives that matured at age 4 or 5 (Clayton, 1976).

Reproduction--Spawning migrations begin during early March in the Southern part of the range and late April to early May in New Bedford Harbor (Bourque, 1986). Adult fish migrate from the ocean to the New Bedford Harbor estuary and finally to freshwater to spawn. Water temperature is the dominant environmental factor influencing the rate of alewife migration. When water temperatures are below 11°C, migration does not occur into freshwater (see Table 1.). Above this threshold, alewives respond to warming or cooling trends by a corresponding increase or decrease in movement. Daily movement of adults in the freshwater portion of the migration may be characterized by unimodal or bimodal peaks. Movement may occur during day or night. In the Parker River most fish move in the late afternoon; no nighttime activity has been observed. In other studies in Massachusetts and Rhode Island nighttime migration has been documented. Spawning occurs in freshwater ponds at all times of the day, with no discernable periods of increased or decreased intensity. By late June most adults have migrated downstream and returned to sea. In the Parker River, emigration occurs at all hours from sunrise to sunset, but no movement has been observed at night (Clayton, 1976).

Eggs, larvae, juveniles--Eggs of the alewife are broadcast randomly at the spawning site. They are demersal and are somewhat adhesive to vegetation and the substrate. The diameter of the egg increases from 0.9 mm

TABLE 3. PHYSICAL CHARACTERISTICS OF PARKER RIVER - PLUM ISLAND SOUND ESTUARY

Date	Time	Tidal stage	Temperature (°F) Water	Temperature (°F) Air	Salinity (parts per thousand)	pH	Dissolved oxygen (ppm)	Carbon dioxide (ppm)	Detergent (ppm)	Transparency (feet)
January 26	10:15 a.m.	High +4(hrs)	30	34	31.5	8.0	10.0	10.0	0.2	--
February 9	2:00 p.m.	Low +3-1/2	30	35	28.0	8.0	10.0+	10.0	0.2	--
March 25	10:50 a.m.	Low	40	58	24.0	8.0	10.0	10.0	0.1	15+
April 28	1:45 p.m.	High +5	52	58	25.0	8.0	10.0+	5.0	0.1	15+
May 21	2:00 p.m.	Low +4	66	64	24.0	8.0	10.0	10.0	0.1	15+
June 14	12:30 p.m.	High +1	62	52	29.0	8.0	10.0+	10.0	0.1	10
July 12	1:15 p.m.	High +3	69	72	31.0	8.0	10.0+	5.0	0.1	15+
August 25	9:00 a.m.	High	66	78	30.0	8.0	10.0+	10.0	0.1	--
September 24	7:35 a.m.	Low +4	70	74	28.0	7.5	10.0	5.0	0.1	--
October 15	12:40 p.m.	Low +3-1/2	56	63	30.0	8.0	10.0+	5.0	0.1	10
November 16	3:00 p.m.	Low +4	46	50	31.0	8.0	10.0+	5.0	0.2	15+
December 16	3:25 p.m.	Low +4	38	40	29.0	8.0	10.0+	5.0	0.2	--

Source: Division of Marine Fisheries, Massachusetts. William C. Jerome, Jr., Arthur P. Chesmore, and Charles O. Anderson, Jr. A Study of the Marine Resources of the Parker River -Plum Island Sound Estuary. March 1968.

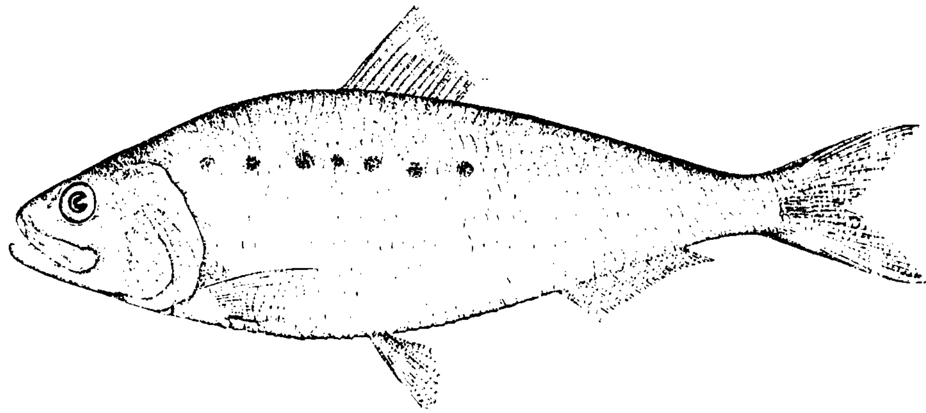
(unfertilized) to 0.94 - 1.25 mm after fertilization and water hardening. Hatching time depends on temperature; it occurs in 6 days at 15.6°C and in 3 days at 22.2°C. Optimum hatching (38 percent) occurs at an incubation temperature of 17.8°C (Figure 2.). The larvae are 3.5 to 5.0 mm long at hatching, and are transparent. They remain near the spawning grounds until the late larval stage and then move into deeper water (Clayton, 1976). Young anadromous alewives spend most of their first summer in freshwater ponds where they feed on zooplankton and dipteran larvae (Clayton, 1976). Seaward migration of juveniles into the New Bedford Harbor estuary may begin as early as July and is completed during the fall. The size of migrating juveniles is usually from 55 to 75 mm (fork length), with a mode of 65 mm. Overwintering of juveniles in the ponds has not been observed. Little is known about juveniles after they leave freshwater. They may, however, spend the remaining portion of their first year in the New Bedford Harbor estuary, thus being subjected to PCB exposure and then migrate to sea after their first year (Clayton, 1976). This seaward migration may account for bioconcentration and biomagnitication of PCBs in New Bedford Harbor.

Feeding, predation, diseases--Alewives in New Bedford Harbor feed on zooplankton as larvae, juveniles, and adults. A high degree of food selectivity has been observed. Copepods, cladocerans, and insect larvae are important items in the diet of all freshwater stages of alewives. Alewives are an important forage species. In freshwater, young alewives are preyed upon by largemouth bass, yellow perch, white perch, walleyes, and other piscivores. In the estuaries fish such as bluefish and striped bass are important predators (Clayton, 1976). The tolerance of low salinities and the feeding habits of the alewife result in the potential for high exposure to PCBs in New Bedford Harbor.

Utilization--

New Bedford Harbor has not been a significant port for landings of alewife. In 1984, only 125 lbs were landed (NMFS, 1986).

Atlantic Menhaden (*Brevoortia tyrannus*)--



Range and distribution--The Atlantic menhaden, *Brevoortia tyrannus*, is found from Nova Scotia to Palm Beach, Florida (Clayton, 1976). Menhaden are euryhaline, and can occur in estuarine waters at all life stages. In Massachusetts, menhaden have been recorded at a maximum water temperature of 25.7°C and a salinity as low as 29.7 parts per thousand (Figures 1.and 2.). In New Bedford Harbor, they are found in zones 1 through 8 (Bourque, 1986). Tagging studies off the eastern coast indicate that adults migrate northward during the spring and early summer and southward in the fall (Clayton, 1976). It is therefore possible that individuals exposed to PCBs in New Bedford Harbor may be caught in areas outside the immediate vicinity of the Harbor.

Population characteristics--Some menhaden are sexually mature by their first year, but most by age 2 or 3. Fecundity estimates range from 38,000 to 630,000 for females 203 to 345 mm in fork length. It has been suggested that ova mature continually and are released periodically. The sex ratio at each age remains nearly equal on both an annual and geographical basis. The adult menhaden are mostly 305 to 381 mm long and weigh 300 to 500 g (Clayton, 1976).

Reproduction--Menhaden are believed to spawn in coastal oceanic waters and the larvae enter estuaries and bays where they metamorphose. However, there is evidence that spawning occurs in large bays, like Buzzards Bay. Eggs can be found from mid to late April through June. Estimated larval mortality is 8 to 15 percent daily or 71 to 91 percent mortality over the first 15 days

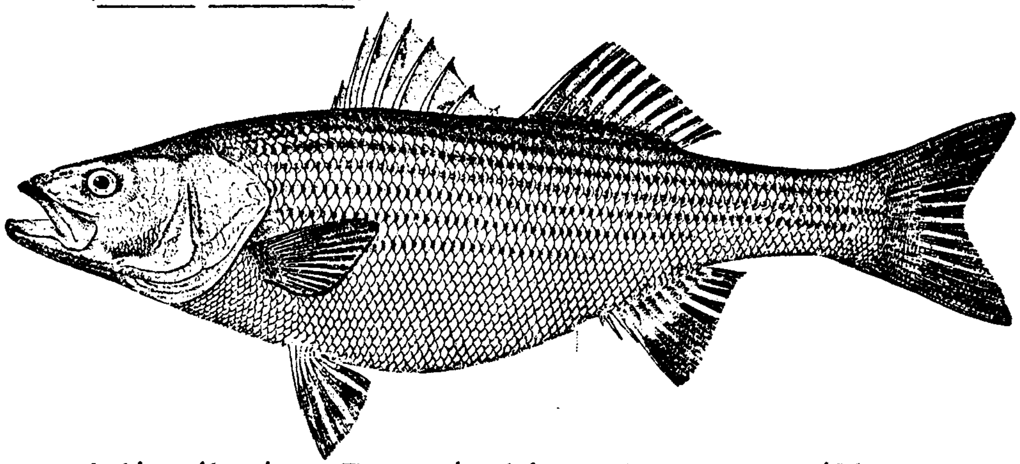
(Clayton, 1976). New Bedford Harbor is a potential spawning ground for this species, resulting in PCB exposure for eggs, larvae and adults, which have been observed in zone 3 (Govoni, 1973).

Eggs, larvae, juveniles-- The eggs of menhaden are pelagic and about 1.5 to 2.0 mm in diameter. Incubation is rapid and larvae are about 4.5 mm long at hatching. The larvae mature into juveniles in the estuaries having made the in shore migration in late winter and early spring. Juveniles will remain in the estuaries for 6 to 8 months before they return to the sea in September and October (Clayton, 1976). Some juveniles will overwinter in the larger estuaries, like New Bedford Harbor. Significant exposure to PCBs is also possible during this period.

Feeding, predation, diseases--Larvae tend to feed exclusively on copepods, during daylight and early evening. Juveniles shift from an invertebrate diet to diatoms and plant fragments. Filter-feeding begins as the gill rakers become more highly developed and schools of menhaden can exhaust local standing crops of plankton. No other estuarine species eats both zooplankton and phytoplankton during early life in this fashion. The adult menhaden is a voracious feeder and may deplete food sources in upper estuarine areas rapidly. The menhaden is potentially exposed to PCBs in New Bedford Harbor via epithilial tissue and gill contact with contaminated water as well as through the food web.

Utilization--The menhaden is an important commercial resource; U.S. landings in 1975 were 275,000 metric tons. However, New England landings are small and New Bedford Harbor has no records for landings of this species.

Striped Bass (Morone saxatilis)--



Range and distribution--The striped bass, Morone saxatilis, occurs from the St. Lawrence River to the St. John's River in northern Florida to Louisiana (Clayton, 1976). The majority extend from Cape Cod to Cape Hatteras. Except during migrations, adults are located strictly near shore in salt, brackish, and freshwater environments like New Bedford Harbor. In Massachusetts waters striped bass are summer transients, regularly appearing in estuarine and nearby coastal waters in temperatures from 14.0 to 18.0°C and in salinities as low 25.3 parts per thousand (Figures 1. and 2.). Many of these fish are believed to be produced in Chesapeake Bay and regularly migrate northward along the coast. In New Bedford Harbor the striped bass has been found in zones 2 through 8 in low abundance (Bourque, 1986). From November to October a reverse migration occurs, as the bass leave Massachusetts and move to their overwintering grounds. These sites are generally in Delaware and Chesapeake Bays, although some fish overwinter further north off the New Jersey coast and possibly in the Hudson River. Occasionally striped bass overwinter in rivers of southern New England, including Massachusetts (Clayton, 1986).

Population characteristics--Striped bass caught in Massachusetts waters have ranged up to 20 years of age and 127 cm in length. Striped bass live more than 40 years and reach a weight of over 54.4 kg, but specimens heavier than 34 kg are rare. Some female striped bass are sexually mature at age 4, and essentially all are mature by age 6. Males tend to mature earlier than females; most males are sexually mature by age 2 and virtually all by age 3. Fecundity varies with the size of the female: about 14,000 eggs are produced by a 1.4 kg fish, 250,000 by a 2.2 kg fish, and about 5 million by a 22.7 kg fish. Today, as in the past, stocks of striped bass in Massachusetts waters and the Gulf of Maine fluctuate in abundance periodically. The factors controlling this phenomenon are not yet well understood.

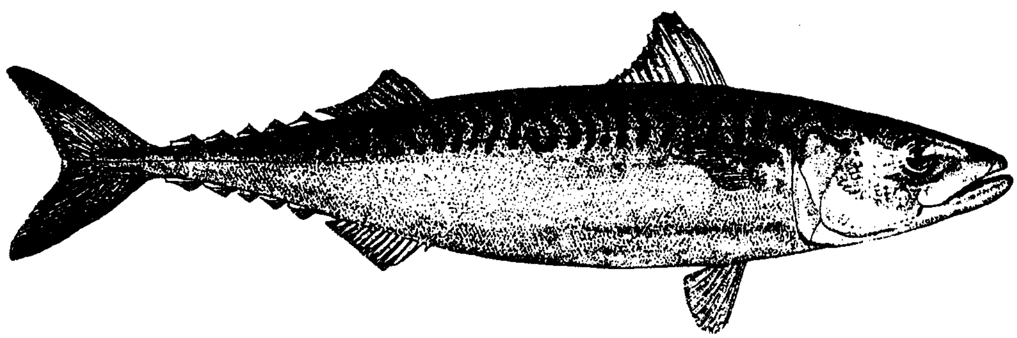
Reproduction--Evidence of spawning has not been reported in Massachusetts in recent years. Striped bass are anadromous and spawn during April through June, depending on the water temperature. Spawning may occur between 12 and 23°C although most eggs are laid at 18°C (see Figure 2.). Spawning fish require rapidly flowing, turbulent waters usually near the saltwater-fresh water interface of an estuary. In New Bedford Harbor the hurricane barrier and PCBs may inhibit this species reaching suitable spawning grounds in zones 1 and 2.

Eggs, larvae, juveniles--The eggs of striped bass are nonadhesive, becoming pelagic in fast flowing water but semi-demersal in quiet water. The pelagic and semi-demersal characteristics of striped bass eggs can subject them to PCB exposure by both surface water contact and direct contact with contaminated sediments. Developing eggs may remain in their natal river due to tidal fluctuations or be swept into brackish water before hatching. Eggs hatch in 30 hours at 21-22°C, 48 hours at 18°C, and 70 to 74 hours at 14 to 16°C. The young usually remain in their natal estuarine system until they are about 2 years old, whereupon they begin their migration (Clayton, 1976).

Feeding and predation--The striped bass is a voracious feeder, consuming both fish and invertebrates in the shore zone and estuaries. In the Gulf of Maine there are reports that they prey primarily on herring, rainbow smelt, sandlance, eels, silver hake, squid, crabs, lobsters, and sea worms all found in New Bedford Harbor. In estuarine waters they may often be associated with mussel beds that produce large numbers of polychaetes. Feeding often occurs in schools during darkness, the period of maximum activity for seaworms. Juveniles feed more extensively on amphipods, shrimp, and small crabs (Clayton, 1976).

Utilization--The striped bass is a recreational species in Massachusetts, and is distributed along most of the Massachusetts coastline. In 1972 Massachusetts commercial landings totaled well over 500 MT; most were caught by hook-and-line (Clayton, 1976). However, the abundance of this species has dropped considerably in Massachusetts waters. Landing statistics for New Bedford Harbor indicate that only 5,800 lbs were brought ashore in 1985 (NMFS, 1986), reflecting in part the recently imposed fishing regulations implemented to protect this species, as well as its increasing scarcity.

Atlantic Mackerel (Scomber scombrus)--



Range and distribution--The Atlantic mackerel, Scomber scombrus, occurs on the continental shelf on both sides of the Atlantic; in the west it is found from southern Labrador south to Cape Hatteras (Clayton, 1976). The fish winter offshore along the edge of the continental shelf and move shoreward during the spring. Mackerel entering the Gulf of Maine are usually plentiful in the western gulf by early June. Normally, mackerel have left the Gulf of Maine by late September, but they may be replaced by fish moving southward from the Gulf of St. Lawrence. In New Bedford Harbor they have been found in zone 5 only (Clayton, 1976).

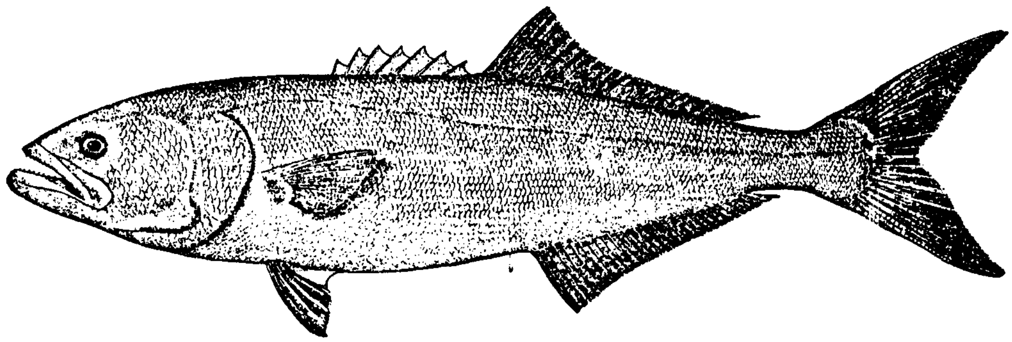
Reproduction--It has been concluded that two major spawning areas exist: one off New Jersey to Long Island and another in the Gulf of St. Lawrence. Mackerel spawn from May to early July off Canada and as early as April off Virginia; the most important spawning area extends from the Chesapeake Capes to Massachusetts Bay and the second area is in the Gulf of St. Lawrence. Most mackerel mature at age 2 and spawn by day or night probably near the surface. Fecundity ranges from 546,000 to 1,000,000 (Clayton, 1976).

Eggs, larvae, juveniles--The pelagic eggs of the mackerel are 1.01 to 1.28 mm in diameter. Hatching occurs 90 to 102 hours after fertilization at an average incubation temperature of 13.8°C. Eggs are most commonly taken at sea temperatures from 9 to 13°C and are most common in the upper 15 to 25 m of the water column. The larvae are 3 mm long at hatching and grow to 10 mm in about 26 days and to 50 mm in another 40 days, at which time they become juveniles and begin to school (Clayton, 1976).

Feeding, predation, diseases--Young mackerel eat the larvae of small crustaceans, especially copepods, and fish. Although reproduction occurs in the outer zones (5 through 8), young as well as adult mackerel move into the inner harbor of New Bedford where they can take advantage of the abundance of prey items. Therefore, while not spending extended periods of time in contact with contaminated surface water, they are subject to biomagnification of PCBs through the food web. Their major predators are sharks, bluefish and striped bass; cod eat juvenile mackerel as do squid. There are many parasites but none are known to have a noticeable effect on population size (Clayton, 1976).

Utilization--The fishery has been a highly variable one due to fluctuations in year-class strength. New Bedford Harbor landing statistics indicate that only 13,000 lbs were handled in 1984 and that this species was not landed at all in 1985 (NMFS, 1986).

Bluefish (Pomatomus saltatrix)--



Range and distribution--The bluefish, Pomatomus saltatrix, is a coastal species distributed from Cape Cod to South America. Schools of bluefish migrate northward in spring and summer. Adults and juveniles regularly appear in New Bedford Harbor in zones 1 through 8 (Bourque, 1986). When water temperatures decline to 12-15°C adults move offshore to wintering grounds, and juveniles move south along the coast (Clayton, 1976).

Population characteristics--The maximum length attained by bluefish is approximately 110 cm. They are sexually mature by their second year. Fecundity is 900,000 mature eggs for a 52.8 cm specimen, and 1.1 million for a 58.4 cm fish (Clayton, 1976).

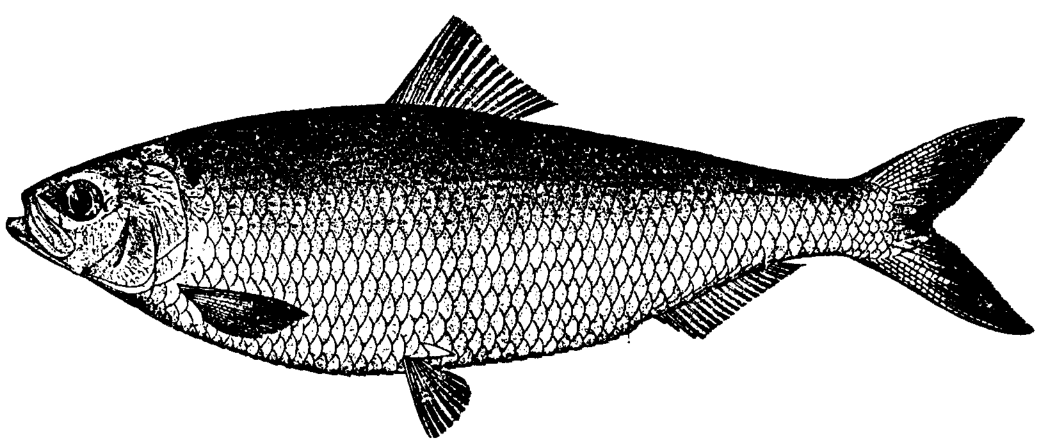
Reproduction--Two major areas and seasons of spawning occur; one during April and May between southern Florida and North Carolina and another between June and August from cape Hatteras to Cape Cod, including New Bedford Harbor. Spawning occurs primarily offshore, peaking in July at a water temperature of 22°C and salinity of 33 parts per thousand (Figures 1. and 2.) (Clayton, 1976).

Eggs, larvae, juveniles--The eggs of bluefish are buoyant and measure 0.9 to 1.2 mm in diameter. Fertilized eggs hatch in 46 to 48 hours at 20°C. Larvae are 2.0 to 2.4 mm long at hatching, and feeding begins at a length of approximately 3.0 mm. Larvae inhabit surface waters, most often found at the edge of the continental shelf. Juvenile bluefish (snapper blues), move inshore during the first year (Clayton, 1976). By midsummer, juveniles appear in the New Bedford Harbor estuary and coastal waters (Bourque, 1986). This pelagic lifestyle and the voracious appetite of the adults and juveniles can contribute to direct exposure to PCBs via the water column and food web.

Feeding, predation, diseases--Bluefish are voracious feeders, consuming a large variety of fishes and invertebrates throughout the water column. Mackerel, menhaden, herring, alewife, and Atlantic tomcod, all of which are found in New Bedford Harbor are often important food items. Invertebrates commonly include shrimp, lobster, squid, crabs, mysids, and annelid worms which are common to New Bedford Harbor. Juveniles are presumably preyed upon by many predatory fish species (Clayton, 1976). An abundance of young bluefish in the near shore zones of the harbor probably contributes to attracting predaceous species. The extensive feeding of the bluefish, as well as the varied diet makes *Pomatomus* a prime candidate for the biomagnification of PCBs in New Bedford Harbor.

Utilization--Bluefish are a recreational and commercial species during the warmer months in New Bedford Harbor. Commercially, about 159 metric tons of bluefish were landed in Massachusetts in 1972, primarily by angling and otter trawls. Recent landing statistics for New Bedford Harbor indicate that only 11,970 lbs were brought ashore in 1985 (NMFS, 1986).

Blueblack Herring *Alosa aestivalis*--



Range and distribution--The blueblack herring, *Alosa aestivalis*, is a fish of eastern North America that ranges from Nova Scotia to the

St. John's River, Florida (Clayton, 1976). In the spring it enters New Bedford Harbor to spawn and can be found in zones 1 through 8, thus being exposed to varied PCB concentrations. After spawning it returns to the ocean, apparently moving to offshore, bottom water during winter (Bourque, 1986). In New Bedford Harbor its abundance is low and the blueblack herring has shared a common fate with the alewife in coastal streams and estuaries in Massachusetts. Destruction of spawning areas, obstructions in the river (hurricane barrier), and increased levels of river pollutants (high PCB concentrations) may be responsible for decline or loss of spawning stocks (Clayton, 1976). Blueblack herring are still found with alewives in New Bedford Harbor, however, Brad Bourque (Shellfish Warden, New Bedford) feels these may only be remnants of formerly substantial local populations.

Population characteristics--Adult blueblack herring generally live to age 7. However, fish 8 years of age have been observed in the Georges Bank area. No historical data is available on spawning runs in New Bedford Harbor, but in the Connecticut River at Holyoke Dam, Massachusetts, spawning fish range from 3 to 7 years; age 4 predominated among males and age 5 among females (Clayton, 1976). Although the sex ratio probably approximates 1:1 in the ocean, differential ratios may exist in spawning areas, because of different age of recruitment into the spawning population between the sexes. Fecundity estimates varied between 32,925 for an age 5 specimen and and 354,270 for an age 7 fish (Clayton, 1976).

Reproduction--As an anadromous species, the blueback herring enters brackish water in the spring, usually by mid-May in New Bedford Harbor, when water temperatures reach 21 to 24°C (Figure 2.) (Clayton, 1976). It is probably the long journey from the harbor entrance to the saltwater/freshwater interface in zone 1, that is responsible for the greatest exposure (via the water column) to PCBs. The consumption of contaminated crustaceans and zooplankton (preferred prey items) increases exposure for this species. It has been reported that the blueback will spawn at temperatures as low as 14 and 15°C. Data concerning downstream movement of spent adults are sparse, however it is suggested that a rapid egress by mid-August occurs at the Acushnet River (Clayton, 1976).

Eggs, larvae, juveniles--Blueback herring eggs are demersal (benthic), somewhat adhesive, semi-transparent, and yellow. Their average diameter is 1.0 mm. Incubation occurs in 50 hours at water temperatures of 22°C. At hatching the length of the larvae averages 3.5 mm. The young are 30 to 50 mm long within a month. The juvenile fish are fairly common in the New Bedford Harbor estuary throughout the late summer and fall. Young-of-the-year first appear in the estuary by July and remain until October, attaining an average length of 70 mm (Clayton, 1976). It has been suggested that their ability to use both saltwater and freshwater nurseries is highly advantageous for the species because population size does not become so dependent on the nursery potential of only freshwater areas. In the case of New Bedford Harbor this may be more of a liability then an asset. Since zone 1 water temperatures are conducive to spawning and incubation, this may cause blueblack eggs and juveniles to be in direct contact with the highest level of PCB contaminated sediments and surface water (GCA, 1986a).

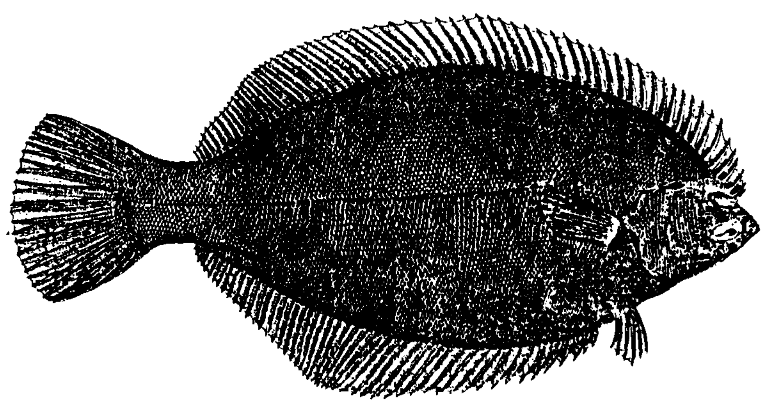
Feeding, predation, diseases--Juvenile bluebacks frequently eat crustaceans (Cladocera and Anostraca), and it appears that food items remain the same throughout the seasons (Clayton, 1976). Also, in many coastal streams in Massachusetts, a direct relationship exists between standing crops of zooplankton and growth and feeding of young-of-the-year blueback herring. Adult food consists primarily of copepods, pelagic shrimp, fish eggs, and larvae. In the Hampton-Seabrook estuary, New Hampshire, barnacle cyprids, cumaceans, and decapods were important food items in the stomachs of adult herring examined (Clayton, 1976). Bluefish and striped bass in New Bedford Harbor feed heavily on juvenile blueback herring, which may have a significant effect on population levels (Clayton, 1976).

Utilization--Traditionally alewives and blueback herring have been classed together commercially as river herring and therefore processed or used in the same manner. No special fishery or processing now exist in New Bedford for blueback herring, but they are routinely caught commercially with alewives. No statistics exist for blueblack herring landed at New Bedford Harbor.

Sediments--

Demersal (bottom-living or benthic) fish and invertebrates live below the littoral zone and most species remain at or just above the bottom (as epifauna), but some browse and bury themselves in the sediment surface. Many species of benthic fish and invertebrates are found in New Bedford Harbor. This analysis of those species will discern what role their specific life history characteristics will play in PCB exposure at New Bedford Harbor. The following fish and invertebrates from New Bedford are representative of the benthic life styles: winter flounder (Pseudopleuronectes americanus), American eel (Anguilla rostrata), scup (Stenotomus chrysops), tautog (Tautoga onitis), Atlantic ribbed mussel (Modiolus demissus), blue mussel (Mytilus edulis), Atlantic bay scallop (Aequipecten irradians), Eastern oyster (Crassostrea virginica), and the American lobster (Homarus americanus) (Table 4. is a partial list of benthic organisms known to inhabit New Bedford Harbor). The uptake and retention of PCBs by these fish and invertebrates is via direct contact with contaminated sediments, however, direct contact with the water mass and feeding habits will contribute to exposure. Below is a concise description of these organisms and how their life history characteristics reflect PCB exposure in New Bedford Harbor.

Winter Flounder (Pseudopleuronectes americanus)--



Range and distribution--The winter flounder, Pseudopleuronectes americanus, is found from southern Labrador south to Georgia and is most common off the New England coast (Clayton, 1976). Also called the blackback flounder, it is found in estuarine waters and salt water as deep as 130 m, but

TABLE 4. SPECIES PROFILE FOR NEW BEDFORD HARBOR BENTHIC ORGANISMS

Genus and species	Common name	Abundance[a]	Distribution (zones)	Behavior[b]	Age	Habitat & food	Health[a]	[BCF][c]
Pseudopleuronectes americanus	Winter Flounder	M	1 - 8	Predatory	Juveniles/adult	Carnivore	F	-
Anguilla rostrata	American Eel	M	1 - 5	Predatory	Juveniles/adult	Carnivore	F	-
Stenotomus chrysops	Scup	M	2 - 8	Predatory	Juveniles/adult	Carnivore	F	-
Tautoga onitis	Tautog	M to H	2 - 8	Sedentary	Juveniles/adult	Carnivore	G	-
Modiolus demissus	Ribbed Mussel	H	2 - 4	Sessile	Juveniles/adult	Herbivoce	G	-
Mytilus edulis	Blue Mussel	H	2 - 4	Sessile	Juveniles/adult	Herbivoce	G	-
Crassostrea virginica	Eastern Oyster	L	2 - 4	Sessile	Juveniles/adult	Herbivoce	P	8,100
Aequipecten irradians	Bay Scallop	L	3	Sessile	Juveniles/adult	Herbivoce	P	-
Urosalpinx cinerea	Oyster Drill	H	2 - 4	Predatory	Juveniles/adult	Carnivore	G	45,000
Homarus americanus	American Lobster	M to H	2 - 7	Predatory	Juveniles/adult	Carnivore	G	-
Uca pugnax	Fiddler Crab	L	-	Predatory	Juveniles/adult	Carnivore	F	-
Balanus balanus	Barnacle	H	2 - 5	Sessile	Juveniles/adult	Carnivore	G	-
Limulus polyphemus	Horseshoe Crab	M	2	Predatory	Juveniles/adult	Carnivore	F	1,298
Pagurus longicarous	Hermit Crab	M	2 - 8	Predatory	Juveniles/adult	Carnivore	F	-
Crangon septemspinosa	Pistol Shrimp	L	3 and 5	Sedentary	Juveniles/adult	Detritivore	F	140

P = Poor L = Low
F = Fair M = Moderate
G = Good H = High
E = Excellent

[a]This is a qualitative indicie based on site-specific data.
[b]Characteristics of particular significance in exposure assessment.
[c]EPA Ambient Water Quality Criteria for PCBs (EPA-440/5-80-068).

Source: Bourque, 1986; Clayton, 1976; and GCA, 1986a.

is more common at shallow depths inshore (Clayton, 1976). It has been found in zones 1 through 8 in New Bedford Harbor (GCA, 1986a). Migratory studies have shown the movement of the winter flounders to be temperature regulated with seasonal dispersal southeastward along the New England coast. However, juvenile flounders remain in the estuaries until their third year (Clayton, 1976). As a result, this may expose juveniles to significant levels of PCBs in New Bedford Harbor via the water column at an important stage in the development of the individual.

Population characteristics--Fecundity for this species is estimated at 200,000 to 1,500,000 eggs per female, per year, with an average of 600,000. It has recently been demonstrated that less than 40 newly hatched larvae per 100,000 survive their first year. It appears that the physical characteristics of the spawning grounds are important in determining survival rates (Clayton, 1976).

Reproduction--The New Bedford Harbor estuary provides a spawning ground for the winter flounder from January to May. During the warmer months the adults will move offshore, but are believed to return to the estuary of their origin for spawning (Clayton, 1976). Such migratory behavior has the potential to expose New Bedford Harbor populations to PCBs on an annual basis. Winter flounders spawn on sand or silt-sand bottoms of estuaries. Although spawning has been recorded in depths to 75 m, this is not common (Clayton, 1976).

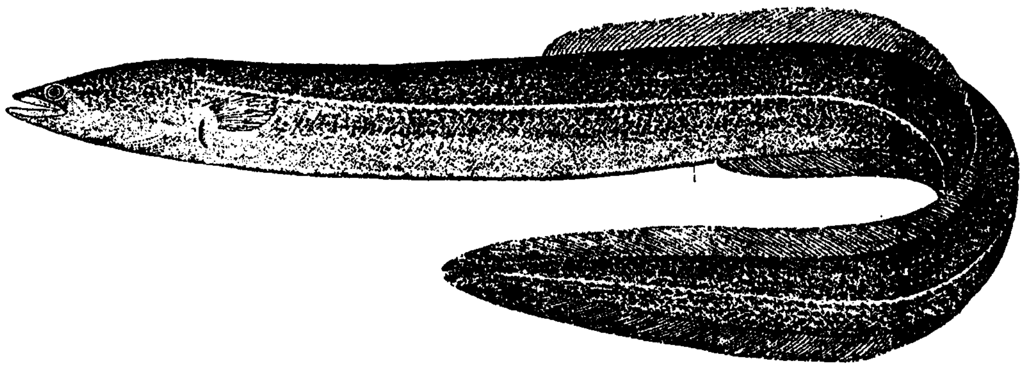
Eggs, larvae, juveniles--Winter flounder eggs are demersal and adhesive, ranging from 0.75 to 0.85 mm in diameter. Eggs can be found from late April to June in most New England estuaries. Direct exposure to contaminated sediments and water is likely in New Bedford Harbor. Incubation of eggs requires 15 to 18 days at a temperature of 2.7 to 3.3°C, and larvae are about 3 to 3.5 mm long at hatching; metamorphosis is complete when fish are 9 mm long. Larvae are abundant in estuaries from March through June (Clayton, 1976). Juvenile flounders generally remain close to the sand or sand-silt bottoms of the estuary, and will not begin migrating until their third year (Clayton, 1976).

Feeding, predation, disease--Winter flounders feed primarily by day. The adult flounder is limited to smaller invertebrates such as shrimps, amphipods and clams, due to its gape size. Larvae will feed on copepod nauplii, polychaetes and eggs of invertebrates. After metamorphosis, the fish eat mainly crustaceans and polychaetes. During food shortages, the flounder appears to sacrafice egg production in order to maintain body weight (Clayton, 1976). As a result of the winter flounder's feeding habits, this species may bioaccumulate PCBs in New Bedford Harbor, via ingestion of contaminated sediments and prey. The major predator of the winter flounder appears to be the striped killifish (Fundulus majolis), with the small hydromedusa, Sarsia tubulosa, contributing to larvae mortality, however, juveniles will be taken by most piscivores (Clayton, 1976).

Utilization--The winter flounder represents a valuable marine resource; commercial landings in Massachusetts alone were worth 3 million dollars in 1972. Although most winter flounders are caught offshore, inshore fisheries still represent a significant portion of the catch. In 1975, approximately 9 million pounds were landed in New Bedford Harbor, worth 3 million dollars. In 1980, this increased to approximately 14 million pounds, worth 5 million dollars. Landings dropped slightly in 1985 to 10 million pounds, but were worth approximately 11 million dollars (NMFS, 1986).

Although a fishing ban has been placed on winter flounders which extends through zones 1 to 5, it is possible that fish exposed to PCBs in the upper harbor regions may migrate beyond the area prohibited to fishing. It is, therefore, possible that fish taken from Buzzards Bay and landed in New Bedford Harbor have been exposed to PCBs. This obviously has implications for public health, since the winter flounder is primarily fished for human consumption.

American Eel (Anguilla rostrata)--



Range and distribution--The American eel, Anguilla rostrata, is found from Labrador to the West Indies and is common in New England coastal streams and rivers (Clayton, 1976). In New Bedford Harbor the American eel has been found in zones 1 through 5 (Bourque, 1986). As eels attain sexual maturity, they migrate in the fall to open sea to spawn. Juveniles return to coastal waters during the late winter or early spring and some travel upstream to freshwater areas. Eels spend most of their adult lives in the same water body; they are chiefly nocturnal and often lie buried in the estuary sediments during the daytime (Clayton, 1976). This behavior has the potential to subject the eel to significant exposures via dermal contact with contaminated sediments in New Bedford Harbor. The activity of the eel decreases as the water temperature declines and they therefore spend most of the winter burrowed in the estuary bed. PCB tissue residues as high as 730 ppm have been found for this species in zone 1, confirming the significance of the exposure via sediment contact (Kolek, 1981).

Population characteristics--Differential growth exists between sexes; females attain lengths up to 122 cm and males up to 60 cm. Females have been reported to carry between 5 and 10 million eggs (Clayton, 1976).

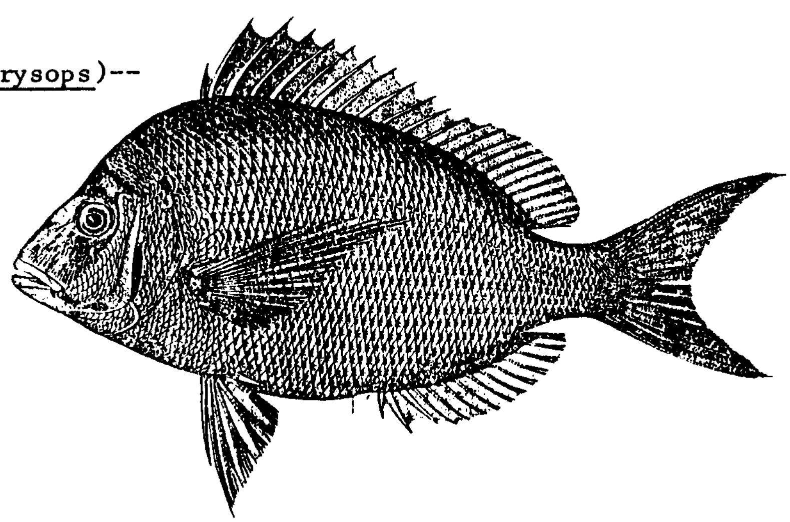
Reproduction--Spawning occurs in oceanic waters beyond the continental shelf. Little information is available on the specific locations. It is presumed that adults die after spawning (Clayton, 1976).

Eggs, larvae, juveniles--Eggs are presumed to be pelagic, gaining their buoyancy from large amounts of lipid (Clayton, 1976). The high concentration of lipids has the potential to expose the embryo to an increased level of PCBs, since these compounds are highly lipophilic. Larvae are transparent, slender and possess teeth. They range from 65 to 90 mm in length and are pigmented by the time they reach coastal waters. Some of the juveniles ascend rivers and streams, while others remain in estuarine waters (Clayton, 1976). The migratory behavior of juveniles suggests that they frequent the upper estuarine waters of New Bedford Harbor where the PCB concentrations are highest.

Feeding, Predation, Disease--American eels are carnivorous, consuming fish, insects, snails and annelids. Feeding occurs primarily at night with little to no activity during the day. In estuarine waters polychaetes, crustaceans and bivalves are generally the most important foods. Young eels are part of the diet of many larger fishes in both freshwater and marine environments, and thus form and important link in the food chain (Clayton, 1976).

Utilization--Small, local commercial and sport fisheries exist for the American eel in tidal waters. There is little demand for this species; larger eels are of commercial value, while smaller eels are used as bait for striped bass. In 1984, landings at New Bedford Harbor were 4,215 lbs. None were landed in 1985 (NMFS, 1986).

Scup (Stenotomus chrysops)--



Range and Distribution--The scup, Stenotomus chrysops occurs regularly from North Carolina to Cape Cod (Clayton, 1976). Adults school in groups of similar size and are caught in depths of 2 to 37 m, over smooth or rocky bottoms. The scup is found in Massachusetts waters in the summer and early fall, migrating southward for the winter (Clayton, 1986). In New Bedford Harbor, the scup is found in zones 2 through 8 (Bourque, 1986).

Population characteristics--Most adults are less than 35 cm long and the sex ratio appears to be 1:1 on the basis of commercial catches studied. Both males and females are mature by their second year (Clayton, 1976).

Reproduction--Little documentation exists on the reproductive habits of the scup. Inshore movements of scup during the spring probably represent spawning migrations. For southern New England stocks, June is the month of peak reproductive activity (Clayton, 1976).

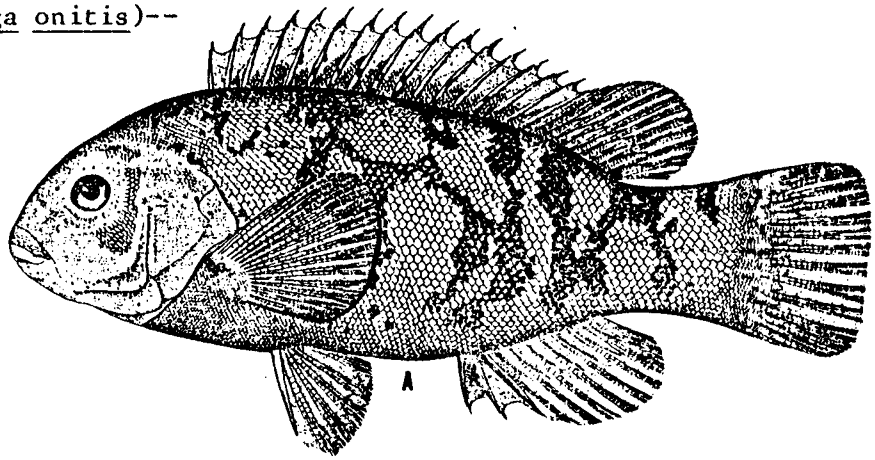
Eggs, larvae, juveniles--The eggs of scup are buoyant, and are 0.83 to 1.15 mm in diameter. Eggs are present in zone 5 of the New Bedford Harbor estuary from May through June in water temperatures of 8.5 to 23.7°C (see Table 1.) (Govoni, 1973). Incubation takes about 40 hours at 22°C (Clayton, 1976).

Larvae are about 2 mm at hatching. They become demersal at lengths of 15 to 30 mm. Juveniles are common in shallower and more saline portions of bays and estuaries (Clayton, 1976). Dermal contact and ingestion of PCB contaminated sediments are major exposure routes for the scup in New Bedford Harbor.

Feeding, predation and disease--Adults are primarily benthic feeders, consuming small crustaceans, annelid worms, mollusks, squid, hydroids, sand dollars and occasionally young fish. Adults do not feed during spawning. Adults fall prey to cod, bluefish and weakfish (Clayton, 1976).

Utilization--In 1972 over 227 metric tons, worth over $250,000 were landed in Massachusetts. Fluctuations of scup in the southern New England fishery are possibly caused by the varying abundances of successive year classes (Clayton, 1976). In 1985, 40,000 lbs were landed at New Bedford Harbor, worth approximately 22 thousand dollars.

Tautog (Tautoga onitis)--



Range and distribution--the tautog or blackfish, Tautoga onitis, is a North American coastal fish ranging from Nova Scotia to North Carolina. The tautog represents a prominent member of inshore benthic communities (Clayton, 1976). This species has been found in zones 2 through 8 in New Bedford Harbor (Bourque, 1986). Tautogs will enter estuarine waters, but not freshwater. The tautog will migrate onshore in spring and offshore in autumn. While inhabiting estuaries and inshore waters in New Bedford Harbor from May to October, adult populations appear to be localized (Clayton, 1976). Populations which inhabit the upper zones in New Bedford Harbor, during the summer, are thus exposed to high concentrations of PCBs for 5 to 6 months. Some young tautogs remain inshore and overwinter in a torpid condition, which increases the duration of exposure.

Population characteristics--The tautog is relatively long lived and slow growing. The male grows faster than the female in length, but not in weight. Fish become sexually mature by the second or third year, and the number of eggs produced by a female increases as a function of weight (Clayton, 1976). Eggs of the tautog have been observed in zone 5 of the New Bedford Harbor estuary (Govoni, 1973).

Reproduction--Spawning can occur in Massachusetts from May through August; the peak occurs at water temperatures of 17° to 20°C (see Figure 2.). Spawning occurs primarily in weedy, inshore areas. In Narragansett Bay, peak spawning was found to occur between 13° and 14°C, and it is estimated that the duration of spawning activity for each fish may exceed 2 weeks (Clayton, 1976).

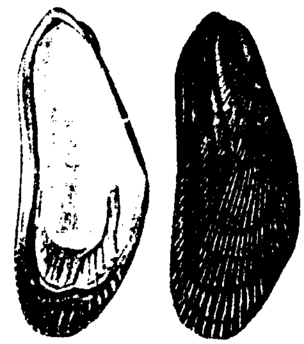
Eggs, larvae, juveniles--The eggs of tautog are buoyant and are about 0.9 to 1.0 mm in diameter. Hatching occurs in 42 to 45 hours at 20 to 22°C. Larvae are about 2.2 mm at hatching. Larvae are most frequently collected near the bottom of the esturary bed, at the mouth of the river, since inshore areas are often heavily vegetated. Tautog larvae can be collected from June to August at water temperatures of 20.0 to 23.5°C. Juveniles occupy the typical adult habitat, where salinities are above 22 parts per thousand, preferring vegetated areas. Juveniles will overwinter in the estuary (Clayton, 1976). Tautog of age 0 (young-of-the-year) and 1 have been collected in Narragansett Bay and New Bedford Harbor at depths of 9 to 15 m (Govoni, 1973).

Feeding, predation, diseases--Adults feed commonly on intertidal organisms, including blue mussels, barnacles, and crabs. Their diet also includes clam worms, scallops, amphipods, shrimp, isopods, sand dollars and small lobsters. Tautog have been observed to compete with cunner for mussels during May and June, when it is the major food for both species (Clayton, 1976). This benthic feeder has the potential to bioaccumulate significant amounts of PCBs, since it consumes substantial quantities of benthic invertebrates.

Utilization--The tautog represents an important resource for Massachusetts as a sport fish, as it moves inshore during the spring. Tautog are not generally plentiful enough to be of any commercial value. In 1985, only 1,440 lbs were landed at New Bedford Harbor.

Common Blue Mussel
(Mytilus edulis)

Atlantic Ribbed Mussel
(Modiolus demissus)



Range and distribution--The common blue mussel, Mytilus edulis, and the Atlantic ribbed mussel, Modiolus demissus, are common from Nova Scotia to Florida (URI, 1973). Large beds of these mussels exist in zone 2 through 4 in New Bedford Harbor (Bourque, 1986). Blue mussel beds are found from the low tide mark to depths of several meters. Subtidal beds are known in Narragansett Bay, Long Island Sound, and in the muddy bottoms of Cape Cod Bay, as well as New Bedford Harbor (URI, 1973). Below the low tide mark the mussels are larger and their meats are proportionately heavier. Mytilus edulis is well suited to cold northern waters, as it is able to tolerate freezing. It can survive at -10°C as compared to Mercenaria mercenaria which succumbs at -6°C (URI, 1973).

The ribbed mussel is found embedded in mudsand flats at the low-tide mark and prefers brackish water. Their shell is thin and yellowish brown, with numerous strong radiating ribs. This bivalve is eurythermal and able to withstand temperatures from -22°C to 36-40°C (Tucker, 1968).

Population characteristics--Wherever there is solid substratum, and the salinity does not fall too low, the blue mussel is likely to be abundant. Near the mouths of many estuaries there are extensive areas dominated by Mytilus, which at first site appears to be attached to the surface of the mud. Closer inspection generally show that the tough byssus threads, which are secreted by a gland in the foot, penetrate through the surface layers and are attached to a stone (URI, 1973). The ionic concentration of the blood of Mytilus edulis, follows that of the external medium down to a salinity of

10 parts per thousand, below this salinity there appears to be some active osmotic regulation, but the mussel cannot survive permanently in salinities below 4 parts per thousand (URI, 1973).

Ribbed mussels are about 4 inches long when they are fully mature, and although sedentary, ribbed mussels are not permanently anchored by the byssal threads (URI, 1973). The adaption of the ribbed mussel to varying salinities is accomplished by regulation of its internal volume. This volume response, however, is unidirectional. While the mussel responds to a low salinity by extruding solute, a high salinity causes it to shrink passively. The ability of the ribbed mussel to withstand perturbations in salinity and temperature have contributed to its success in estuaries such as New Bedford Habor (URI, 1973). It has been observed at New Bedford Harbor that the ribbed mussel is thriving in many tidal marsh areas where it is exposed to air more than water (GCA, 1986b). In these areas the mussel are consuming more oxygen aerially than aquatically. It is proposed that "air-gaping" coupled with the physiological adaptations of extensive tolerance to dehydration and a very high enzyme thermostability makes this possible (URI, 1973).

Reproduction--At spawning time the eggs and sperm of the blue mussel are shed freely into the surrounding water, and may be so numerous as to give a milky appearance to wide areas. The fertilized eggs give rise to veliger larvae which become planktonic and spend several weeks drifting in the Harbor (Morton, 1979).

The ribbed mussel is capable of spawning 12 million eggs, all of which can develop into larvae. During this stage the larvae find new settling sites, and gain access to a rich food supply of phytoplankton (URI, 1973). The pelagic characteristics of mussel eggs and the demersal characteristics of the veliger larvae give rise to PCB exposure from contaminated surface waters and sediments at New Bedford Harbor.

Eggs, larvae, juveniles--The blue mussel and ribbed mussel have planktonic larvae with a long larval life of up to 2 or 3 months, before finding a settling site (URI, 1973). Both mussels will settle in great numbers under optimal conditions, and the stock of benthic adults is thus subject to great fluctuations according to seasonal conditions such as temperature, salinity, and food supply (URI, 1973). This extended exposure in the water column can be deleterious to juvenile mussels which may prove to be more sensitive than adults to PCB exposure.

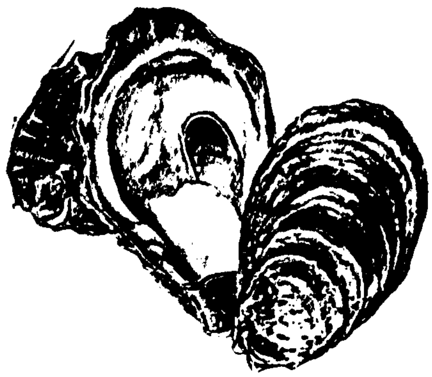
Feeding, predation, disease--The feeding mechanism of the blue mussel resembles that of many other lamellibranchs (bivalves) in that it relies upon the separation of small particles of detritus and plankton from a current of water that flows through the gills (Morton, 1979). This process is called filter feeding.

Ribbed mussels are also filter feeders, filtering water to extract edible particles. In the ribbed mussel the gills have assumed a major function in feeding. The hairlike cilia create currents of water that come in through the tubelike inhalent siphon and pass over the gills. Tiny food particles, such as planktonic algae and protozoa, adhere to a mucous film that passes slowly, in tiny strands, along the ciliated food gutters to the mussels mouth (URI, 1973). This process of filtration is continuous and allows for high exposure to PCBs through direct contact with contaminated water, food, and sediments.

Tautog, scup, and winter flounder eat mussels and clams, and in addition to man can effect population levels of the mussel. There have been instances of the commensal or pea crabs being found in the ribbed mussel and the blue mussel, however, whether or not the relationship is harmful to the mussels is unknown (URI, 1973).

Utilization--In 1985, only 934 lbs of sea mussels were landed at New Bedford Harbor. This species is larger than the blue or ribbed mussel and is generally found in deeper waters. Historically, this port has not handled large quantities of mussels.

Eastern Oyster (Crassostrea virginica)--



Range and distribution--The Eastern oyster, Crassostrea virginica, occurs from Canada to the Gulf of Mexico (URI, 1973) and is in low abundances in zones 2, 3, and 4 at New Bedford Harbor (GCA, 1986b). Oysters are generally found on hard rock bottoms or semi-hard mud, normally setting on areas already inhabited by other oysters. Shifting sand and soft mud are unsuitable substrates (URI, 1973). Crassostrea virginica is euryhaline, and can survive salinities from 3 to almost 40 parts per thousand as an adult (see Figure 1.). The temperature range is from 1°C to 30°C for its entire distribution (see Figure 2.). Oysters are able to withstand very high temperatures when lying closed and exposed on mud flats (URI, 1973). Overfishing, pollution, and the oyster drill, Urosalpinx cenaria are all factors contributing to the decrease in oyster populations at New Bedford Harbor (URI, 1973).

Population characteristics--Oysters reach marketable size in approximately 4 to 5 years. Natural deaths are caused by crowding, silting over and by the overgrowth of other organisms. Crepidula, the slipper shell, barnacles, jingle shells and other spat attach to the oyster shell and compete for food. Silting and sedimintation are other causes of death (URI, 1973).

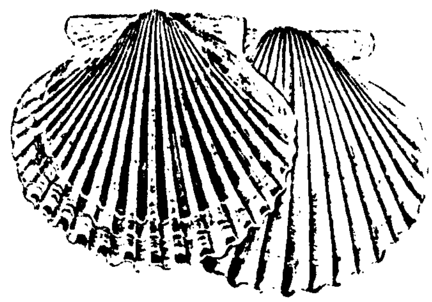
Reproduction--The Eastern oyster is oviparous and is not usually hermaphroditic. There are seasonal changes in gonad development, with early gametogenesis occurring in the fall and being completed in the spring. Gonads ripen at temperatures between 12 to 18°C, but some require higher temperatures. Oysters are induced to spawn by cumulative temperature effects. Spawning can be retarded by low temperatures (URI, 1973).

Eggs, larvae, juveniles--After fertilization a motile trocophore larvae develops. This stage progresses to the veliger stage which is a free swimming form. Just before metamorphosis the organism develops into a pediveliger stage which is characterized by a foot and eyespots. The pediveliger uses its foot to test the substrate before final setting. The trocophore and veliger larvae are subject to direct exposure to PCBs via the contaminated surface water since they are pelagic. The subsequent pediveliger stage can potentially be exposed to contaminated sediments. Mortality of young spat is caused by starfish, flatworms *Stylochus ellipiticus*, crowding and by setting on inappropriate areas (URI, 1973).

Feeding, predation, diseases--Oysters, like clams and mussels, are filter feeders, filtering water to extract edible particles (URI, 1973). This allows for extended periods of direct exposure to PCB contaminated surface waters. Oysters feed on phytoplankton, such as *Isochrysis* and *Monochrysis*. They feed most effectively on particles in the 3 to 4 μm range. Limited food intake delays gonad development. The importance of predators depends on the area of concern. Carnivorous gastropods, such as the oyster drill *Urosalpinx cinerea*, which is in high abundance in New Bedford Harbor, are very destructive to oyster populations (URI, 1973).

Utilization--Based on landing statistics for New Bedford Harbor, this species does not support a significant fishery in the area (NMFS, 1986).

Atlantic Bay Scallop (Aequipecten irradians)--



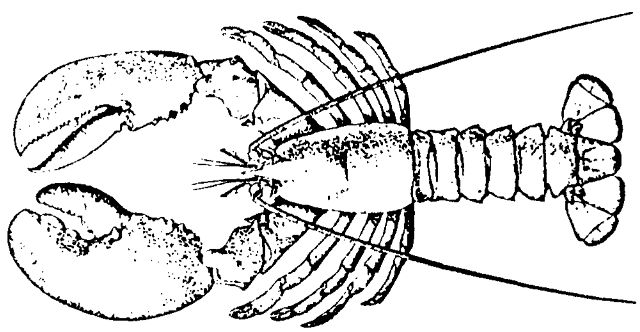
Range and distribution--The Atlantic bay scallop (Aequipecten irradians) is a subtidal bivalve found mostly in the shallow waters of estuaries and often associated with areas supporting eelgrass, Zostera marina (URI, 1973). However, the extensive mortality rate of eelgrass in New Bedford Harbor, resulting from disease may adversely affect the scallop populations (URI, 1973). Aequipecten irradians extends from Cape Cod to New Jersey and is commercially harvested along the mid-Atlantic Bight and in the shallow bays of Massachusetts (URI, 1973). In New Bedford Harbor the bay scallop has been found in zone 3 (GCA, 1986a). The scallop populations vary greatly on an annual basis. A population which supports a fishery one year may be completely absent the next. Possible causes for this instability are predation and the scallop's sensitivity to pollution (URI, 1973). The scaracity of this species in New Bedford Harbor is a possible reflection of overfishing and PCB contamination.

Reproduction and life stages--Reproduction is coordinated to environmental changes in temperature and food supply. Aequipecten irradians fails to reach reproductive maturity and spawn at temperatures of 10 to 15°C, but completes the cycle at 20 to 35°C (see Figure 2.). Spawning normally occurs in early summer, but may occur in fall for southern populations. The planktonic larvae set in about 10 days, and although brief, the planktonic larvae may be exposed to direct contact with PCBs in the surface water. By the end of one year, the adults are approximately 5 to 7 cm in shell length (URI, 1973).

Feeding and predation--The Atlantic Bay scallop is a filter feeder. Much of the food taken by the scallop seems to be suspended benthic material. The process by which the scallop feeds may account for extended periods of PCB exposure to the visceral organs. The major predators of this species are starfish, crabs, and snails (URI, 1973).

Utilization--In 1968, 210,000 pounds of bay scallops were taken from Massachusetts waters. Massachusetts supports one of the larger commercial fisheries for this species, however, recent scallop landings in New Bedford Harbor have primarily been comprised of the sea scallop (*Placopecten megallanicus*). In 1985, total landings for sea scallops amounted to 9 million pounds, worth approximately 43 million dollars (NMFS, 1986).

American Lobster (*Homarus americanus*)--



Range and distribution--The American lobster, *Homarus americanus*, occurs from Labrador to North Carolina (URI, 1973). In southern New England it is found from the subtidal zone to the continental shelf and has been identified in zones 2 through 7 in New Bedford Harbor (GCA, 1986a). Although the lobster is termed non-migratory, daily movements may expose each lobster to contact with varying amounts of PCBs. Lobsters will overwinter in inshore waters, moving into shallow water in fall and deeper waters in spring and early summer. Older lobsters tend to be less migratory, suggesting that these individuals will be exposed for the longest period in New Bedford Harbor. The lobster is a bottom dweller that is found on silty sands, and is nocturnal in shallow water. During the daytime it will rest in mud burrows or other suitable shelters (URI, 1973). Burrowing in New Bedford Harbor may resuspend contaminated sediments, thereby increasing the potential for exposure to PCBs in the water column.

Reproduction and life stages--Mating takes place after the female has molted. Sperm is held in a seminal receptacle as long as nine months while the eggs are maturing. When mature, eggs are extruded, fertilized and attached to the swimmerets under the abdomen. They remain there for 10 to 12 months until hatched during the summer, in inshore populations like that in New Bedford Harbor. Planktonic larvae drift near the surface for several weeks before becoming demersal. During this time water currents will determine their movement within the zones of New Bedford Harbor. Planktonic larvae thus have the potential to be exposed via the water column and sediments (URI, 1973).

Juvenile and young adults grow about 14 percent in length and gain 50 percent in weight with each molt. Molting frequency may well be a function of food supply and temperature. It has also been hypothesized that crowding and lack of shelter may also effect the molting cycle (URI, 1973).

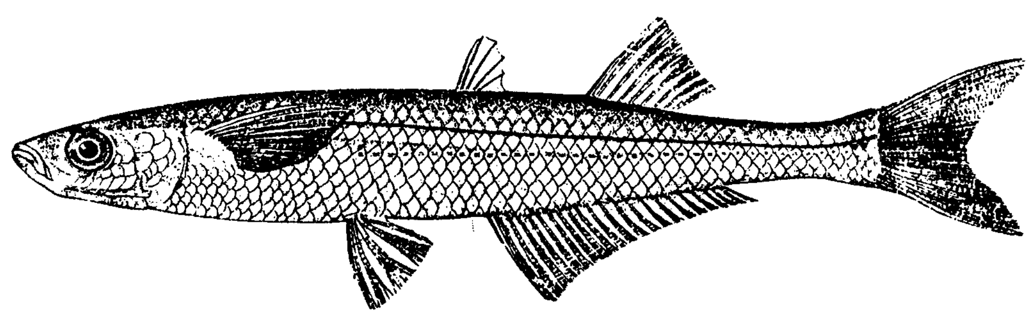
Feeding and predation--Lobsters are carnivores, obtaining only a small part of their food from scavenging. Prey of the lobster includes any fish, mollusks or crustaceans that can be caught and killed by the chelate legs. Feeding has the potential to expose the lobster to PCBs via two routes. The taking of benethic invertebrates from the substrate disturbs the contaminated sediments, which may be ingested during feeding, and the prey itself may have bioconcentrated PCBs, and thus contribute to the dose received by the lobster. In turn the lobster is preyed upon by the tautog, rainbow smelt, American eel, and striped bass (URI, 1973), all of which are found in New Bedford Harbor.

Utilization--The American lobster is the most valuable product of the commercial fishery in the Northwest Atlantic Ocean, and 14.9 percent of the catch in 1968 was taken from Massachusetts. In the New Bedford area, approximately 50 commercial and 100 recreational lobstermen exist. In 1985, 1.6 million pounds were landed at New Bedford Harbor, worth approximately 5.3 million dollars (NMFS, 1986).

Food Webs--

Within the marine environment a major role of many organisms is as a food source (forage) for other fish and invertebrates. These prey organisms (fish and invertebrates) inhabit the estuaries providing an important feeding ground for many other species. The following fish and invertebrates from New Bedford Harbor are important food web organisms: Atlantic silverside (Menidia menidia), mummichog (Fundulus heteroclitus), blue crab (Callinectes sapidus), green crab (Carcinus maenas), soft-shell clam (Mya arenaria), and the quahog (Mercenaria mercenaria), (Table 5. is a partial list of food web organisms associated with New Bedford Harbor.) These organisms contribute to the uptake of PCBs within the food web, and may even be responsible for increasing concentrations of PCBs in organisms relative to their trophic status. The individual life history characteristics of these organisms is indicative of their PCB exposure, and how they become transmitters via their consumption by other organisms. Below is a description of these fish and invertebrates, and how their life history characteristics reflect PCB exposure in New Bedford Harbor.

Atlantic Silverside (Menidia menidia)--



Range and distribution--The Atlantic silverside, Menidia menidia, occurs in estuaries from the southern Gulf of St. Lawrence to southern New Jersey (Clayton, 1976). The Atlantic silverside has been found in seven Massachusetts estuaries at 0 to 28.5°C and salinities of 0 to 33.5 parts per thousand (Figures 1. and 2.). In New Bedford Harbor the silverside is found in zones 1 through 4 (Bourque, 1986). The silverside is a common inshore

TABLE 5. SPECIES PROFILE FOR NEW BEDFORD HARBOR FOOD WEB ORGANISMS.

Genus and species	Common name	Abundance[a]	Distribution (zones)	Behavior[b]	Age	Habitat & food	Health[a]	[BCF][c]
Menidia menidia	Altantic Silverside	M	1 - 4	Schooling	Juveniles/adult	Ominivore	F	-
Fundulus heteroclitus	Mummichog	M	2 - 4	Sedentary	Juveniles/adult	Omnivore	F	-
Mya arenaria	Soft-Shell Clam	L	1 - 5	Burrowing	Juveniles/adult	Herbivore	F	-
Mercenaria mercenaria	Quahog	H	1 - 9	Burrowing	Juveniles/adult	Herbivore	G	-
Loligo peali	Atlantic Squid	L	5	Predatory	Juveniles/adult	Piscivore	P	-
Callinectes sapidus	Blue Crab	L	1 - 4	Predatory	Juveniles/adult	Omnivore	F	230,000
Carcinus Maenas	Green Crab	H	1 - 4	Predatory	Juveniles/adult	Omnivore	G	-
Cancer irroratus	Rock Crab	L	3 - 7	Predatory	Juveniles/adult	Omnivore	F	-
Libinia emarginata	Spider Crab	M	1 - 8	Predatory	Juveniles/adult	Omnivore	F	-
Palaemonetes vulgaris	Grass Shrimp	L	3 and 4	Sedentary	Juveniles/adult	Detritivore	F	27,000

P = Poor L = Low
F = Fair M = Moderate
G = Good H = High
E = Excellent

[a]This is a qualitative indicie based on site-specific data.
[b]Characteristics of particular significance in exposure assessment.
[c]EPA Ambient Water Quality Criteria for PCBs (EPA-440/5-80-068).

Source: Bourque, 1986; Clayton, 1976; and GCA, 1986a.

species, that rarely leaves the estuary, it is normally in residence throughout the year although it may move into deeper water during the winter. In the summer it is commonly found in cordgrass, Spartina alterniflora (Clayton, 1976).

Population characteristics--The Atlantic silverside matures at age 1 and is short-lived. The average life-span is only 1 year, by which time it may reach a length of 90 mm. A few fish reach age 2. Specimens collected from the Annisquam River - Gloucester Harbor area in 1966 to 1967 were 15 to 140 mm long. Most adults were 85 to 95 mm long and most juveniles 30 to 40 mm (Clayton, 1976).

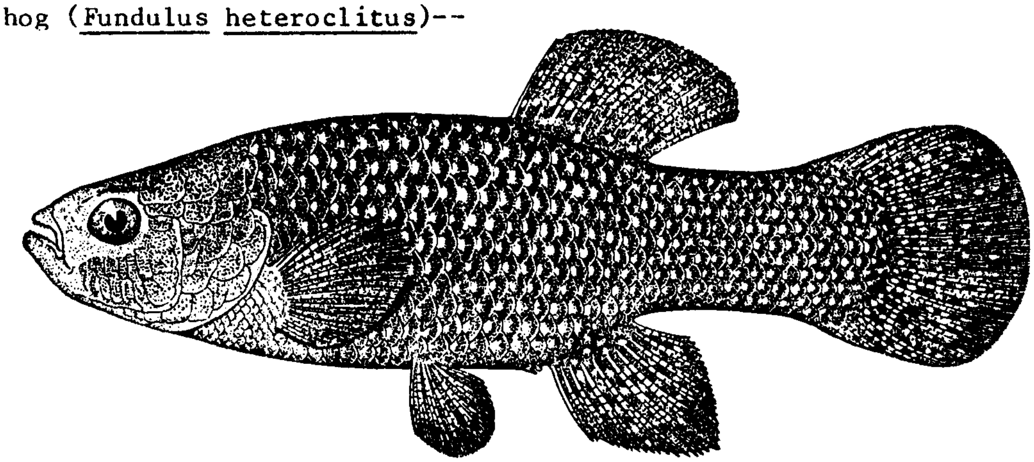
Reproduction--The silverside spawns from May to early July in southern New England and later in the Gulf of Maine. They spawn in large schools, depositing eggs on sand among Spartina at high tide (Clayton, 1976). Spawning grounds in New Bedford Harbor would be expected in the upper harbor area close to the freshwater/saltwater interface, where PCB concentrations are highest.

Eggs, larvae, juveniles--Eggs are 1.1 to 1.2 mm in diameter and have sticky filaments that attach to the bottom or to vegetation. Hatching occurs in 9 days; the newly hatched larvae measures 5 mm. Growth is rapid, but fry less than 25 mm long are present throughout the summer because of the length of the spawning season. This species, although highly tolerant of low temperatures, appears to require a water temperature of 20°C (Figure 2.) to begin spawning (Clayton, 1976).

Feeding, predation, diseases--Adults feed on copepods, shrimp and annelids. They are fed upon by striped bass and other larger estuarine fish-eating species, but are somewhat protected by their choice of a shallow water habitat (Clayton, 1976). The feeding habits of this species and its preference of inshore waters leads to a potentially significant exposure to PCBs in New Bedford Harbor.

Utilization--Silversides are an important estuarine forage resource, but are only rarely used as bait because they are small and soft (Clayton, 1976).

Mummichog (Fundulus heteroclitus)--



Range and distribution--The mummichog, Fundulus heteroclitus, occurs from the Gulf of St. Lawrence to Texas in estuaries and brackish tidal pools (Clayton, 1976). It is found in zones 2 through 4 in New Bedford Harbor (Bourque, 1986). The mummichog is typically located in sheltered tidal areas and salt marsh channels and ditches, and probably is never more than 100 m from shore (Clayton, 1976).

Population characteristics--The mummichog's maximum size is 13 to 15 cm, and it is thought to spawn in the second year of life. No difference in sex ratios have been observed. The mortality rate for first year fish has been estimated as high as 99.5 percent. For age one and older individuals, mortality ranged from 51 to 57 percent/year (Clayton, 1976).

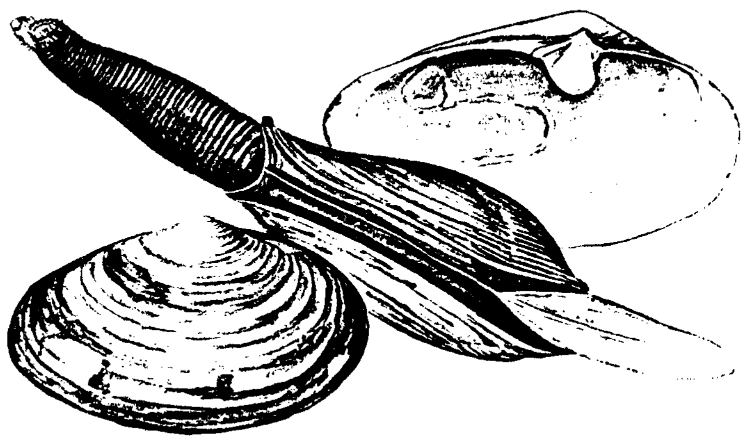
Reproduction--Spawning occurs between June and August in New England waters. Eggs are demersal, dropping to the substrate after being extruded. Mummichogs also lay eggs in empty shells of the Atlantic ribbed mussel, Modiolus demissus, which is common in New Bedford Harbor. This behavior is believed to protect the eggs from predation (Clayton, 1976). Since the eggs of the mummichog are demersal they may be exposed to PCBs in New Bedford via direct contact with contaminated sediments.

Eggs, larvae and juveniles--Pale yellow eggs, 2 mm in diameters are produced that adhere to the substrate. Eggs hatch in 9 to 18 days, depending on temperature, and are extremely hardy since they are often subject to periods of desiccation. Larvae are 7 mm long at hatching and fins are fully developed by 11 mm (Clayton, 1976).

Feeding, predation, disease--Small mummichogs grow rapidly on a diet of harpacticoid copecods, amphipods, benthic diatoms and plant detritus. Diet may be influenced by tide level, time of day, and season. Mummichogs are preyed upon by larger predatory fishes and birds near to the shore. The mummichog is an important link in the food web of many estuaries. In New Bedford Harbor it appears to represent a link between the smaller invertebrates and both benthic and pelagic piscivores (Clayton, 1976).

Utilization--This species is often used by experimental embryologists and physiologists for such studies as pituitary gland research and ectotoxicity testing (Clayton, 1976).

Soft-Shell Clam (Mya arenaria)--



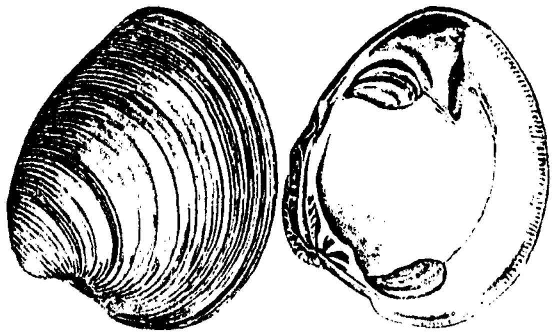
Range and distribution--The soft-shell clam, Mya arenaria, is distributed along the east coast of North America south to Cape Hatteras. This species may penetrate the upper estuarine regions since it has a good tolerance for low salinities (URI, 1973). It is found in New Bedford Harbor in zones 1 through 5 (Bourque, 1986). The soft-shell clam can survive in salinities of 4 parts per thousand and withstand a change of 18 parts per thousand in a few minutes (Figure 1.) (URI, 1973). Adult Mya arenaria are found buried in fine sand or sand-mud as much as 2 feet below the estuary bed (URI, 1973).

Reproduction and life stages--The soft-shell clam reaches sexual maturity at one year of age and when approximately 2 cm long. Spawning begins when water temperatures rise to between 10 and 15°C (Table 1.). In New England, the principal spawning occurs from June to mid-August. Larvae normally spend a 2-week pelagic period in the plankton before settling. The larvae attach to sand grains or other objects with byssal threads until they are approximately 7 mm long. Adults then burrow deep into the soft substrate (URI, 1973). The soft-shell clam thus has the potential to be exposed to PCB in New Bedford Harbor via both the water column, in the larval stage and the sediments in the juvenile and adult stages.

Feeding and predation--The soft-shell clam is a filter feeder and studies have shown its growth rate to be directly dependent on the concentration of flagellates in the plankton (URI, 1973). This is likely to be true for many estuaries, because *Mya arenaria* are found in the upper reach of an estuary where flagellates are often more numerous than diatoms in the plankton. The rate of feeding of this species decreases with decreasing salinity (URI, 1973). The green crab, *Carcinus maenas* is the major predator of the soft-shell clam, and is abundant in New Bedford Harbor. This voracious feeder can dramatically reduce population numbers. Other predators include moon snails, oyster drills, conchs and benthic fish (URI, 1973). The predator-prey relationship of the green crab and soft-shell clam is of particular importance in New Bedford Harbor, since it allows calms from zone 1 to contribute potentially high levels of PCBs to the food web. Species that do not pentetrate the estuarine waters as far as zone 1 may experience the effects of biomagnification via consumption of the green crab which unlike the non-migratory clam moves into the coastal zones of the harbor.

Utilization--The soft-shell clam is the fourth most economically important mollusk in New England, harvested primarily for human consumption (URI, 1973).

Quahog (Mercenaria mercenaria)--



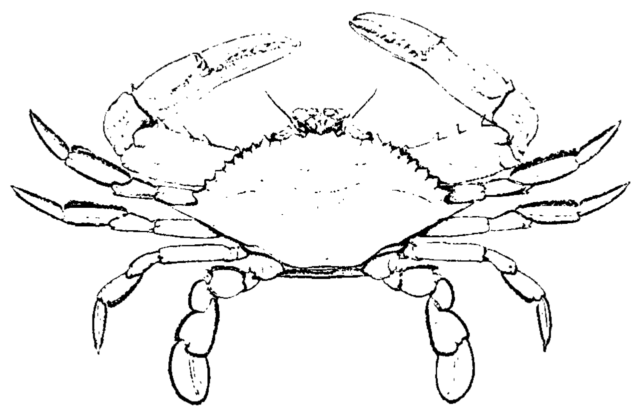
Range and distribution--The range of the northern hardshell clam Mercenaria mercenaria, extends from the Gulf of St. Lawrence to the Gulf of Mexico and is found mainly in shallow bays, coves and estuaries (URI, 1973). In New Bedford Harbor the quahog has been observed in zones 1 through 9 (GCA, 1986a). The quahog burrows into the substrate which usually consists of sand or sand-clay. This species is sedentary, remaining in localized areas (URI, 1973). Individuals in the upper harbor area at New Bedford are therefore subject to significant exposures for long periods of time.

Reproduction and life stages--At approximately 1-year of age and 1 cm in length, almost all members of a quahog population possess mature male gonads. By the end of the second year, approximately half of the population undergo sex reversal, and these clams become sexually mature females. Spawning occurs along their range from late spring to mid-August as water temperatures increase above 20°C. Larvae reared in salinities of 27 parts per thousand and temperatures of 25 to 30°C, in the laboratory set by the end of 7 days, but under natural conditions it is likely that a longer period of time is required (Figures 1. and 2.) (URI, 1973). After setting, quahogs burrow into the soft bottom substrate (URI, 1973). This is a major exposure route for this species in New Bedford Harbor and may contribute to resuspension of contaminated sediments. Maximum growth occurs during the summer months and quahogs may attain lengths of 3 1/2 cm after 2 or 3 years (URI, 1973).

Feeding and predation--Like most clams, the quahog is a filter feeder removing suspended plankton and other food particles from the water (URI, 1973). The quahog may, therefore, bioconcentrate contaminants. Depending on the level of PCBs in the water column, and the degree of sediment suspension; bioconcentration is a potentially significant factor for the quahog in New Bedford Harbor. Juvenile quahog are the prey of snails, crabs and lobsters, while their shells are still thin. As shells thicken, they provide greater protection and man becomes the major predator (URI, 1973).

Utilization--Approximately 13 million pounds of quahog meat was taken in 1970 between Rhode Island and Virginia. Massachusetts waters yield about 7.0 percent of the total U.S. quahog catch annually (URI, 1973).

Blue Crab (*Callinectes sapidus*)--



Range and distribution--The blue crab, *Callinectes sapidus*, has a range from Nova Scotia to the Gulf Coast (URI, 1973). It is basically a bottom dwelling species and is found in shallow waters in estuaries and bays. In New Bedford Harbor it has been found in zones 1 through 4 (GCA, 1986a). The blue crab can osmoregulate over a wide range of salinities, although the male can osmoregulate better at low salinities than the female. This explains why males may remain in brackish water throughout the year, showing limited movement, while females migrate into more saline water, having mated in estuarine waters (URI, 1973). Tagging studies have indicated that most crabs, both male and female, do not migrate between estuaries (URI, 1973). It is, therefore, likely that populations in New Bedford Harbor have been exposed to PCBs for some time. This is supported by relatively high tissue concentrations that have been detected in C. sapidus (Kolek, 1981).

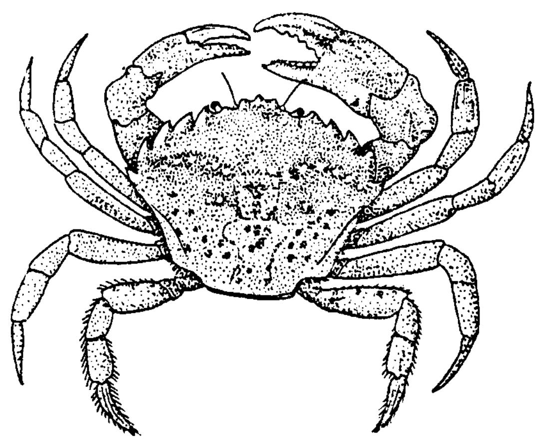
Population characteristics--The blue crab can grow to approximately 20 cm in width, and adult size is reached in about 1-1/2 years (URI, 1973). Males reach maturity in 18 to 19 molts and then continue to grow and molt. Females reach maturity in 18 to 20 molts, but growth and molting then ceases. The total number of eggs laid by one individual is 700,000 to 2 million (URI, 1973).

Reproduction and life stages--Blue crabs mate from May to October. Females are receptive after molting. The peak mating occurs in August and September (Kaestner, 1980). The male carries the female until she molts; sperm is then introducted into the seminal receptacles. Females will only mate once a year, but males may mate with more than one female (Kaestner, 1980). Mating occurs in the less saline waters of estuaries and is followed by a migration of females to waters of higher salinity. Most females will spawn twice, once in spring and again in late summer or early fall. The females fasten the fertilized eggs to their pleopods. Hatching occurs in 15 days at 26°C and larvae require salinities of 20.1 to 31.1 parts per thousand to survive (Figures 1. and 2.). There are normally seven zoeal stages before hatching into the megalopa. The megalopa molts into a crab after 6 to 20 days. Young crabs migrate into estuarine waters in August (Kaestner, 1980).

Feeding and predation--The blue crab is bottom dwelling and omnivorous. Important predators of the larvae blue crab are jellyfish, combjellies, and fish. Young crabs are preyed on by benthic fishes such as the windowpane, tautog, winter flounder, and the american eel. Some pelagic fish may also take blue crab, these include the striped bass, bluefish, mackerel and spiny dogfish (URI, 1973). The diversity of both the prey and predators of the blue crab allow bioaccumulation through the food web. Since the majority of these species are found in New Bedford Harbor, the blue crab represents an important link in the bioaccumulation of PCBs in this ecosystem.

Utilization--The Atlantic blue crab supports the largest crab fishery in the United States. However, large fluctuations in abundance are characteristic of this species. This is apparently due to variable survival rates in the first year of life which are probably related to environmental conditions. It appears that little can be done to stabilize blue crab populations; crab stocks should be managed regionally to protect against environmental degradation (URI, 1973). Total crab landings for New Bedford Harbor in 1985 were 5.1 million pounds, worth approximately 2.2 million dollars (NMFS, 1986).

Green Crab/Shore Crab (*Carcinus maenas*)--



Range and distribution--The green crab, *Carcinus maenas*, is in high abundance in zones 1 through 4 in New Bedford Harbor (GCA, 1986b). This estuarine crab has the ability to live in both sea water and fresh water. This species inhabits a wide range of habitats from open rocky shores to sheltered mud flats and salt marsh pools. It is most numerous where shelter is available, and large numbers of small specimens may be found under stones in the middle reaches of estuaries (URI, 1973).

Population characteristics--The green crab exhibits rhythmic patterns of locomotory activity with peaks of activity coinciding with high tide and with darkness. This crab also moves up and down the shore. The larger specimens move further than the smaller specimens, and show some seasonal variation in this movement. In summer many of the crabs move up the shore with the advancing tide and remain on the shore when the tide ebbs, provided that there is sufficient shelter on the shore. However, in winter a much higher proportion of the population moves down again with the tide. During the coldest months the crabs show no signs of moving upshore with the tide. There is also evidence that estuarine individuals move seaward during the cold weather, and that females carrying eggs tend to remain at the seaward ends of estuaries until the larvae hatch (URI, 1973).

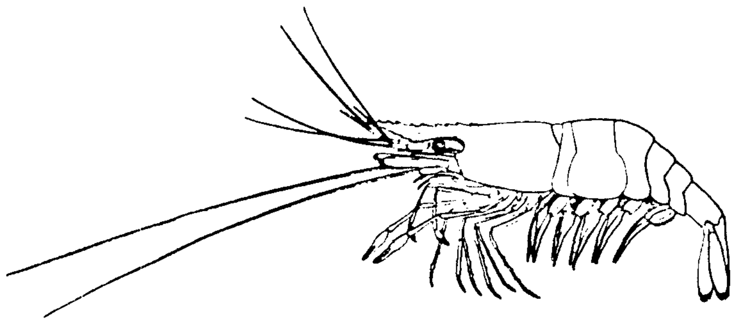
Reproduction--Females with eggs attached to the abdominal pleopods are found throughout the year at New Bedford Harbor, but are most abundant in February and March (GCA, 1986b).

Eggs, larvae, juveniles--The larvae which hatch from the eggs are zoea. Such larvae are most abundant in the plankton in the spring and early summer. The number of zoeal stages is probably about seven, followed by metamorphosis into a megalopa, which resembles a small crab with a thin extended abdomen. The megalopa can both swim and walk. The megalopa metamorphose into small crabs and their life span is 3 to 4 years (URI, 1973). The zooplankton stage is conducive to direct exposure to PCBs through the water column and having become adults direct contact occurs via contaminated sediments in and around the intertidal zone (URI, 1973).

Feeding, predation, disease--The green crab appears to be a generalized scavenger, eating anything that it finds or catches. This wide range of feeding habits is coupled with an ability to osmoregulate at salinities lower than the blood concentration, so that the crab is well adapted to live in estuaries (URI, 1973). Bluefish, striped bass, scup, mackerel, and tautog, eat large quantities of green crabs and other crabs at New Bedford, and effect the green crab population significantly (URI, 1973).

Utilization--Green crabs have minor economic importance as bait for sport fishing in coastal areas, and are routinely used in New Bedford by local fishermen (Bourque, 1986).

Grass Shrimp (Palaemonetes vulgaris)--



Range and distribution--The grass shrimp, Palaemonetas vulgaris, is an intertidal shrimp found in moderate abundance in zones 3 and 4 in New Bedford Harbor (GCA, 1986b). Burrowing into the substrate protects this crustacean from predators. Palaemonetes, by fanning itself with the pleopods and with beats of the abdomen throws sand up; settling into the depression it lets itself be covered by the slowly settling sandgrains. This technique though a unique way to avoid predation, makes exposure to contaminated sediment very likely (Kaestner, 1980). Although the grass shrimp was not observed in zones 1 or 2, it is a common littoral brackish shrimp, and able to withstand a wide range of salinities.

Population characteristics--Grass shrimp average about 3.7 cm in length, rarely exceeding 6 cm. They are active swimmers in shallow brackish water, at times colorless and completely transparent. Fecundity estimates vary between 100 to 450 eggs for an adult shrimp (Kaestner, 1980).

Eggs, larvae, juveniles--For the grass shrimp the rate of development, the time between molts, and the number of molts depend on nutrition. Thus, larvae of similar size and development may be of different ages and may have passed through a different number of molts (Kaestner, 1980). It has been hypothesized that vulnerability to contaminants like PCBs is greatest during the molt process, when the shrimp tissue is soft and porous. In well-fed animals, pereopods 3 to 5 (swimming and walking appendages) appear after two molts, at this point the juvenile resembles an adult (Kaestner, 1980).

Feeding, predation, diseases--The grass shrimp is not specialized in its feeding and takes whatever it can find. As an omnivore it often takes plant parts, but the preferred food item for grass shrimp is Neomysis vulgaris (Isopod) (Kaestner, 1980).

The grass shrimp is an essential food source in New Bedford Harbor, and the main predators of this small shrimp are: striped bass, bluefish, scup, tautog, and the Atlantic mackerel. The grass shrimp is parasitized by an isopod (Cancricepon elegans) whose mouth parts form a sucking cone and remove blood from the shrimp. Little if any damange is done in this one-sided relationship (Kaestner, 1980).

Utilization--The grass shrimp is an important estuarine forage resource, and is used as bait by some fishermen. It has no commercial value, because of its small size (URI, 1973).

Summary of exposed species analysis--The identification of the habitat requirements of these marine organisms shows the importance of New Bedford Harbor in supporting these populations. The species found in New Bedford Harbor rely on the estuary as a spawning ground, a forage resource, and an overwintering habitat. The unique physical characteristics of the estuary, such as salinity and temperature gradients, provide the ideal conditions for sensitive anadromous and catadromous species to survive and reproduce. The interaction of these inshore and estuarine species within the harbor is a delicate relationship involving predation, species diversity, habitat types, and nutrient spiraling. Any environmental disturbance affecting the balance within this ecosystem has potentially deleterious consequences.

The data concerning the specific distribution and abundance of species within New Bedford Harbor are limited. However, it does appear that certain species are not as prevalent as expected in the upper estuary (GCA, 1986b). Since no conclusive data on distribution and abundance of fish and invertebrates exist, site-specific ecotoxicity data become increasingly important in evaluating the status of the New Bedford Harbor aquatic ecosystem.

REFERENCES

Bourque, B., Shellfish Warden, New Bedford Harbor. Personal communication with Michael Donato, Alliance Technologies Corporation (formerly GCA Technology Division, Inc.), September 8, 1986.

Clayton, G., C. Cole, and S. Murawski. Common Marine Fishes of Coastal Massachusetts. 1976.

GCA(a). Endangerment Assessment Work Plan New Bedford Harbor, 1986.

GCA(b). Site investigation by GCA personnel, September 7, 1986.

Govoni, J.J. The distribution of some marine fish eggs and larvae in the Acushnet and Westport River Estuarine Systems, Massachusetts, SMU, 1973.

Kaestner, A. Invertebrate zoology, Volume 3, 1980.

Kolek, A., and R. Cuervals. PCB Analyses of Marine Organisms in the New Bedford Area (1976-80). Commonwealth of Massachusetts Division of Marine Fisheries. 1981.

Morton, J.E. Molluscs, 5th edition. 1979.

NMFS. Preliminary Commercial Fishery Landings by Region, State, and Port. The National Marine Fisheries Service Resource Statistics Division, 1986.

Tucker-Abbott, R. A Guide to Field Identification of North American Seashells. 1968.

URI. University of Rhode Island. Coastal and Offshore Environmental Inventory, Cape Hatteras to Nantucket Shoals. Marine Publication Series #2. Saul Sailia, Program Coordinator. 1973.

APPENDIX A

DEFINITION OF THE STUDY AREA

Study Area --

In GCA's draft work plan (March, 1986), GCA divided the New Bedford Harbor area into ten distinct goegraphical zones for describing the potential study area. These zones, depicted in Figure 1, are described as follows:

- Zone 1. Acushnet River, from the cranberry bogs to the Coggeshall Bridge.
- Zone 2. Middle harbor area, from the Coggeshall Bridge to the Pope's Island (Hutchinson Road or Route 6) Bridge.
- Zone 3. Lower Inner Harbor, Pope Island to the Hurricane Barrier.
- Zone 4. Outside the Hurricane Barrier to a line reaching from the eastern end of Fort Phoenix to a point on shore directly west of the Butler Flats Lighthouse.
- Zone 5. From Zone 4 south to Sconticutt Point.
- Zone 6. Clark's Cove.
- Zone 7. South from Sconticutt Point to the fishing restriction line.
- Zone 8. Outside the fishing restriction line.
- Zone 9. Appaganonsett Bay.
- Zone 10. All points outside the above zones (includes parts of Nasketucket Bay).

The environmental assessment will focus on the following areas:

Zones 1 through 7 (i.e., all zones within the fishing enclosure limit), with particular emphasis on Zones 1-4, which are the areas of highest contamination (and presumably highest environmental damage) and are also the areas around the potentially responsible parties.

The Environmental Assessment will confine itself to aquatic habitats. The wetlands and surrounding terrestrial habitats in the vicinity of the New Bedford Harbor will not be evaluated as part of of this Environmental Assessment. The wetlands are being evaluated as part of an ongoing Environmental Assessment being conducted by the U.S. Army Corps. of Engineers.

The study area, outlined with solid black lines in Figure 1, includes all land water included in the area from a line at the south edge of Zone 7 and north to the top of the harbor. The Public Health Assessment will focus on the following areas:

- Areas where the potential for human contact with contaminated sediments is high and the potential for air emissions exist (e.g., contaminated mudflats, beaches, or waters);
- Areas where high ambient air concentrations of PCB have been measured.
- Zones 1-7 in the harbor for biota data.

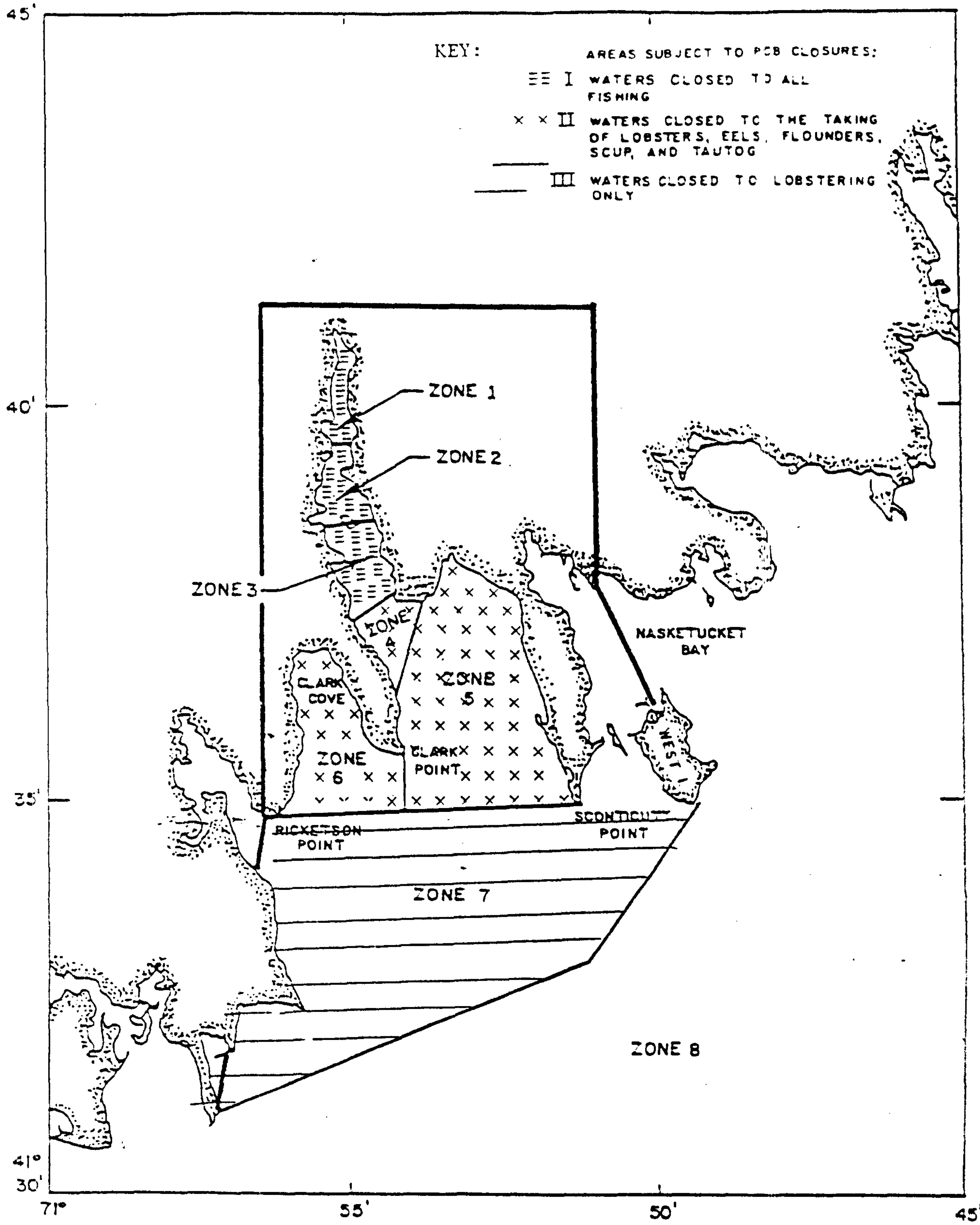


Figure 1. Endangerment assessment study area.