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316 DEMONSTRATION
FOR
PILGRIM NUCLEAR POWER STATION
UNITS 1 AND 2

JULY 1975

PREPARED BY
ENVIRONMENTAL ENGINEERING DIVISION
STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS 02107

J.O. 12577

316 DEMONSTRATION
PILGRIM NUCLEAR POWER STATION
UNITS 1 AND 2
BOSTON EDISON COMPANY

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ABSTRACT

The following document is a demonstration pursuant to Sections 316(a) and 316(b) of the Federal Water Pollution Control Act for Pilgrim Station, Units 1 and 2. The demonstration includes aspects of Type 2 and Type 3 demonstrations as defined in the draft guidance manual published by the Environmental Protection Agency in September 1974.

The demonstration analyzes engineering, hydrological and biological, data pertaining to Pilgrim Station and the surrounding waters of Cape Cod Bay. It presents an assessment of the environmental effect of Pilgrim Station on the surrounding waters of Cape Cod Bay.

The assessment is supported by an analysis which conservatively establishes quantitative estimates of station-induced mortality for each of the representative species. The assessment concludes that no adverse effect to a balanced indigenous population of shellfish, fish, and wildlife in the surrounding waters is expected as a result of the operation of Pilgrim Station, Units 1 and 2, with the proposed once-through cooling systems. It demonstrates that environmental effects resulting from the operation of the proposed once-through cooling systems associated with Pilgrim Station, Units 1 and 2, are minimal and that the requirement to provide closed-cycle cooling is more stringent than is necessary to ensure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife in and on the receiving waters.

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SECTION 1

INTRODUCTION

The Federal Water Pollution Control Act Amendments of 1972 require steam electric generating power stations such as Pilgrim Station to have the best available control technology by 1983 for minimizing the discharge of pollutants. This has been interpreted for thermal discharges as some form of closed-cycle cooling. Under the 316(a) exemption, alternate effluent limitations may be granted if the Applicant can demonstrate that the effluent limitations are more stringent than are: "... necessary to assure the protection and propagation of a balanced indigenous population of shellfish, fish and wildlife in and on the body of water into which the discharge is to be made...". With respect to the effects associated with the intake, Section 316(b) of the Federal Water Pollution Control Act Amendments of 1972 specifies that the location, design, construction, and capacity of the cooling water intake structure shall reflect the best technology available for minimizing adverse environmental impact.

This report considers the effects of both the station discharge and intake, and addresses both Section 316(a) and 316(b) requirements. It utilizes technical guidance from both Type II and Type III demonstrations, as described in the draft technical guidance manual used by the Environmental Protection Agency in September 1974.

Since the proposed Unit 2 discharge will be combined with the Unit 1 discharge, this demonstration considers the combined effects of both units 1 and 2.

The data for the analysis of ecological, engineering, and hydrologic information on which the 316 demonstration is based are reported in the Applicant's Environmental Report and AEC Environmental Impact Statements for Pilgrim Station. Various reports and results of environmental and engineering studies associated with Pilgrim Station have been used. Pertinent scientific literature has also been used and referenced in preparation of the demonstration.

The demonstration presents data describing the oceanography of the water surrounding Pilgrim Nuclear Power Station. The design and operation of this station is described as it affects the intake and discharge of the circulating water system.

The aquatic community of Cape Cod Bay and the water surrounding Pilgrim Station is also described; these include benthic communities, planktonic communities, and fish communities.

The report outlines the rationale for selection of representative species considered by the demonstration. A list of species is given, and the rationale supporting the selection of each species is developed. Life history characteristics of the representative species are also described.

The demonstration contains assessments of Pilgrim Station's impact on the representative species. The analysis considers the effects of entrainment into the circulating water system, entrapment at the intake structures, and effects relating to the thermal discharge of the station. The impact assessment approach in this document is to identify potential impacts which could occur, and, based on available data and expected station characteristics, to quantify the effects of the station on representative species.

This analysis requires that a number of conservative assumptions be made which overstate the magnitude of the station-induced effects. This results, however, in quantitative impact determinations which otherwise would not be possible.

A summary is presented containing the predictions developed in the quantitative analysis and provides judgments relating to the expected environmental impact caused by Pilgrim Station.

SECTION 2

ENGINEERING AND HYDROLOGIC DATA

This section presents engineering data relating to the design and operation of the circulating water systems for Pilgrim Station. Oceanographic information for Cape Cod Bay and the waters surrounding the station are also presented. This material has been selected on the basis of its relevancy to the 316 Demonstration. Additional and more detailed information may be obtained from the final environmental report for Pilgrim Station, and the semi-annual reports listed in Appendix A which describes marine ecology and hydrothermal studies.

2.1 OCEANOGRAPHY

Physical oceanographic characteristics near Pilgrim Station are influenced primarily by characteristics of the Atlantic Ocean and of Cape Cod Bay. The station location relative to Cape Cod Bay is shown in Figure 2-1.

Cape Cod Bay is a broad, open-mouthed water body formed by the eastward and northward extension of Cape Cod from the coast of Massachusetts. The mouth is not well marked on the western side, but for the purpose of this description a line extending from Race Point westward to Green Harbor is considered to designate the mouth of Cape Cod Bay. The length of this line is 17.5 nautical miles. The Bay's greatest width (24 nautical miles) is along an east-west line near its southern limits. The north-south dimension of the Bay is slightly less than 20 nautical miles.

Cape Cod Bay has a surface area of approximately 365,000 acres. Except for the southeast corner of the Bay at Billingsgate Shoal, depths generally increase rapidly with distance from the shore. The greatest depth, approximately 180 feet, occurs at the mouth of the Bay. Approximately half the surface area of the Bay has depths greater than 100 feet; the volume-mean depth is also approximately 100 feet. The water volume of Cape Cod Bay is approximately 3.6×10^7 acre-feet.

Stellwagen Bank is located north of Race Point, outside Cape Cod Bay. Stellwagen Bank influences the physical oceanography of Cape Cod Bay, particularly in its effect on wave action. The Bank is an area with typical minimum water depths of 80 feet. For the purpose of this description, the limit of the Bank is defined by the 120-foot depth contour. The Bank is approximately 20 nautical miles long and varies in width from 2 nautical miles at its northern end to 7 nautical miles at its southern boundary.

These waters in the vicinity of the site are assigned to Class SA, Coastal and Marine Waters, of the Massachusetts Water Quality Standards adopted by the Massachusetts Division of Water Pollution Control on March 3, 1967. Table 2-1 presents the standards of quality for Class SA waters.

The following sections provide details on tides, waves, currents, bay-flushing, and temperatures, of the waters in the vicinity of Pilgrim Station.

2.1.1 Tides

Tides at Pilgrim Station are semidiurnal (two high waters and two low waters each 24-hour period). Tide records for the area are available from the U.S. Coast and Geodetic Survey Tide Stations located in Boston Harbor. Tide data are published annually for Gurnet Point and Plymouth.

Tide levels at Pilgrim Station are similar to those at Boston. The mean tidal range at Boston is 9.1 feet, and the spring tidal range is 10.6 feet. The datum relationship at Pilgrim Station is that mean sea level is 4.78 feet above mean low water (MLW). The estimated average yearly maximum astronomical high tide is +11.7 feet MLW, and the estimated average yearly minimum astronomical low tide is -2.3 feet MLW.

The highest still-water tide level recorded in this area is +15.3 feet MLW. This level occurred at Boston on February 24, 1723. Tide levels of +14.8 feet MLW have occurred once in 1851 and again in 1909.

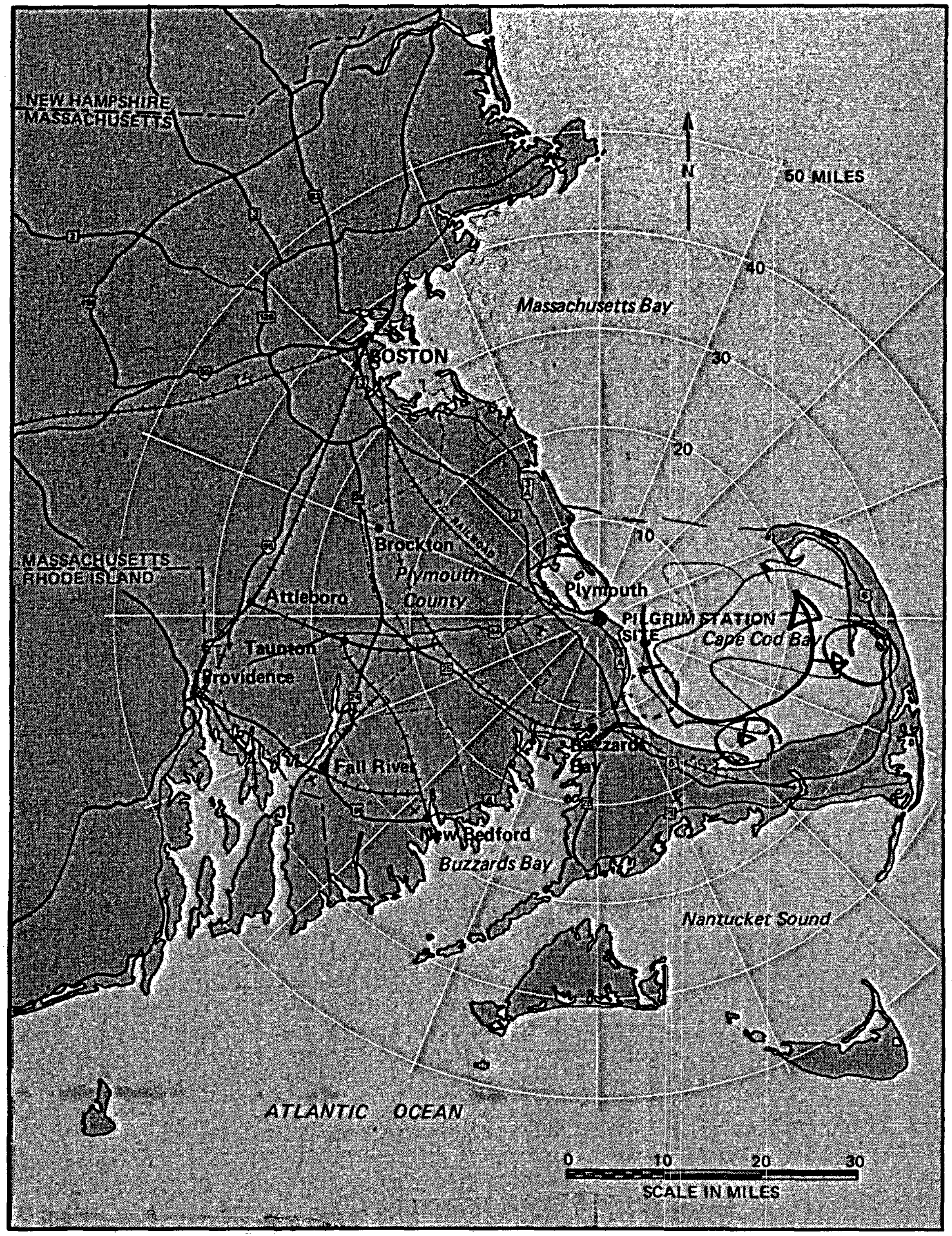
2.1.2 Waves

The Pilgrim Station site is exposed to waves generated in the North Atlantic and that approach the site from the north through 60 degrees east of north (N 60°E). The site is sheltered from other distantly generated wave-approach directions by Cape Cod to the east and the Massachusetts and Maine coastlines to the north. Wave refraction analysis has indicated that the maximum-period wave that can reach the area of the site without being significantly diminished in height by refraction is approximately 12 seconds.

The site is exposed to locally generated waves from direction N 20°E through S 60°E. However, all directions except those from N through N 60°E are fetch-limited.

2.1.3 Currents

The general current regime near the Pilgrim site is a function of tidal currents, geostrophic counterclockwise circulation in Cape Cod Bay, wind-induced motion, nearshore wave-induced current, and, at the station site, local currents induced by the Unit 1



from
Pilgrim Nuclear Power Station
Environmental Report - Unit 2

FIGURE 2-1

LOCATION OF PILGRIM SITE

TABLE 2-1

COMMONWEALTH OF MASSACHUSETTS WATER QUALITY STANDARDS FOR COASTAL AND MARINE WATERS ASSIGNED TO CLASS SA

	Item	Criteria
(1)	Dissolved oxygen	Not less than 6.5 mg/l at a time
(2)	Sludge deposits/solid refuse/floating solids/oil/grease/scum	None allowable
(3)	Color and turbidity	None in concentrations that will impair any usage specifically assigned to this class
(4)	Coliform bacteria per 100 ml	Not to exceed a median value of 70 and not more than 10 samples shall ordinarily exceed 230 during any monthly sampling period
(5)	Taste and odor	None allowable
(6)	pH	6.8 to 8.5
(7)	Allowable temperature increase	None except where increase will not exceed recommended limits on the most sensitive water use
(8)	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal, or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses
(9)	Radioactivity	None in concentrations or combinations which would be harmful to human, animal, or aquatic life for the designated water use. None in such concentrations that would result in radionuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans
(10)	Total phosphate	Not to exceed an average of 0.07 mg/l as P during any monthly

TABLE 2-1 (CONT'D)

Item	Criteria
	sampling period
(11) Ammonia	Not to exceed an average of 0.2 mg/l as N during any monthly sampling period

Note: Class SA = Suitable for any high quality water use including bathing and water contact sports; suitable for approved shellfish areas.

circulating-water intake and discharge. Studies indicate that the tidal component of the currents is weak in the inshore waters off the station site out to a distance of about 3/4 mile from shore (water depths 40 feet and less). The local water movement near the station site is strongly to wind action.

2.1.3.1 Tidal Currents

Results of measurement and analysis of tidal currents at Gurnet Point, Manomet Point, and 1 mile E of Ellisville Harbor have been published by the U.S. Coast and Geodetic Survey. Tidal currents along the western and southwestern side of Cape Cod Bay are generally directed parallel to the coast, except in or near the entrances to appended harbors. Maximum ebb and flood currents appear to vary considerably for the three U.S. Coast and Geodetic Survey locations nearest the station site. The maximum tidal currents for the Gurnet Point, Manomet Point, and Ellisville Harbor area vary from 0.3 to 1.4 knots.

Maximum tidal currents determined from measurements at stations located approximately 1/2 mile and 1 mile offshore from the Pilgrim site are 0.08 knot and 0.25 knot, respectively. The direction of these current changes with tidal stage in an elliptical rotary fashion.

2.1.3.2 General Circulation

Information on the general pattern of flow in the northwest Atlantic off the coasts of the New England states and the Maritime Provinces of Canada shows that a coastal current flows southward along the coast of Maine and Massachusetts (Oceanographic Atlas of the North Atlantic Ocean, Section I: Tides and Currents, U.S. Naval Oceanographic Office Publication No. 700). A portion of the flow enters Cape Cod Bay along the western shore of the Bay, circulates counterclockwise, and leaves the Bay on the eastern side. The flow then swings eastward around Cape Cod and finally southward. Interpolation of the isopleths of mean speed given in Reference 5 suggests that the probable average speed of this counterclockwise flow in the bay is not less than 0.3 foot per second.

2.1.3.3 Wind-Induced Motion

The speeds associated with the tidal motion and with the general circulation pattern in Cape Cod Bay are in a range suggesting that wind-induced motion will at times dominate the flow. Wind blowing over deep water produces a direct wind-driven motion in the surface layers directed to the right of the wind in the Northern Hemisphere. In shallow water, the wind-induced flow is more nearly in the direction of the wind. The speed of the wind-induced surface flow has been shown to be roughly 2 percent of the wind speed.* Thus, a wind speed of 15 knots would induce a surface current of about 0.3 knot or 0.5 foot per second.

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*Applies for wind speeds measured at 30 feet above water surface.

2.1.3.4 Wave-Induced Motion

Waves approaching the shore at an angle will induce longshore currents. The Pilgrim Station site is exposed to wave action N through N 60° E, and it can therefore be expected that wave-induced current will generally be directed down the coastline toward the southeast, i.e., in the same direction as flood-tide currents and the geostrophic circulation in Cape Code Bay. Additional longshore currents may be induced by the mass transport of water towards shore by waves.

2.1.4 Bay Flushing

The waters of Cape Cod Bay are exchanged for "new" water from outside the bay by at least three processes:

- Tidal exchange
- The general counterclockwise circulation
- Wind-induced motion

These processes are amenable to first-order numerical estimates of the fractional rate at which the waters of the Bay are replaced by "new" water.

2.1.4.1 Initial Estimates of Flushing Rate

Prior to the availability of any long-term current meter measurements in Cape Cod Bay, the flushing rate was estimated by Dr. D.W. Pritchard of the Chesapeake Bay Institute as follows.

The intertidal volume (i.e., the difference in the volume of the Bay at high water and at low water) represents approximately 9.3 percent of the mean volume of the Bay. This means that 9.3 percent of the volume of the Bay moves in and out through the mouth each tidal cycle. Experience in other coastal water bodies has shown that perhaps as much as 70 to 80 percent of the water that leaves the Bay on ebb tide returns to the Bay on the next flood. The remaining 20 to 30 percent represents new water, and two tidal cycles occur each 24.84 hours. Assuming a 20 percent exchange rate on each tidal cycle, the Bay water renewal rate by tidal action is thus about 3.5 percent per day.

The inflowing current at the mouth of the bay, with a mean speed of at least 0.3 foot per second, is conservatively estimated to occupy at least a third of the cross-section of the mouth. The mean depth at the mouth of the Bay is 150 feet, and the width is 17.5 nautical miles or 1.06×10^5 feet. The cross-sectional area of the mouth is therefore 1.6×10^7 square feet, and the fractional rate of renewal by inflowing current is about 8.8 percent per day.

The early estimates did not attempt to quantify the flushing action related to wind-induced motions. When all circulation effects are taken into account, however, it was estimated that the mean renewal rate would be at least 12.3 percent per day. A renewal rate of 12.3 percent per day would provide a mean residence time of 8 days for water or for any water-borne component.

2.1.4.2 1974 Analysis of Flushing Rate

The description given above of the long-term mean circulation into and out of Cape Cod Bay, and within the Bay, was based on data summarized on charts contained in Oceanographic Atlas of the North Atlantic Ocean, Section I, Tides and Currents, U.S. Naval Oceanographic Office Publication No. 700. The estimate of 0.3 ft sec^{-1} for the current flowing into the Bay along the western shore was obtained by interpolation of the isopleths of mean speed given in the referenced publication.

Analysis of current meter data collected at Station A, located in 32 feet of water (MLW) approximately one-half mile offshore from the plant site for the period April 20, 1973, through August 28, 1973; and at Station B, located in 53 feet of water (MLW) approximately 1.3 miles offshore from the plant site for the period August 14, 1973 through November 1, 1973 gives the following results. Tidal currents at both stations exhibit an elliptical rotary flow, with an amplitude of 0.14 foot sec^{-1} at the inshore station and 0.42 foot sec^{-1} at the offshore station. The long-term mean nontidal current at Station A was 0.038 foot sec^{-1} directed toward the ESE, and at Station B, 0.040 foot sec^{-1} directed toward SE. These values are considerably less than the 0.3 foot sec^{-1} flow which had previously been estimated as the speed of the nontidal counter-clockwise flow around the Bay. The low values of long-term mean nontidal current observed at Station A and Station B do not negate the possibility that a circulation having current speeds on the order of 0.3 foot sec^{-1} exists further offshore from the plant site. However, these observations do warrant a re-evaluation of the flushing rate of Cape Cod Bay.

The analysis of the current observations at Station A and Station B shows that the short-term nontidal residual current is directed very nearly parallel to shore, and is strongly correlated with the wind velocity. The wind factor relating the speed of the wind measured at 300 feet elevation to the speed of the wind-induced current varied depending on the angle of attack of the wind at the coastline, with an average value over all wind directions of 0.0082. This is consistent with the accepted value of approximately 2 percent for winds measured at anemometer height (30 feet), and approximately 1.5 percent for winds measured at 75 feet elevation.

In view of the lack of verification of the assumed flushing flow through Cape Cod Bay having a speed of about 0.3 foot sec^{-1}, consideration of two other flushing mechanisms is pertinent. In evaluating the rate of supply of new dilution water to Cape Cod Bay, it is the long-term (on the order of annual) mean flushing rates which should be considered. To see this, note that the ratio of the volume of Cape Cod Bay (1.6×10^{12} ft^3) to the rate of discharge of condenser cooling water flow gives the time interval over which this volume could supply the condenser cooling water flow for the plant. For Unit No. 1 alone, this time interval is 70 years and for Unit No. 1 plus Unit No. 2, the subject ratio is 21 years. The significance of these relatively long time periods is that the volume of Cape Cod Bay acts as an effective buffer, smoothing out short-term variations in the flushing rate of the Bay.

The annual mean flushing rate of Cape Cod Bay due to wind-induced circulation is considered as follows. The Bay opens to the north, so that a wind having a component from the north would set up an inflow into the Bay over the upper layers of the water column and an outflow from the Bay over the lower layers of the water column. A wind having a component from the south would set up an outflow in the upper layers and an inflow in the lower layers. An analysis of the annual wind rose observed at the 72-foot level at the Pilgrim Station gives a value of 9.5 mph for the average north component of the wind for winds from the northern semi-circle. The average south component of the wind for winds from the southern semi-circle is also 9.5 mph. The wind-induced surface currents resulting from a 9.5-mph wind, as measured at 72 feet elevation, would be 0.21 foot sec^{-1} (since the wind factor for winds measured at this elevation is approximately 1.5 percent). This current would flow out of the Bay for winds having a component from the south and into the Bay for winds having a component from the north, with a counter flow occurring in each case in the deeper layers. Both observation and theory suggest that the steady-state wind-induced flow in such situations varies linearly with depth in the upper half of the water column. Thus, the mean speed of the wind-induced circulation over the upper layers would be 0.105 foot sec^{-1}.

The approximately east-west cross-section marking the mouth of Cape Cod Bay has an area of 1.6×10^7 ft^2. The wind-induced inflow to the Bay for the average northerly component of the wind, or outflow from the Bay for the average southerly component of the wind, would occur over about the upper one-half of the cross-section. The rate of supply of "new" dilution water to the Bay as a result of wind-induced circulation is then, on an annual average, approximately 7.21×10^{10} ft^3 day^{-1}. This corresponds to a renewal rate of the volume of the Bay due to wind-induced circulation of:

$$\frac{7.21 \times 10^{10} \text{ ft}^3 \text{ day}^{-1}}{1.6 \times 10^{12} \text{ ft}^3} = 0.045 = 4.5\% \text{ per day}$$

The mean range of tides in Cape Cod Bay is 9.3 feet. Since the tide is very nearly a standing wave, and since the volume mean depth of the Bay is about 100 feet, the fractional change in volume of the Bay during one tidal cycle is 0.093, or 9.3 percent.

Though the interpolation of the isopleths of mean current speed given in <u>Oceanographic Atlas of the North Atlantic Ocean, Section I, Tides and Currents, U.S. Naval Oceanographic Office Publication No. 700</u>, is questionable for flows within Cape Cod Bay. This procedure is probably valid for the flow which moves southward along the coast of Maine and Massachusetts, then eastward across the mouth of the Bay and around Cape Cod. The average speed across the mouth of the Bay, as deduced from the above-referenced document, is about 0.36 foot sec^{-1}. Hence, during a tidal cycle the water off the mouth of Cape Cod Bay is displaced eastward by 1.61×10^4 feet, or 0.151 of the length of the cross-section at the mouth. Therefore, an average of at least 15.1 percent of the water which leaves the bay on each ebb tide does not re-enter the Bay on the next flood tide, being replaced by "new" water. Therefore, the rate of renewal of Cape Cod Bay by tidal flushing, considering that one tidal cycle takes 12.42 hours is:

$$0.093 \times 0.151 \times \frac{24.00}{12.42} = 0.027 \text{ or } 2.7\% \text{ per day}$$

The combined wind-induced and tidal flushing rate of Cape Cod Bay on a long-term time scale is then 7.2 percent of the volume of the Bay per day. Consequently, the rate of supply of new water to the Bay by these two processes is 1.15×10^{11} ft^3 day^{-1}, or 1.33×10^6 ft^3 sec^{-1}. Also, the mean residence time for water, or for any <u>conservative</u> water-borne contaminant introduced into the bay, would be 13.9 days.

2.1.5 Temperatures

Water temperatures off the Pilgrim Station site have been studied since August 1967, and nearly continuous records have been obtained since June 1970. Temperature patterns have been shown to be highly variable, the variability being influenced primarily by wind-controlled water circulation.

2.1.5.1 Long-Term Temperature Studies

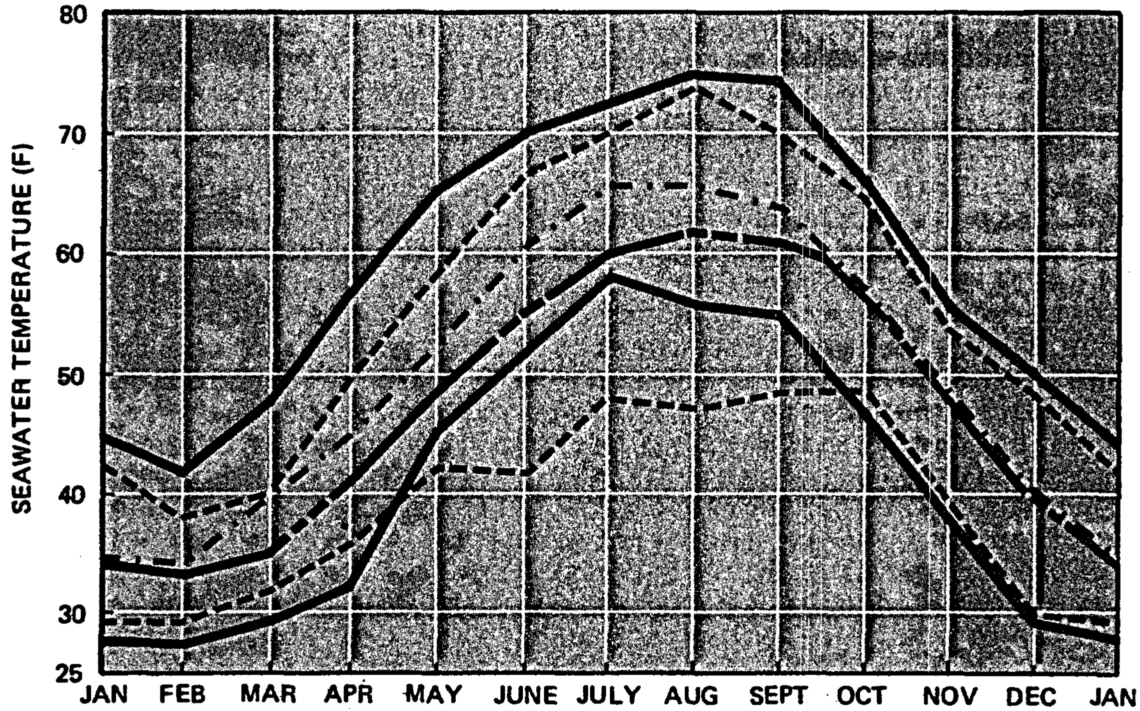
Data on seawater temperature over a long term have been reported from U.S. Coast and Geodetic Survey Tide Stations at Boston, north of the site, and at the eastern entrance of Cape Cod Canal, south of the site. Surface temperatures are measured daily at each station with a single bucket thermometer. The depth of water at both stations is about 10 feet MLW. Records are available for Boston from 1922 to present and for Cape Cod from 1955 to present. Bottom water temperature has been recorded continuously at Boston since 1955. Figure 2-2 shows maximum, minimum, and mean surface temperatures for the Cape Cod Canal and Boston Tide Stations.

Historical records of water temperatures measured at Boston Light Ship and at the east end of Cape Cod Canal (see Figure 2-2) show the wide range of naturally occurring surface temperatures (seasonal variations and year-to-year fluctuations) occurring in the total region of ocean waters between outer Boston Harbor and Cape Cod Canal. Peaks of these long-term temperature ranges are believed to be greater than long-term peak ambient temperatures closer to the Pilgrim site. This is because the water at those somewhat distance sites includes major warm-water intrusions, whose influence is not expected to be felt nearly as much near the Pilgrim site. These influences are (a) Buzzards Bay water coming through the canal, which strongly influences average temperatures at the east end of Cape Cod Canal, and (b) water from Boston Harbor and rivers north of Cape Cod Bay, which influences the Boston Light Ship temperature data. The data below are consistent with this interpretation.

2.1.5.2 Temperature Studies at the Site

Temperature is recorded at a station approximately 2,000 feet offshore from the Pilgrim Site by the Commonwealth of Massachusetts Division of Marine Fisheries. Recordings are made at 2 feet, 10 feet, and 30 feet (bottom) below water level. Daily averages, as well as a daily minimum and maximum temperatures from the data obtained from June 1970 to December 1973, are shown in Figures 2-3 to 2-12. Seasonal temperature changes and weekly ranges of the temperatures from these recorders are illustrated in Figure 2-10. Continuous temperature data from the offshore stations and the Unit 1 intake records for calendar year 1973 are shown in Figures 2-11A and B through 2-12A and B. This data is considered to be much more representative of seasonal changes at the station intakes than are the data shown in Figure 2-2, since the water body near the site is not subject to the strong influence of warmer water from either Buzzards Bay or from Boston Harbor. Close examination of the offshore temperature data reveals large daily fluctuations (typically 5°F to 10°F) superimposed on the more gradual seasonal changes in weekly and monthly average temperatures.

The seasonal variations are significantly greater near the surface of the Bay than on the bottom, and seasonal climatic changes produce a strong temperature stratification during the summer months. Generally during the summer and early fall, the Bay temperatures exhibit a 2-layer structure in which a very strong temperature gradient exists at the interface of the two layers (with temperatures decreasing with increasing water depth). More gradual temperature changes generally occur over the entire depth of the water column within this 2-layer structure. The location (depth) of the "interface" of this 2-



LEGEND

MAXIMUM AND MINIMUM MONTHLY TEMPERATURES

BOSTON

CAPE COD CANAL

MEAN MONTHLY TEMPERATURES

BOSTON

CAPE COD CANAL

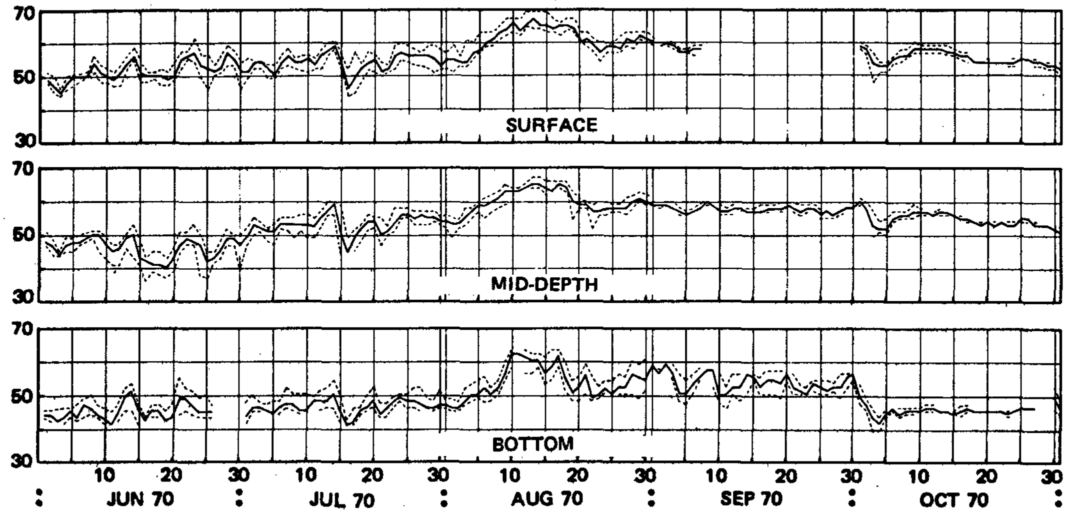
COMPILED FROM:

Surface Water Temperature & Salinity — Atlantic Coast of N. & S. America
Pub. 31-1, 2nd Edition, 1965 U.S. Dept. of Commerce, Coast and Geodetic Survey.

[from
Pilgrim Nuclear Power Station
Environmental Report - Unit 2]

FIGURE 2-2

SURFACE WATER TEMPERATURES AT CAPE COD CANAL AND BOSTON TIDE STATIONS



[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

FIGURE 2-3.

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (JUNE 1970 - OCTOBER 1970)

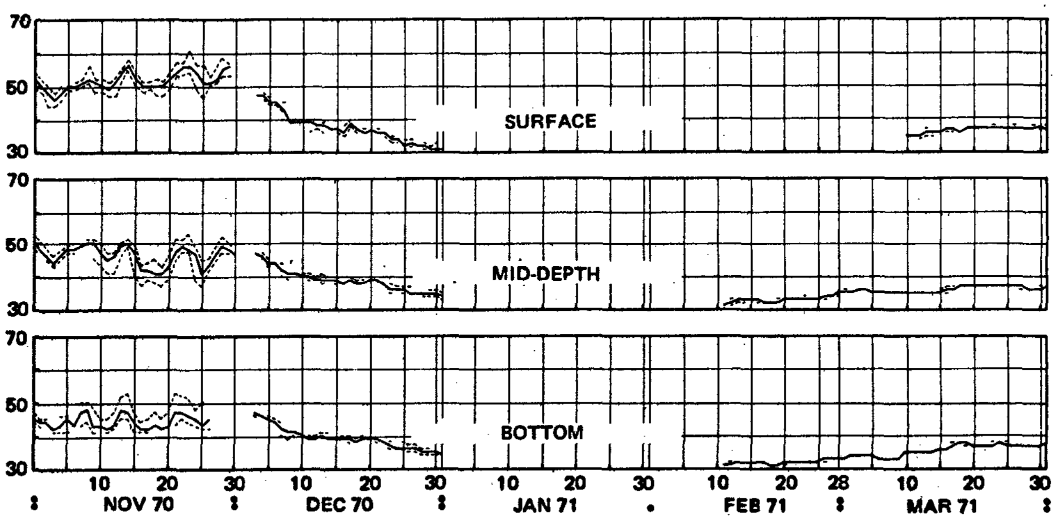


FIGURE 2-4.

[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (NOVEMBER 1970 - MARCH 1971)

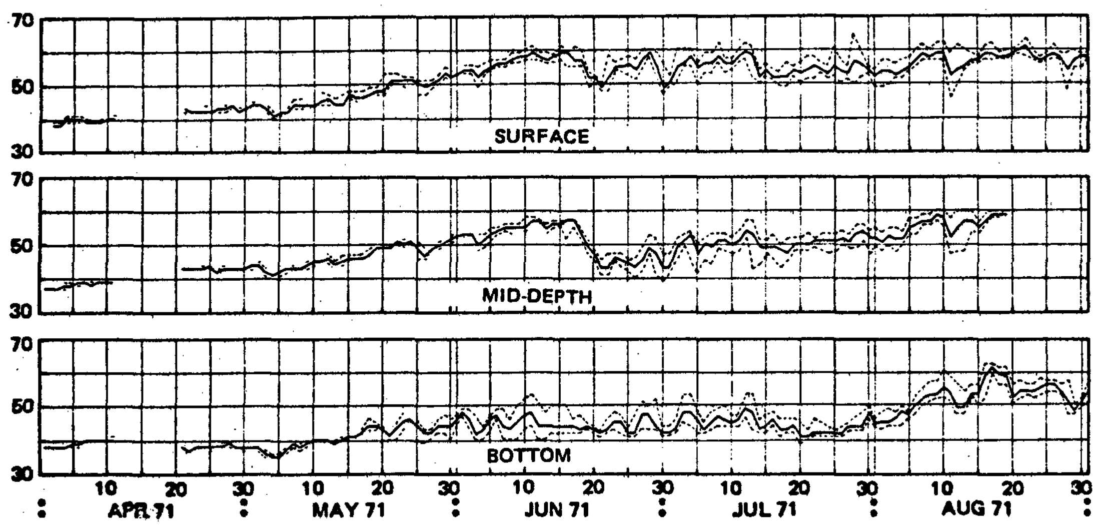


FIGURE 2-5

[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (APRIL 1971 - AUGUST 1971)

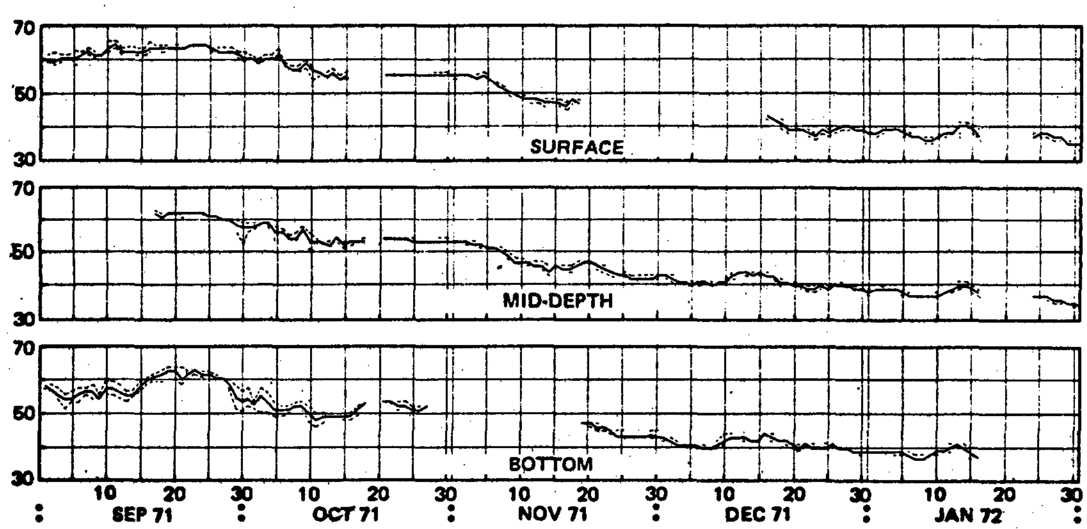
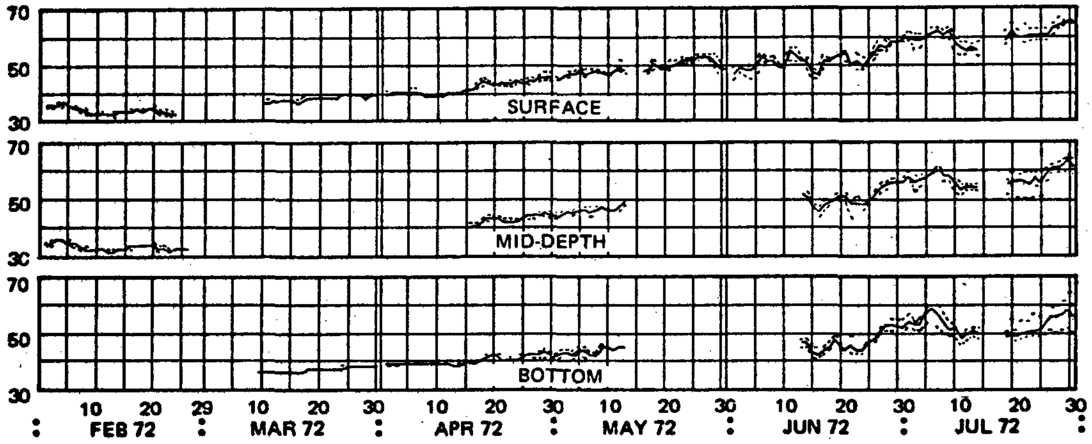


FIGURE 2-6.

[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (SEPTEMBER 1971 - JANUARY 1972)



from
Pilgrim Nuclear Power Station
Environmental Report - Unit 2

FIGURE 2-7

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (FEBRUARY 1972 - JULY 1972)

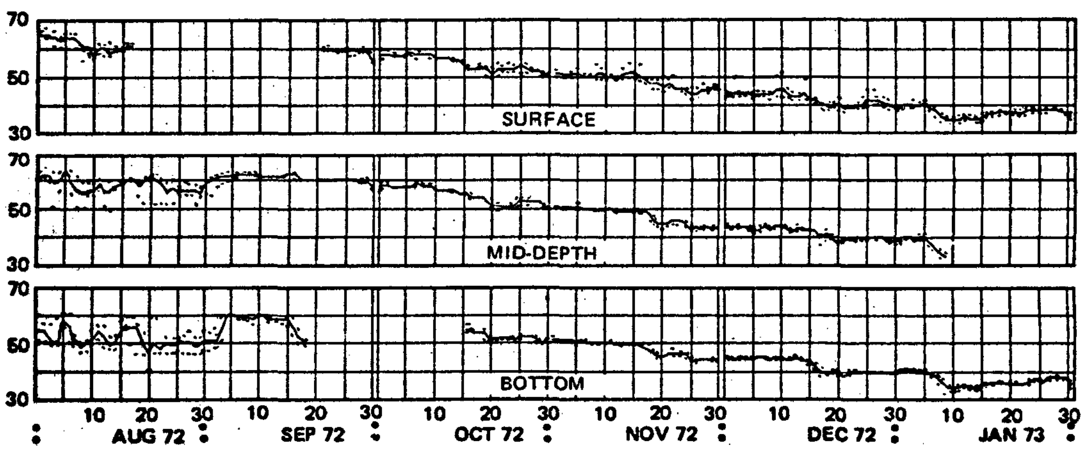


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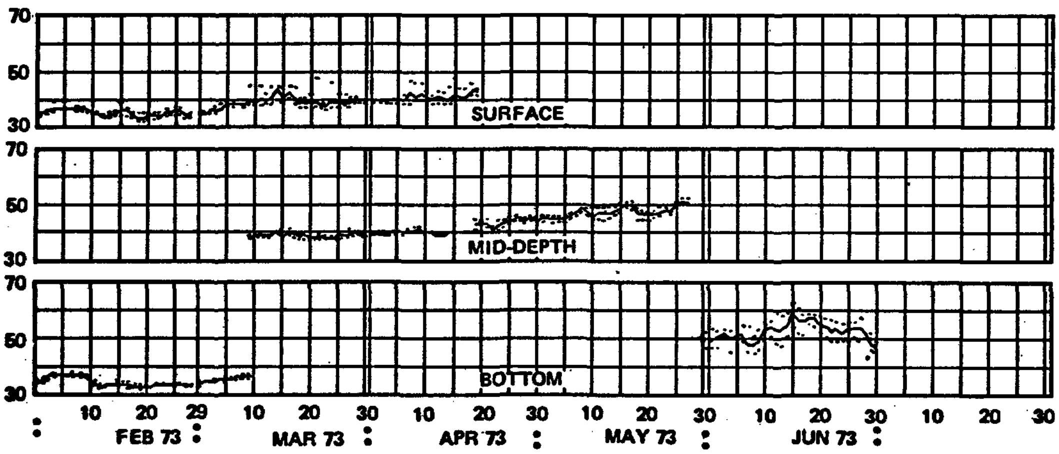
FIGURE 2-8

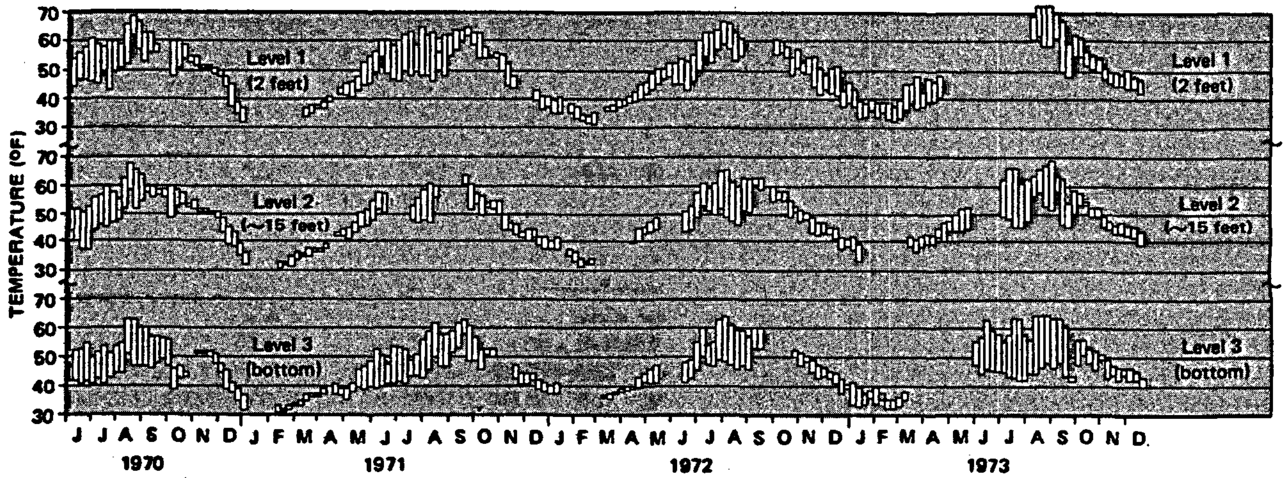
DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (AUGUST 1972 - JANUARY 1973)



[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

FIGURE 2-9

DAILY MAXIMUM, MINIMUM, AND AVERAGE TEMPERATURES AT VARIOUS DEPTHS, OFFSHORE PILGRIM STATION (FEBRUARY 1973 - JUNE 1973)



[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

FIGURE 2-10

WEEKLY TEMPERATURE RANGES EXTRACTED FROM THERMOGRAPH RECORDS AT THREE DEPTHS layer temperature structure is generally referred to as the thermocline. The progressive formation of the seasonal thermocline in Cape Cod Bay near the Pilgrim Station is illustrated in Figure 2-13, which shows the detailed temperature profile as measured by M.I.T. survey teams at various times of the year. These measurements were made in the vicinity of the station, but outside the detectable influence of the Unit 1 discharge. Exact locations associated with each profile are given in the appropriate references of ambient temperatures near the site were summarized as follows (Semi-Annual Report No. 2, Section IV):

"A definite 2-layer structure is found to develop in late spring with a thermocline depth varying between 5-10 m, apparently moving up and down with an ebbing and flooding tide, respectively. Little variation was found in hydrographic profiles (temperature and salinity versus depth) going along the coastline from north of Rocky Point to White Horse Beach. The position of the thermocline did not change in the direction perpendicular to the coastline."

The temperature vs. depth profile shown for 8/30/73 in Figure 2-13 indicates that at the warmest time of the year the depth of the thermocline is close to the same depth as the bottom thermograph from which near-continuous records are shown in Figures 2-2 through 2-12B. The very strong (~15°F) fluctuations in bottom temperatures 1/2-mile offshore during the summer months (Figure 2-12B) are apparently due to fluctuations in the position of the thermocline relative to this location. The frequency of these particular temperature fluctuations generally corresponds to the frequency of the tidal cycle.

During the summer months, when appreciable stratification occurs in the ambient sea waters, the station intakes are expected to draw primarily water whose temperature is between the temperatures recorded at the surface and those at the bottom of the water column at the offshore monitoring station.

Average intake water temperatures, are expected to be slightly higher than temperatures experienced in the absence of the station's thermal discharge due to a small degree of recirculation. Based on the first one-half year of Pilgrim Unit 1 operation, the effect of recirculation on the long-term average intake temperatures is not expected to be significant. This is based on a comparison of the monthly average temperatures obtained from the offshore station at three depths with the measurements of monthly average condenser intake temperatures at Unit 1. These data are shown in Table 2-2 for the period December 1972 to December 1973.

Results of a one-week ambient temperature study performed in September 1971 are shown in Figure 2-14 which include:

- Hourly temperatures at the surface and bottom for a station approximately 1/4 mile off the site (-20 feet MLW),

- Average 10-foot-deep mean current vector, 1/2-mile offshore,

- Anemometer data for the 70-foot station at the onsite meteorological tower, and

- Times of high tide at Plymouth.

Comparison of wind and current data shows the wind vector directed offshore, while the 10-foot-deep current vector onshore, which indicates that the wind-controlled surface current did not extend to the 10-foot water-column level. Noted during the study were periods of upwelling followed by periods of downwelling. This was demonstrated by the general decrease in bottom temperatures during the offshore wind period (upwelling), followed by an increase during the onshore wind period (downwelling). Bottom temperatures at the recording station (-20 feet MLW) are shown to correlate closely with the tide stage, in a fashion similar to bottom temperatures at the -30-foot MLW station previously discussed.

The rapid drop of bottom temperature, usually within an hour of high tide, indicates that the upper limit of the cooler incoming deep floodtide water was close to the depth of the instrument (-20 feet MLW). This seasonal thermocline exists during approximately June through late October and November. The study indicates that fluctuations in the water-column temperatures also occur due to:

- Upwelling, when the offshore winds push the warm surface waters away and allow the cooler bottom waters to be brought to the surface,

- Downwelling, when the onshore winds tend to pile up the warmer surface waters causing them to sink until the entire water column becomes well-mixed, and

- Turbulence, when the wind-generated waves mix the surface and bottom waters.

2.2 STATION CHARACTERISTICS

Pilgrim Station Units 1 and 2 are considered base-loaded, nuclear-powered electrical generating units designed to produce 655 mW and 1,180 mW of electrical energy, respectively, under full load conditions. The units are planned for an anticipated capacity factor of 80 percent. This represents operation of the units over a wide range of load conditions, such that the overall capacity averages 80 percent. For the purpose of this

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

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FIGURE 2-11A:
"COMPARISON OF OFFSHORE AND UNIT 1 INTAKE SEAWATER TEMPERATURES - JANUARY THRU MARCH, 1973"

WITHIN THIS PACKAGE... OR,
BY SEARCHING USING THE DOCUMENT/REPORT
FIGURE 2-11A

D-01

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FIGURE 2-11B:
"COMPARISON OF OFFSHORE AND UNIT 1 INTAKE SEAWATER TEMPERATURES - APRIL THRU JUNE, 1973"

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FIGURE 2-11B

D-02

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FIGURE 2-12A:
"COMPARISON OF OFFSHORE AND UNIT 1 INTAKE SEAWATER TEMPERATURES - JULY THRU SEPTEMBER, 1973"

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FIGURE 2-12A

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FIGURE 2-12B:
"COMPARISON OF OFFSHORE AND UNIT 1 INTAKE SEAWATER TEMPERATURES - OCTOBER THRU DECEMBER, 1973"

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D-04

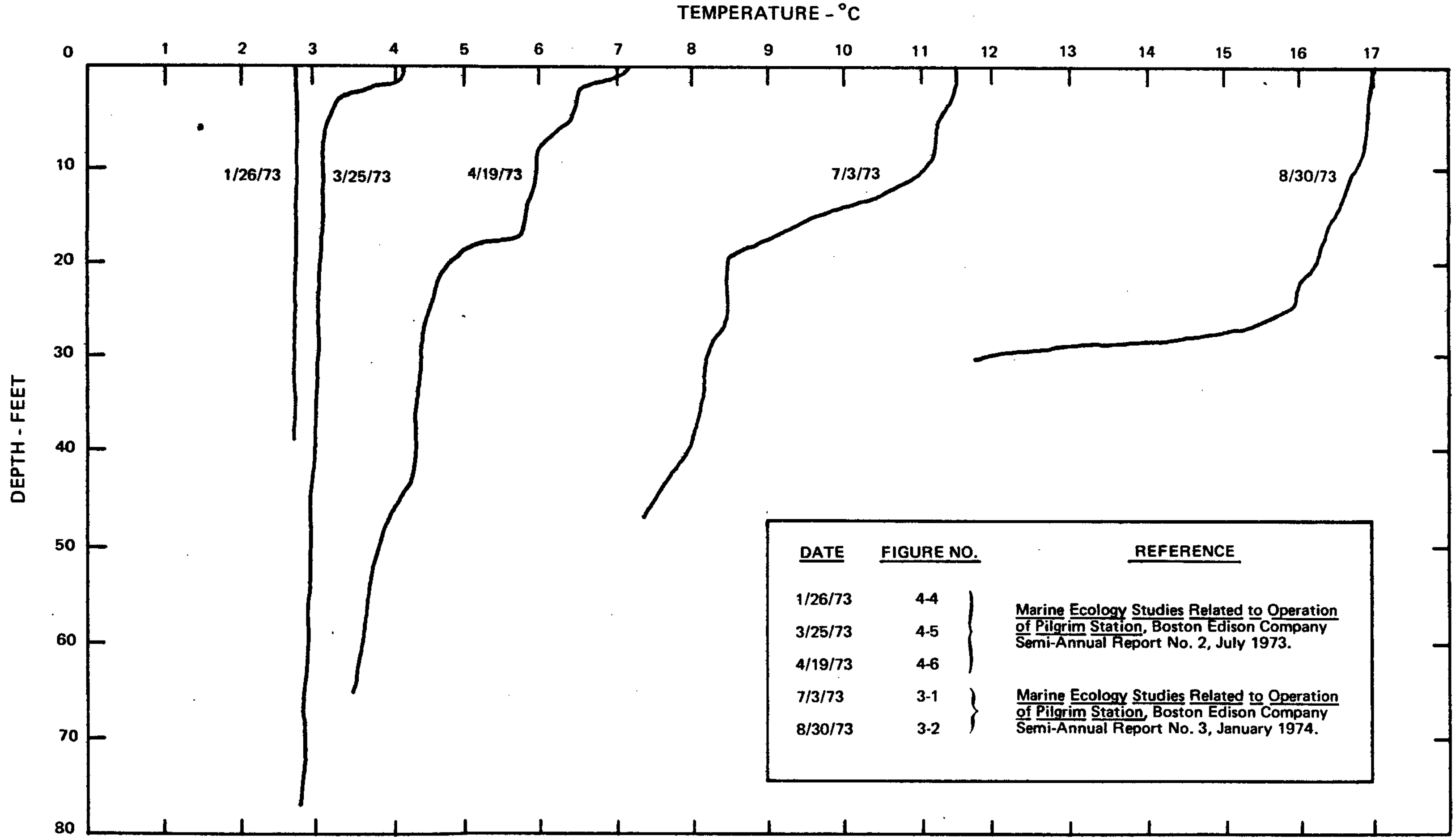

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FIGURE 2-13.

PROGRESSIVE FORMATION OF SEASONAL THERMOCLINE IN CAPE COD BAY

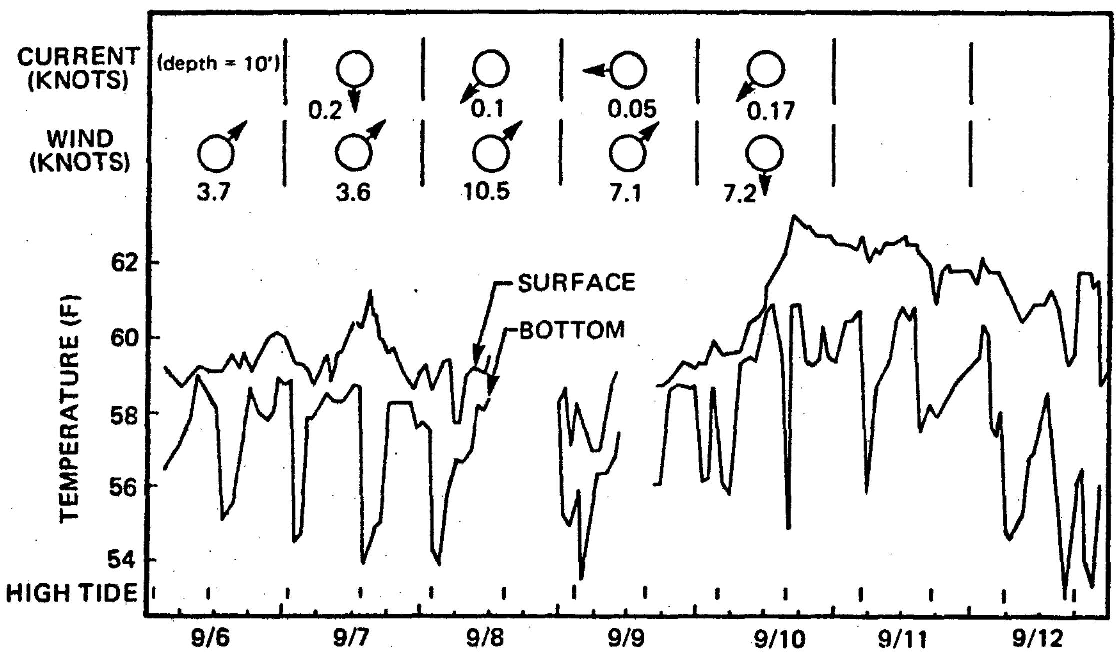
TABLE 2-2

MONTHLY AVERAGES OF WATER TEMPERATURE (°F),
OFFSHORE PILGRIM SITE AND UNIT 1
CONDENSER INTAKE TEMPERATURES

	Temp. at Offshore Station (°F)			
	At 2-ft Depth	At 15-ft Depth	At Bottom (-32 ft MLW)	Unit 1 Intake Temp. (°F)
1972				
December	42	41.4	42	41.6
1973				
January	37	37.3**	36.8	37.3
February	35.1	*	34.7	36.4
March	39	38.7	36.1**	39.3
April	41 (+)	41.9	*	42.4
May	*	47.7	*	48.4
June	*	*	52.6	55.7
July	*	52.1	52.0	54.3
August	56.8	59.1	54.2	57.6
September	63.8	60.6	57.3	60.0
October	55.3	54.2	54.8	54.4
November	47.4	48.0	47.4	48.0
December	44.5	46.0	45.2	44.6

*Data not available

**Based on less than 1/2 month's data



[from Pilgrim Nuclear Power Station Environmental Report - Unit 2]

FIGURE 2-14.

SEA TEMPERATURE, WIND, AND CURRENT AT PILGRIM SITE (1971) demonstration, it is assumed that the station operates at 100 percent load all of the time.

The station withdraws cooling water from Cape Cod Bay via intake structures located south of Rocky Point in Plymouth, Massachusetts. The cooling water is returned to Cape Cod Bay via a discharge channel which is designed to promote rapid dilution of the heated effluent. The cooling water is used primarily to remove heat from the station condensers. Additionally, a small quantity of heat is removed from the station service water systems. The circulating water systems are shown schemetically in Figure 2-15. The total heat rejection during full load operation of Pilgrim Station will be approximately 1.34×10^{10} Btu/hour. This reflects operation of both Units 1 and 2. Unit 1 has a circulating water flow of 690 cfs at a maximum temperature rise of 30°F, and a service water flow of 23 cfs at a maximum temperature rise of 15°F. Unit 2 will have a circulating water flow of 1,700 cfs at a maximum temperature rise of 20°F, and a service water flow of 78 cfs at a maximum temperature rise of 10°F. The combined flow will be 2,560 cfs at a temperature rise of 22°F. Table 2-3 summarizes the contribution of each system. Under reduced load conditions the circulating water flow rates will not normally be reduced, except for substantially reduced power levels over extended time periods. Table 2-4 presents anticipated, typical operating characteristics over a range of possible load conditions.

Minor variations in flow and temperature rise will occur under various tidal conditions due to the hydraulic characteristics of the circulating water system. Table 2-5 presents approximate flows in temperatures for a range of tidal conditions.

The cooling water will be rapidly heated in the station condensers and will remain at essentially constant temperature until discharged. The times at which the cooling water will be subject to increased temperature will vary between Units 1 and 2. Table 2-6 lists travel times through the cooling systems subsequent to heating.

Units 1 and 2 will be capable of operating under transient conditions such as those associated with station startup or shutdown. Unit 1 has, as part of its discharge permit, an allowable maximum discharge temperature transient of 15°F per hour which would not be exceeded except under abnormal operating conditions. It is expected that a similar temperature transient will apply for Unit 2.

2.2.1 Discharge System

Units 1 and 2 will utilize a common discharge channel to return cooling water to Cape Cod Bay. The circulating water will leave the discharge channel as a high velocity surface jet, and will rapidly mix with the surrounding sea water. Figures 2-16 and

2-17 illustrate the discharge channel geometry. The channel is trapezoidal in cross-section with a bottom width of 20 feet and side slopes of 2:1 (H:V). The invert elevation runs level at elevation -4.8 MSL from the seal wells to the point where the channel intersects the beach slope which it then follows. Table 2-5 presents flows, temperatures, and exit velocities for various tidal elevations.

2.2.2 Intake System

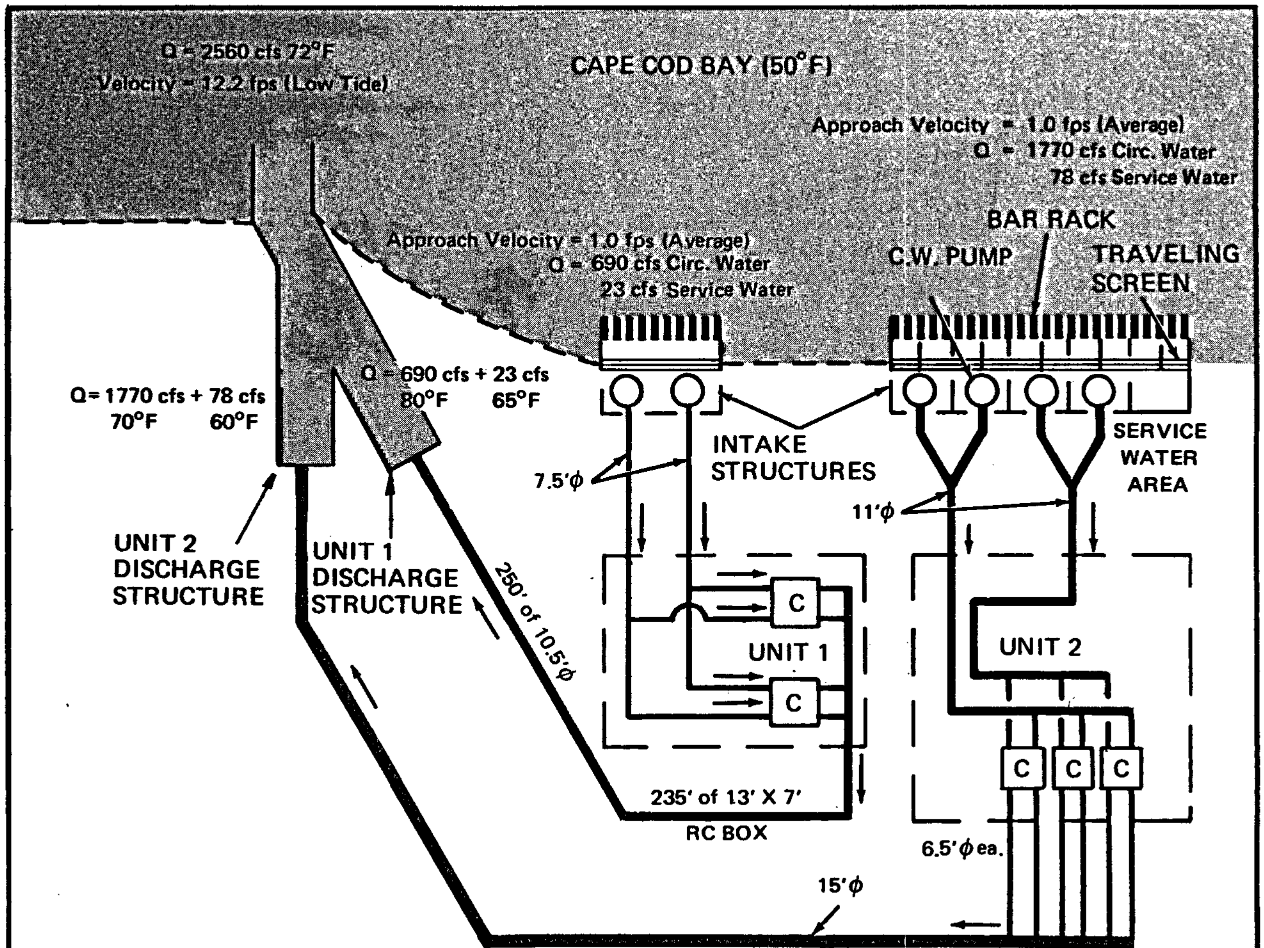
The circulating water and service water drawn from Cape Cod Bay will pass between breakwaters and through a dredged intake channel to the facility's intake structures. Figure 2-18 shows the intake structure for Unit 1. Figure 2-19 shows the intake structure for Unit 2.

The Unit 1 screenwell contains two circulating water pumps having a capacity of about 360 cfs each. Water passes under the skimmer wall whose bottom is at -12 feet MSL at the front of the intake structure. The skimmer wall is designed to prevent the entrance of floating debris. Intake water passes through trash racks designed to intercept debris of large size, 3 inches or greater, and then flows through traveling water screens which remove debris, 3/8 inch and larger. There are two traveling water screens for each of the circulating water pumps. The intake structure is divided into three bays, one for each of the circulating water pumps, and one for the five service water pumps.

Condenser tubes on Unit 1 can be cleaned by back-flushing. This is accomplished by operating a single circulating water pump, closing the discharge valves at each outlet water box, and operating the crossover valve connecting the discharge water boxes. Circulating water will flow naturally through one side of the condenser, cross over, and flow in the reverse direction through the other side, and discharge back to the intake structure through the idle circulating water pump.

The Unit 2 screenwell contains four circulating water pumps having a capacity of about 425 cfs each. Water passes under a skimmer wall, whose bottom is at -8 feet MSL, and then passes through trash racks. Water then passes through traveling water screens. Walls between the traveling screens are provided with openings flush with the face of the screens, thereby providing a continuous path for lateral movement of fish over the entire width of the structure. Openings leading from intake structure to the intake bay are provided at both ends of the structure.

A back-flushing capability is present in the Unit 2 circulating water system design. The four circulating water pumps are manifolded into pairs of pipe lines that convey cooling water to alternate tube bundles of a 3-shell condenser. The two pumps serving a single line can be shut down, and valves are positioned



NOTES:

1. Flows shown assume MLW tide level and two-unit operating conditions.
2. C Denotes condenser
3. Temperatures shown assume intake water temperature of 50°F and two unit operating conditions
4. ϕ = Inside diameter

from Pilgrim Nuclear Power Station Environmental Report - Unit 2

FIGURE 2-15.

CIRCULATING WATER SYSTEM SCHEMATIC

TABLE 2-3

PILGRIM STATION COOLING WATER CHARACTERISTICS
(FULL LOAD)

		Flow (cfs)	Temp Rise (°F)	Heat Rejection (Btu/Hr)
Unit 1	Circulating Water	690	30	4.7×10^9
	Service Water	23	15	7.8×10^7
	Total	713	30	4.8×10^9
Unit 2	Circulating Water	1,770	20	8.0×10^9
	Service Water	78	10	1.8×10^8
	Total	1,848	20	8.2×10^9
Units 1 and 2 Total		2,561	22	1.3×10^{10}

TABLE 2-4

TYPICAL LOAD-DEPENDENT OPERATING CONDITIONS
(UNITS 1 AND 2 COMBINED)

Load (%)	Flow (cfs)	Temp. Rise (°F)	Heat Rejection (Btu/hr)
100	2,561	22.0	1.30×10^{10}
80	2,118	21.3	1.04×10^{10}
60	2,118	16.0	0.78×10^{10}
40	1,723	13.1	0.52×10^{10}
20	1,723	6.6	0.26×10^{10}
0	0	0	0

TABLE 2-5

DISCHARGE CHARACTERISTICS FOR VARIOUS TIDAL CONDITIONS

Elevation (MSL)	Flow (cfs)	ΔT (°F)	Exit Velocity (fps)
MHW(S) + 5.0	2,810	20.0	7.2
MHW + 4.3	2,810	20.0	8.1
MSL 0	2,710	21.0	12.4
MLW - 4.8	2,560	22.0	12.2
MLW(S) - 5.6	2,540	22.5	12.1

TABLE 2-6

TRAVEL TIMES FROM CONDENSER INLET TO CAPE CODE BAY (MINUTES)

Normal Operation (Units 1&2)			Condenser	Pipe	Sealwell to Unit 1 Mixing Pt.	Mixing Point to Bay	Total
Unit 1:	T = 30°F	MHW(S)	0.1	1.0	2.2	1.7	5.0
		MSL	0.1	1.0	2.0	1.4	4.5
		MLW(S)	0.1	1.0	2.0	1.5	4.6
Unit 2:	T = 20°F	MHW(S)	0.1	2.0	0.4	1.7	4.0
		MSL	0.1	2.1	0.4	1.4	3.8
		MLW(S)	0.1	2.2	0.4	1.5	4.0

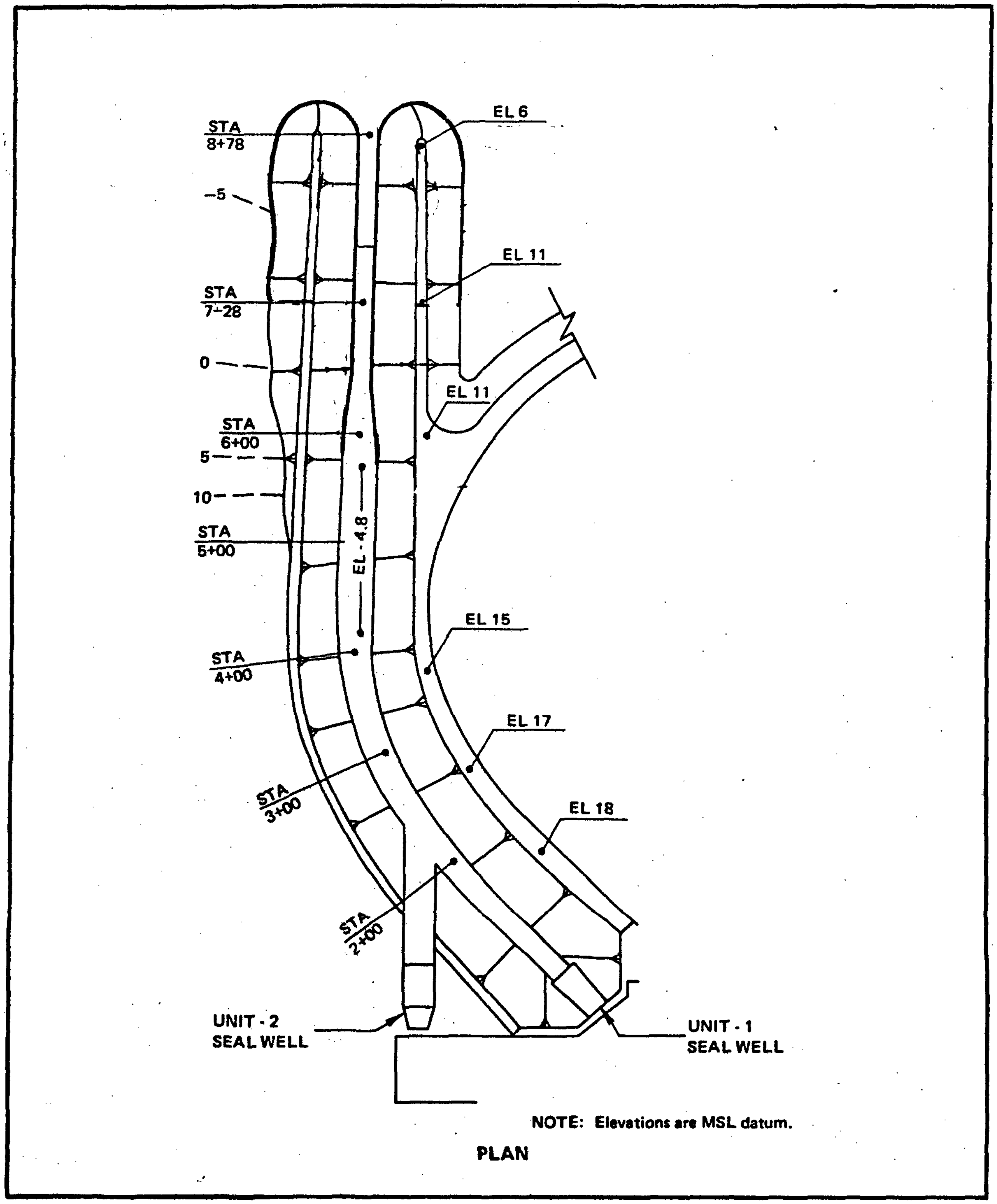


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FIGURE 2-16.
DISCHARGE CHANNEL

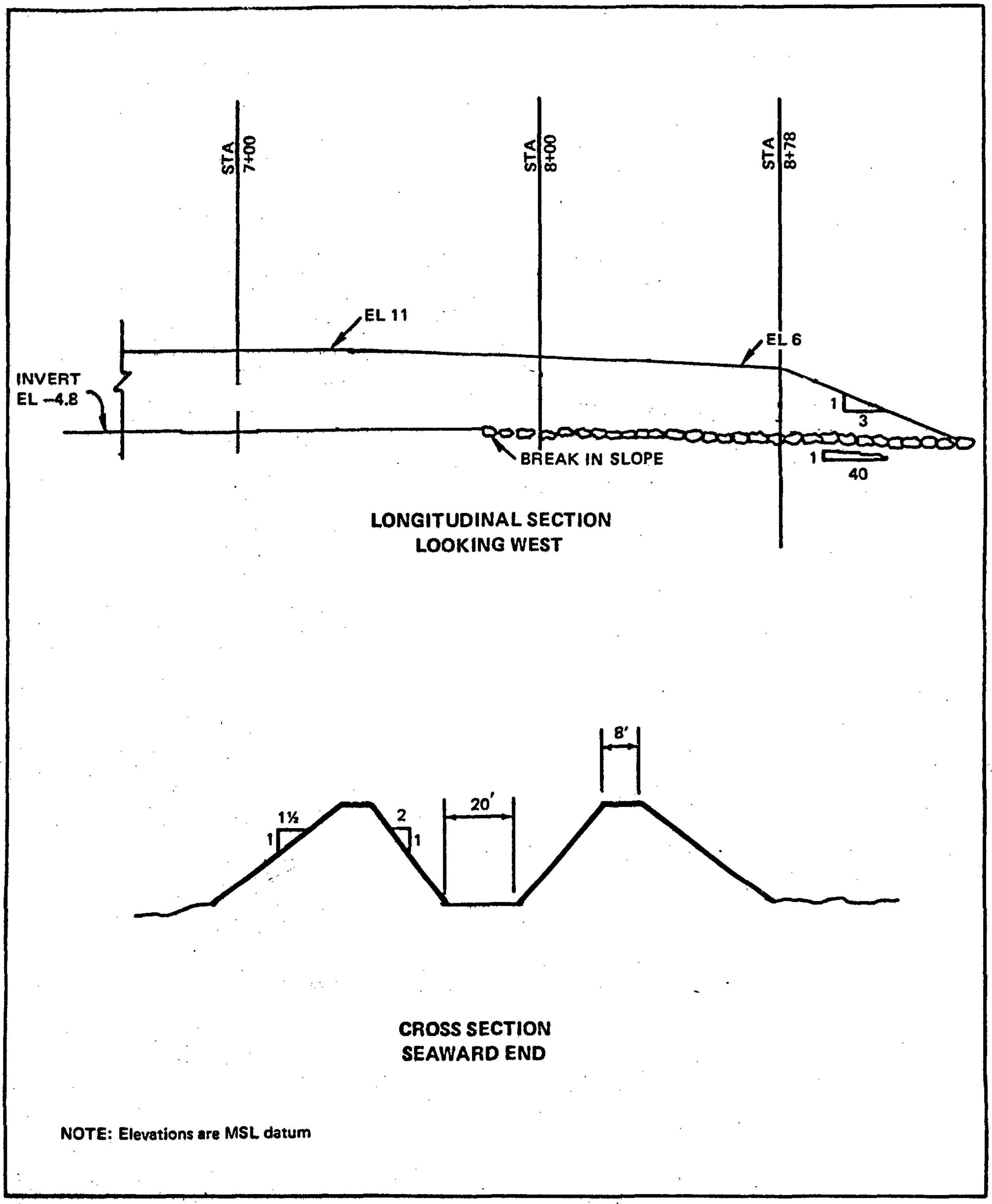

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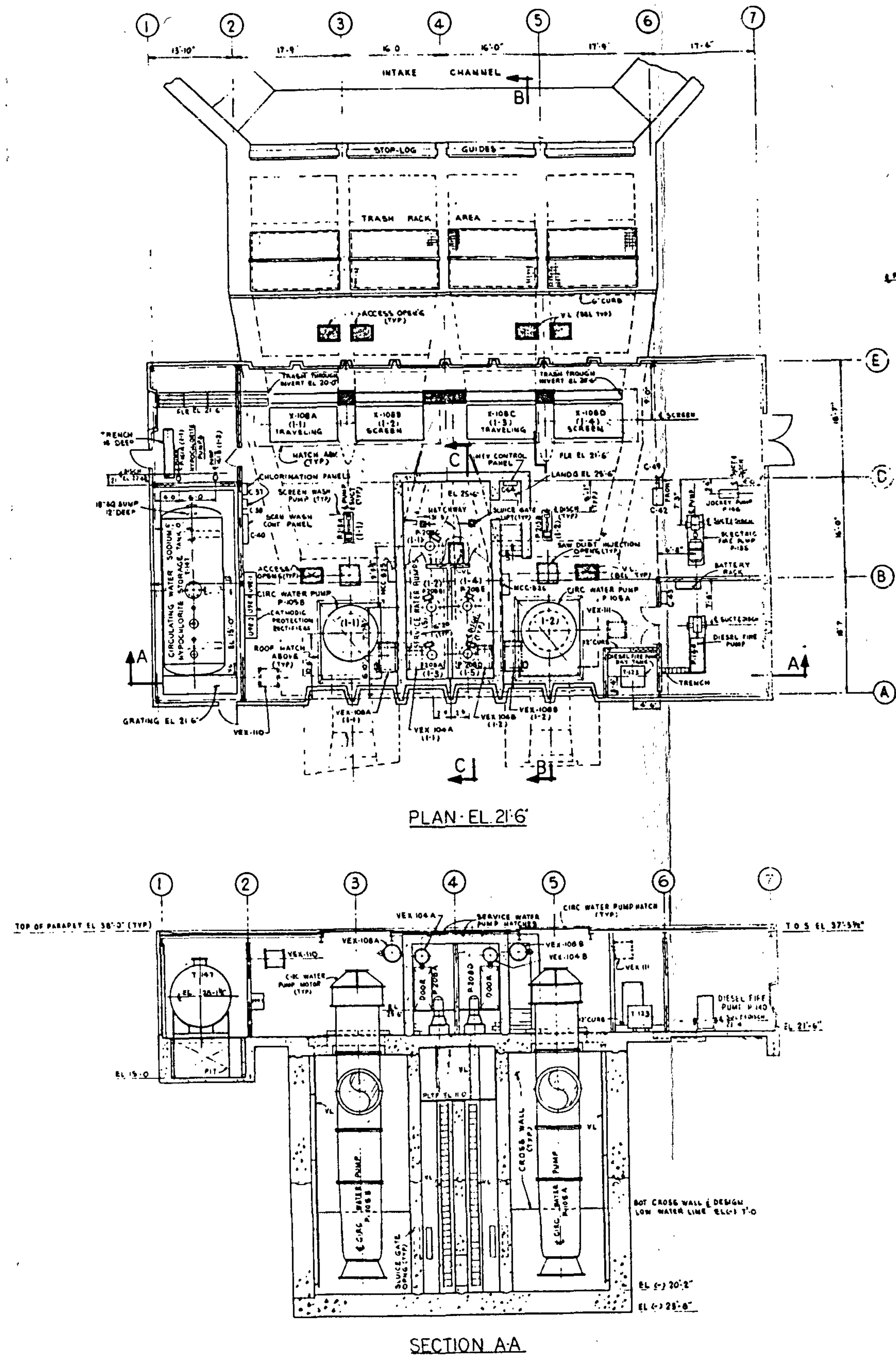
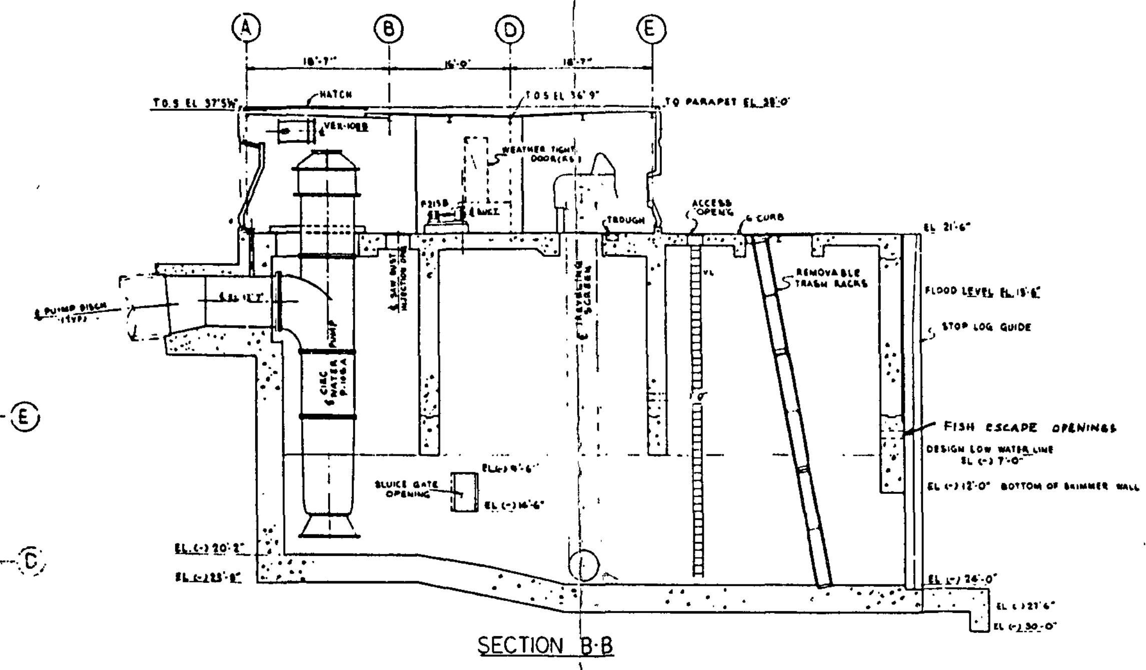
FIGURE 2-17.
DISCHARGE CHANNEL PROFILE
AND CROSS-SECTION





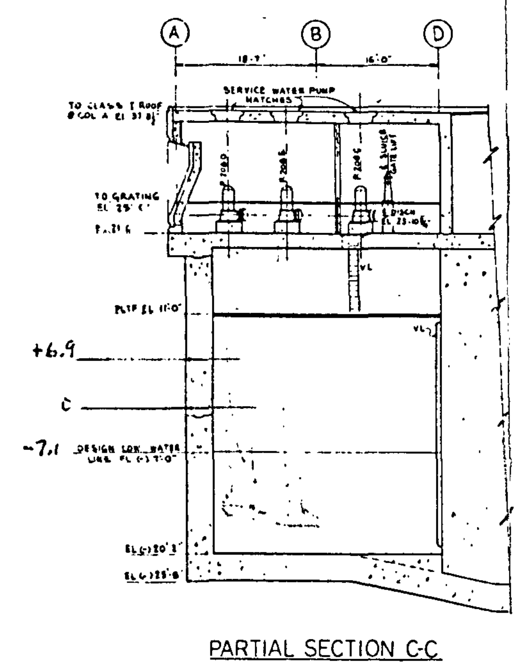


FIGURE 2-18.
INTAKE STRUCTURE - UNIT 1

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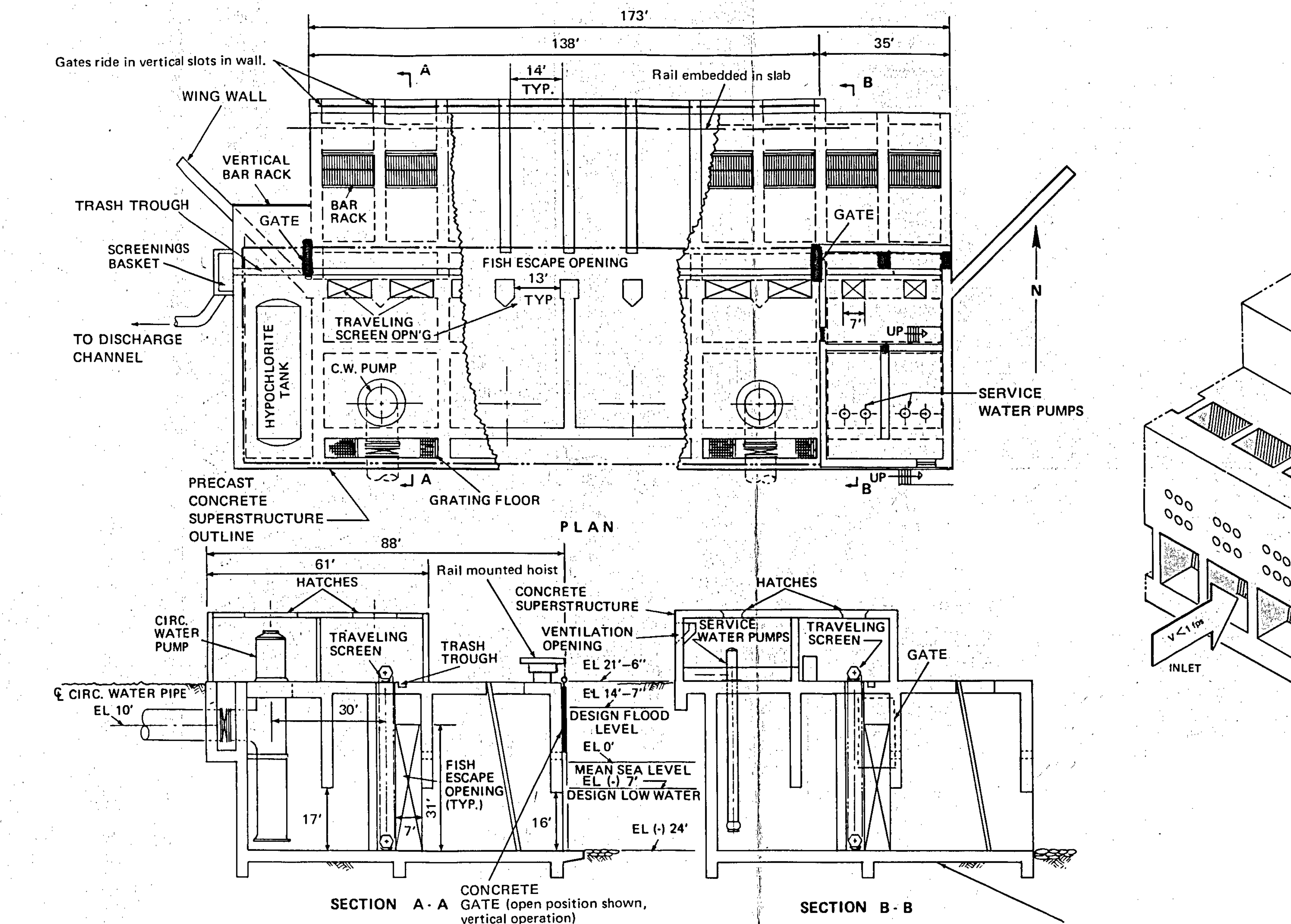

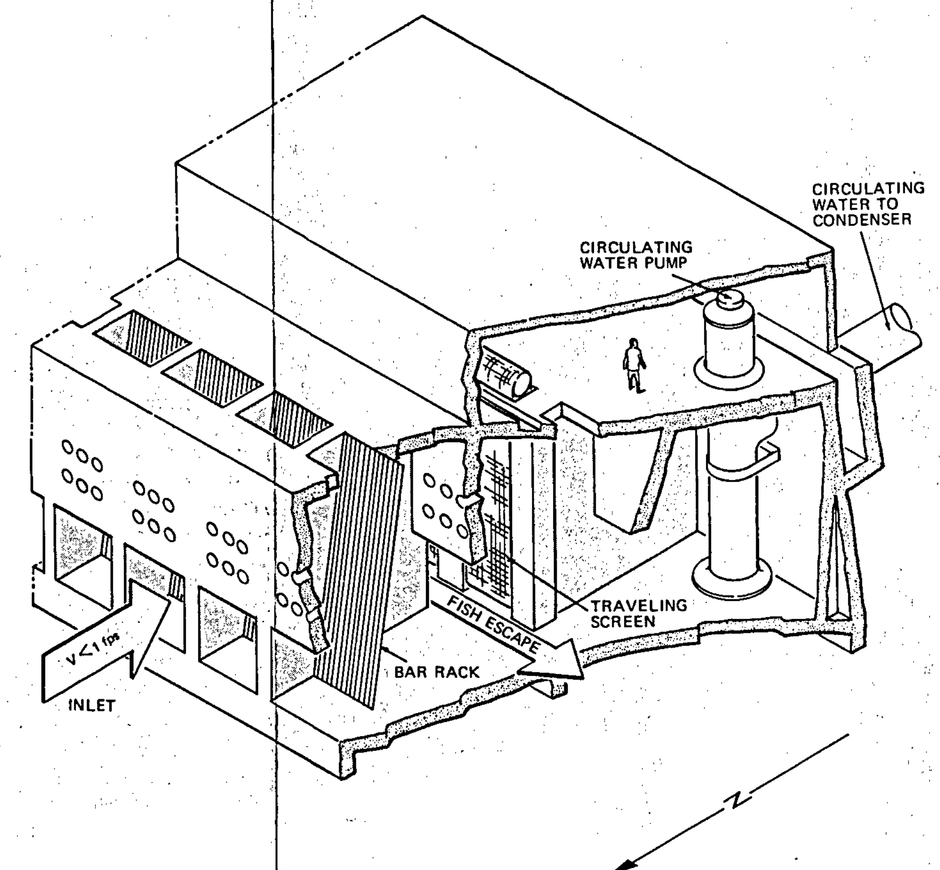

NOTES:
1. Dimensions are approximate.
2. Elevations are mean sea level datum.

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FIGURE 2-19.
INTAKE STRUCTURE - UNIT 2

to permit a portion of the circulating water to return into the intake structure in a manner similar to that used with Unit 1.

It is presently intended that mussels be controlled by backwashing. Based on limited Unit 1 experience, mussels are controlled by subjecting them to temperatures in the range of 100 to 110°F for one to two hours at intervals of two or three weeks when bay water temperature is above 45°F (approximately 225 days per year). This proposed schedule may require adjustment based upon future Unit 1 experience. When back-flushing is necessary during periods of peak ambient temperatures, it is possible that the average temperature of the mixed 2-unit discharge flow will be as high as 95°F for periods of about two hours or less. The number of such peak discharge temperature occurrences is not expected to exceed twelve per year (approximately three occurrences per year for each of the two pairs of Unit 2 circulating pumps, and two Unit 1 circulating pumps).

Table 2-7 presents circulating water intake velocities at various positions for both Unit 1 and Unit 2 screenwells.

2.2.3 Plume Characteristics

A number of experimental and analytical programs have been performed to study the thermal effects of Pilgrim Station. The experimental work performed to date consists of field surveys to document effects occurring during Unit 1 operation. A dye study performed in December, 1972, by Vast, Inc., of Ivorytown, Connecticut, obtained data on the circulation of the thermal plume and measured the vertical distribution of the discharge flow. An infrared aerial survey by Coastal Research Corporation, of Lincoln, Massachusetts, also performed in December, 1972, collected imagery yielding synoptic views of the overall extent of the surface component of the thermal plume. Temperature surveys conducted on a number of dates throughout 1973, by the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics of Massachusetts Institute of Technology, collected horizontal and vertical plume temperatures over a range of tidal and climatic conditions. A second infrared aerial survey conducted by Aero-Marine Surveys of New London, Connecticut, in August 1973, obtained additional synoptic imagery of the surface extent of the thermal plume. A temperature survey conducted concurrently by Marine Resources, Inc., of East Wareham, Massachusetts, collected vertical temperature profiles.

Results of the field studies demonstrate that the shape of the thermal plume produced at Pilgrim Station is highly dependent upon wind-induced and tidal currents. While tidal conditions, being cyclic in nature, would tend to produce periodic swings in the orientation of the thermal plume, wind effects in general are unsteady and variable. This contributes to the thermal plume having a shape and position which is constantly changing with time in an unsteady or noncyclic manner.

In addition to shape and direction, the data also show that the areal extent of the plume is highly transient in nature. This is a result of the unsteady nature of ambient bay water temperatures and meteorological conditions, both of which govern the rate of heat exchange between the thermal plume and its surroundings. Under conditions during which the station heat discharge has been maintained at essentially constant value, the areas within plume isotherms have been observed to vary significantly.

Figure 2-20 illustrates an isothermal map of the Unit 1 thermal plume obtained from an infrared aerial survey.

To date, there is no analytical tool which permits the accurate prediction of nonsteady-state thermal plume behavior. Work is proceeding to develop such a tool for Pilgrim at this time, and it is anticipated that valuable information will result as this program proceeds. At present, two steady-state predictive models have been used to correlate the Unit 1 thermal field data, and to estimate the combined Unit 1 and Unit 2 plume extents. These are the Stolzenbach-Harleman (S-H) model and the Pritchard model. The S-H model is a three-dimensional, semi-analytical, near-field model. The Pritchard model is an empirical model which is applicable to predictions over the entire field.

The S-H and Pritchard models were used to estimate plume characteristics due to operation of Units 1 and 2 at Pilgrim Station. The results of the model are shown in Figures 2-21 through 2-24 and in Table 2-8. The figures present centerline temperature profiles and cross-sectional temperature distributions for both high tide and low tide conditions. Table 2-8 presents plume surface areas for both high tide and low tide conditions.

The approximate extent of the area which could be subjected to thermal effects under different conditions of wind and tide is shown in Figure 2-25. This figure was derived by extrapolating the hydrothermal field survey results for operation of Unit 1, as follows. It was observed that the maximum distance at which increased temperature attributable to operation of the station could be normally identified is about 6,000 feet from the discharge point. This corresponds roughly to a temperature rise of about 1°F. Given that the total heat rejection due to Units 1 and 2 combined will be about three times that of Unit 1 alone, and assuming that the thermal plume with both units operating will be geometrically similar to that associated with Unit 1, but with three times the surface area, it is assumed here that the maximum far field plume extent will be increased proportionally to the square root of 3, or 1.73. This results in the estimate of the ocean surface area which would be subjected to having a detectable temperature increase an extent of approximately 2 miles, as shown in Figure 2-25.

TABLE 2-7

INTAKE WATER VELOCITIES

	Minimum ~~Average~~ Low Astronomical Tide (-7.1 MSL)	MSL	Maximum ~~Average~~ High Astronomical Tide (+6.9 MSL)
Unit 1:			
Approaching Intake Structure	0.8	0.56	0.44
Under Skimmer Wall	1.1	1.1	1.1
Approaching Screens	1.0	0.7	0.56
Through Screens	2.0	1.4	1.1
Unit 2:			
Approaching Intake Structure	0.8	0.6	0.4
Under Skimmer Wall	1	1	1
Approaching Screens	1	0.7	0.5
Through Screens	2.0	1.4	1.0

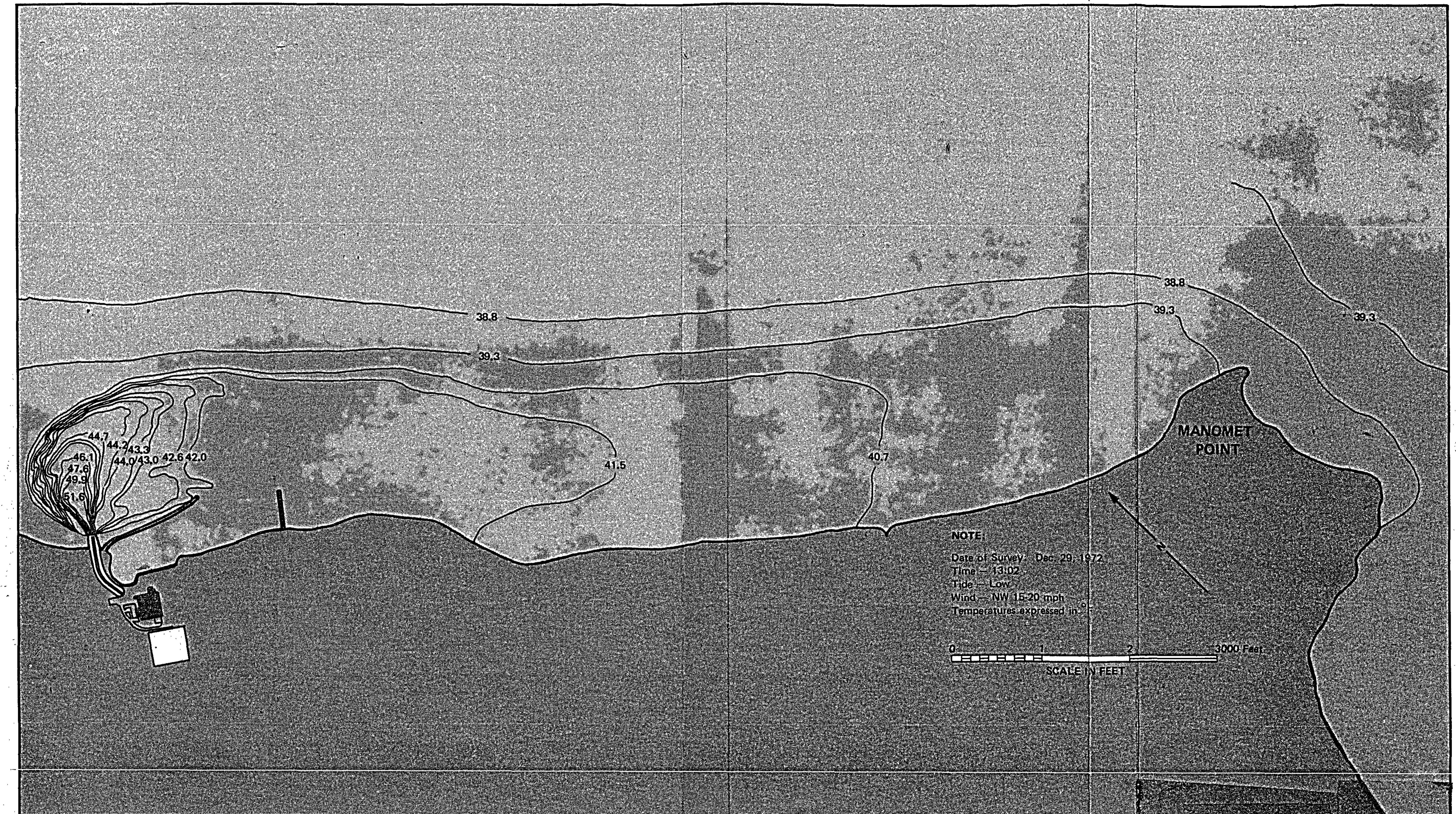

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FIGURE 2-20

LOW TIDE SEA SURFACE ISOTHERM MAP

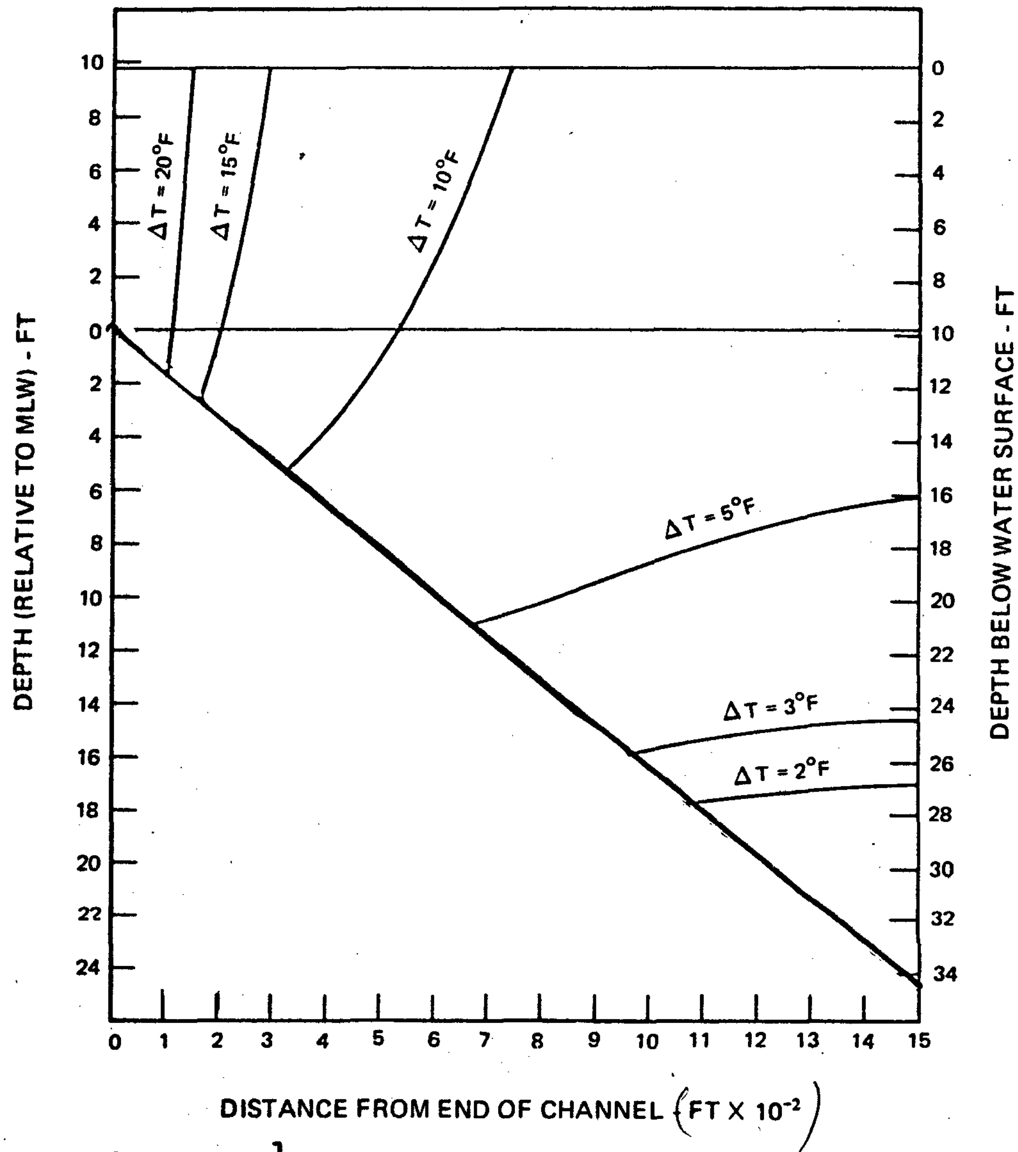

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FIGURE 2-21

PREDICTED VERTICAL EXCESS TEMPERATURE PROFILES ALONG PLUME CENTERLINE - UNITS 1 AND 2 - HIGH TIDE

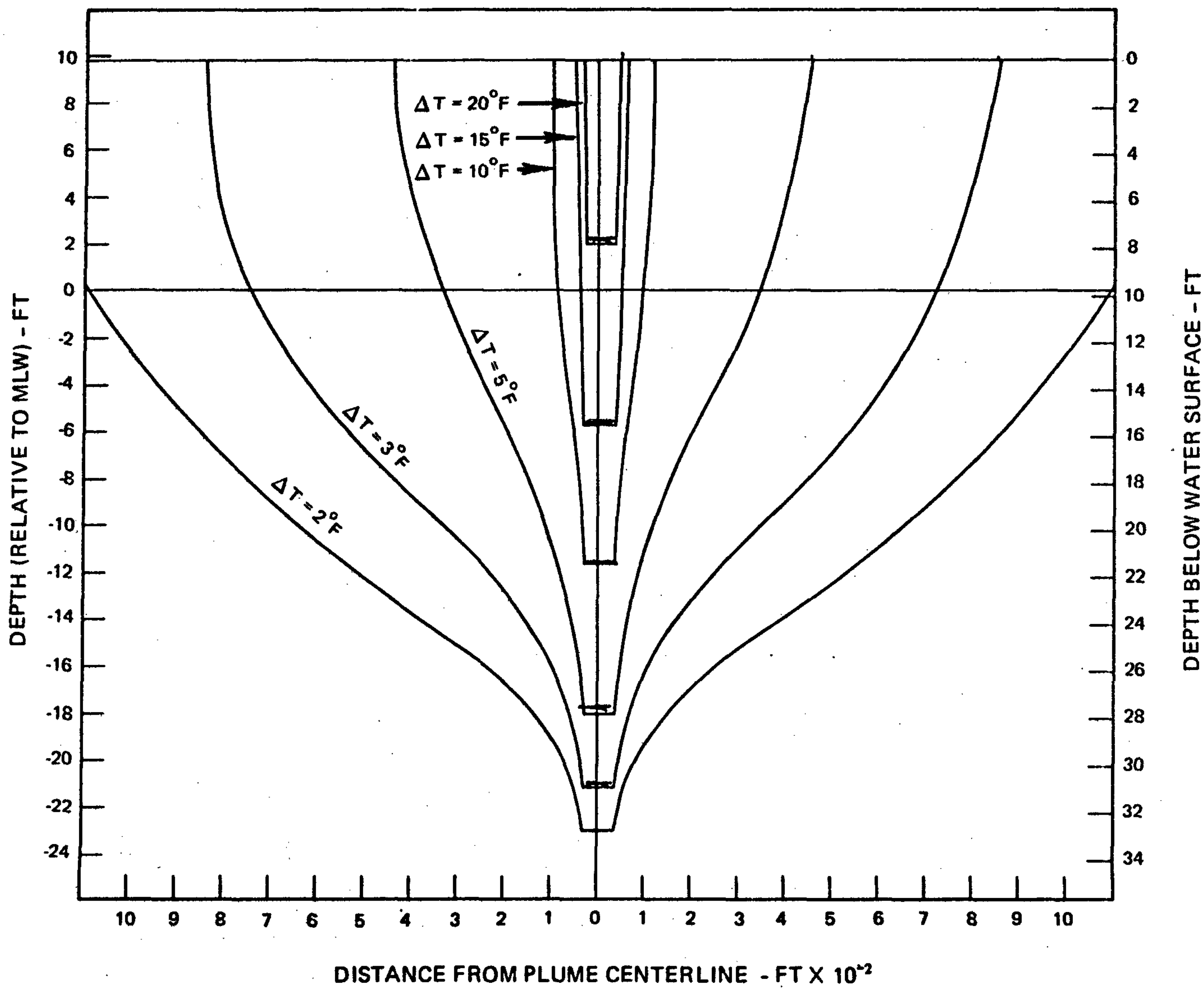

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FIGURE 2-22. PREDICTED VERTICAL EXCESS TEMPERATURE PROFILES AT MAXIMUM PLUME WIDTH (TYPICAL) - UNITS 1 AND 2 - HIGH TIDE

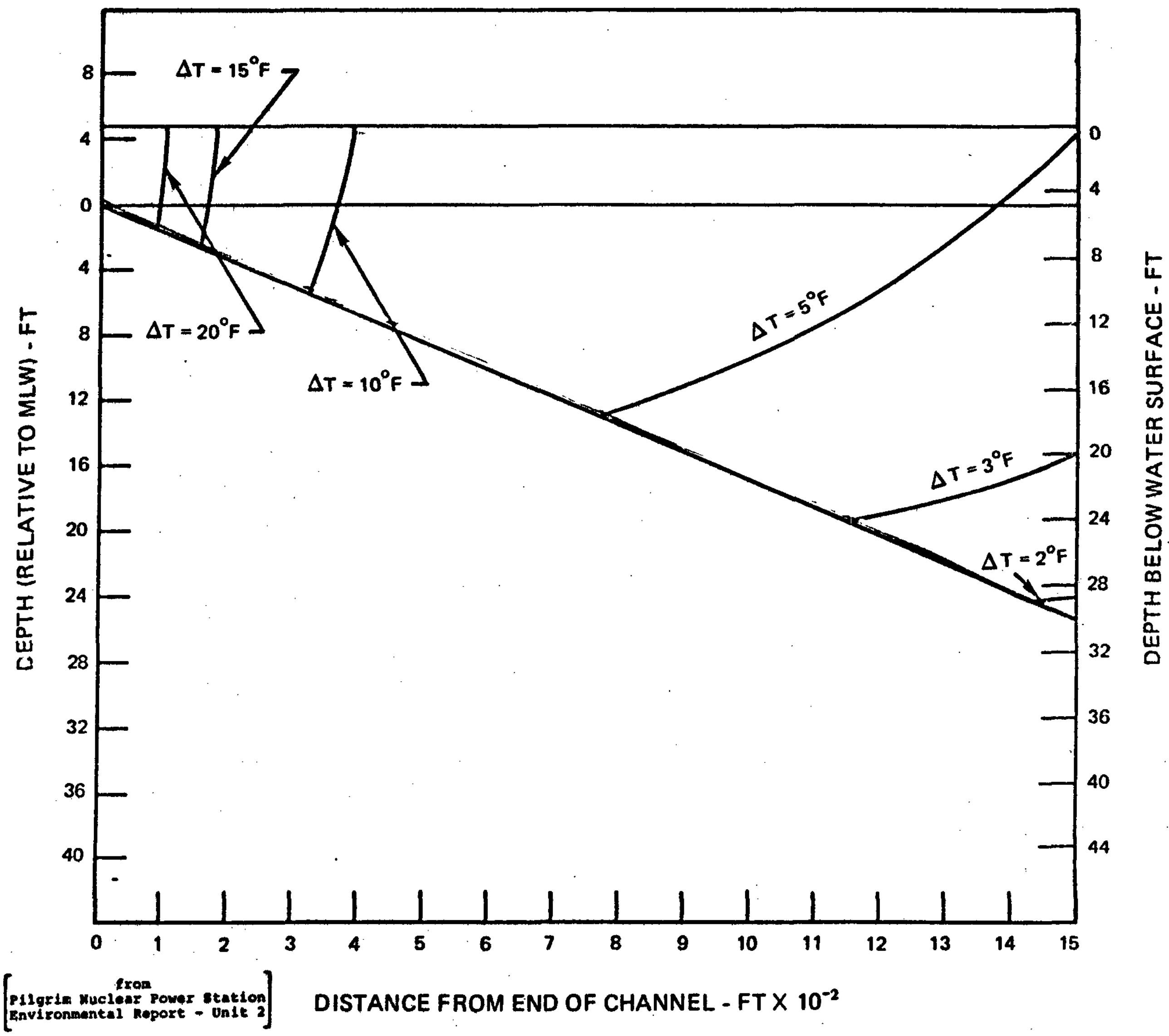

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FIGURE 2-23.

PREDICTED VERTICAL EXCESS TEMPERATURE PROFILES ALONG PLUME CENTERLINE - UNITS 1 AND 2 - LOW TIDE

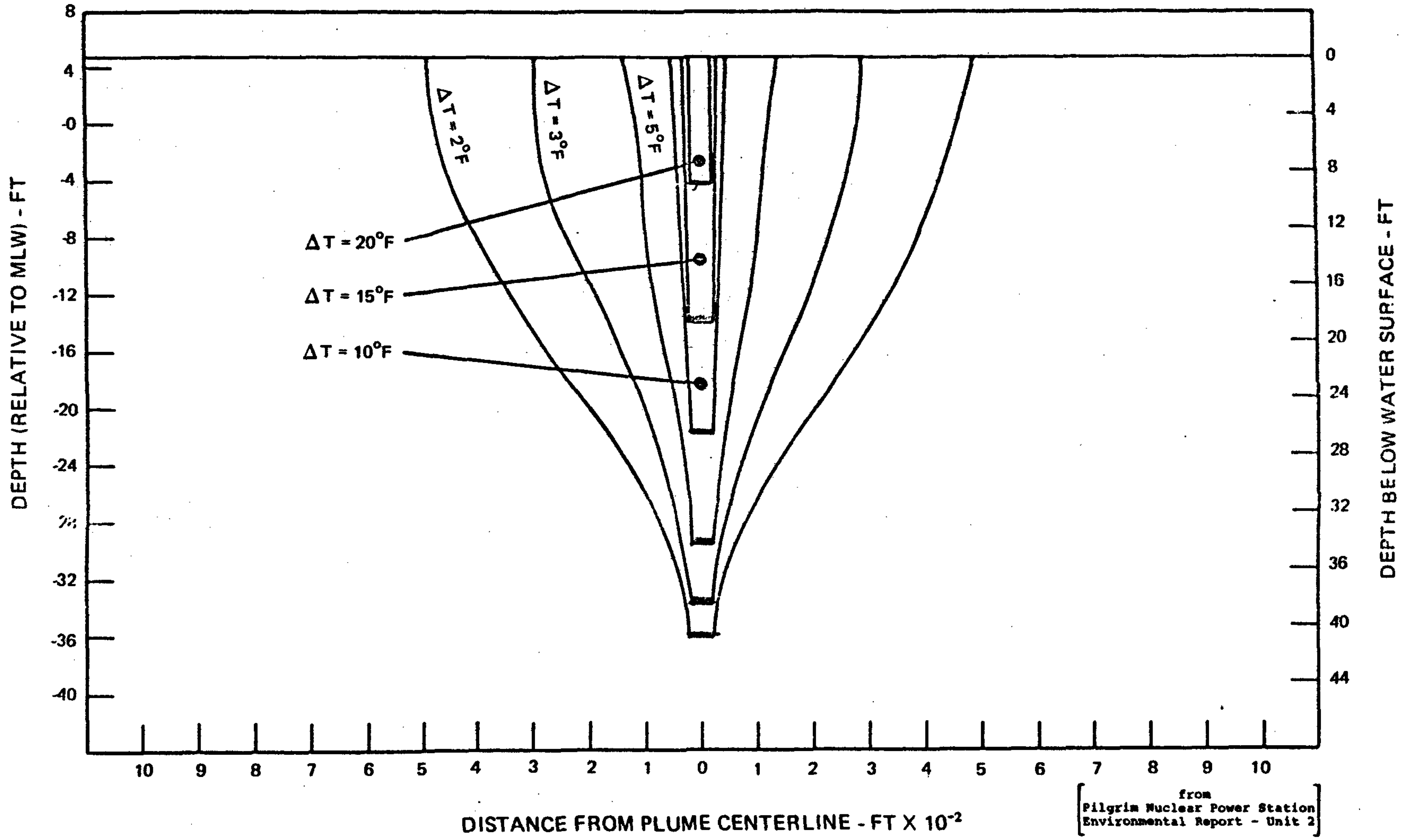

FIGURE 2-24. PREDICTED VERTICAL EXCESS TEMPERATURE PROFILES AT MAXIMUM PLUME WIDTH (TYPICAL) - UNITS 1 AND 2 - LOW TIDE

TABLE 2-8

PREDICTED SURFACE AREAS WITHIN VARIOUS EXCESS TEMPERATURE ISOTHERMS
(Full Power Operation of Units 1 and 2)

	Area Enclosed by Excess Temperature Isotherm (Acres)					
	Low Tide			High Tide		
Temperature Rise	Pritchard Model		S-H Model	Pritchard Model		S-H Model
Above Ambient (°F)	No Recirc.	10% Recirc.	No Recirc.	No Recirc.	10% Recirc.	No Recirc.
20	0.1	0.1	*	0.2	0.2	1
15	0.2	0.2	1	0.4	0.6	3
10	0.6	0.7	3	2	3	11
5	6	8	28	31	47	*
3	23	33	*	101	157	*
2	57	83	*	233	363	*
Associated Half-Depth of Thermal Plume (ft)	26	26	*	21	21	*

* Not Computed

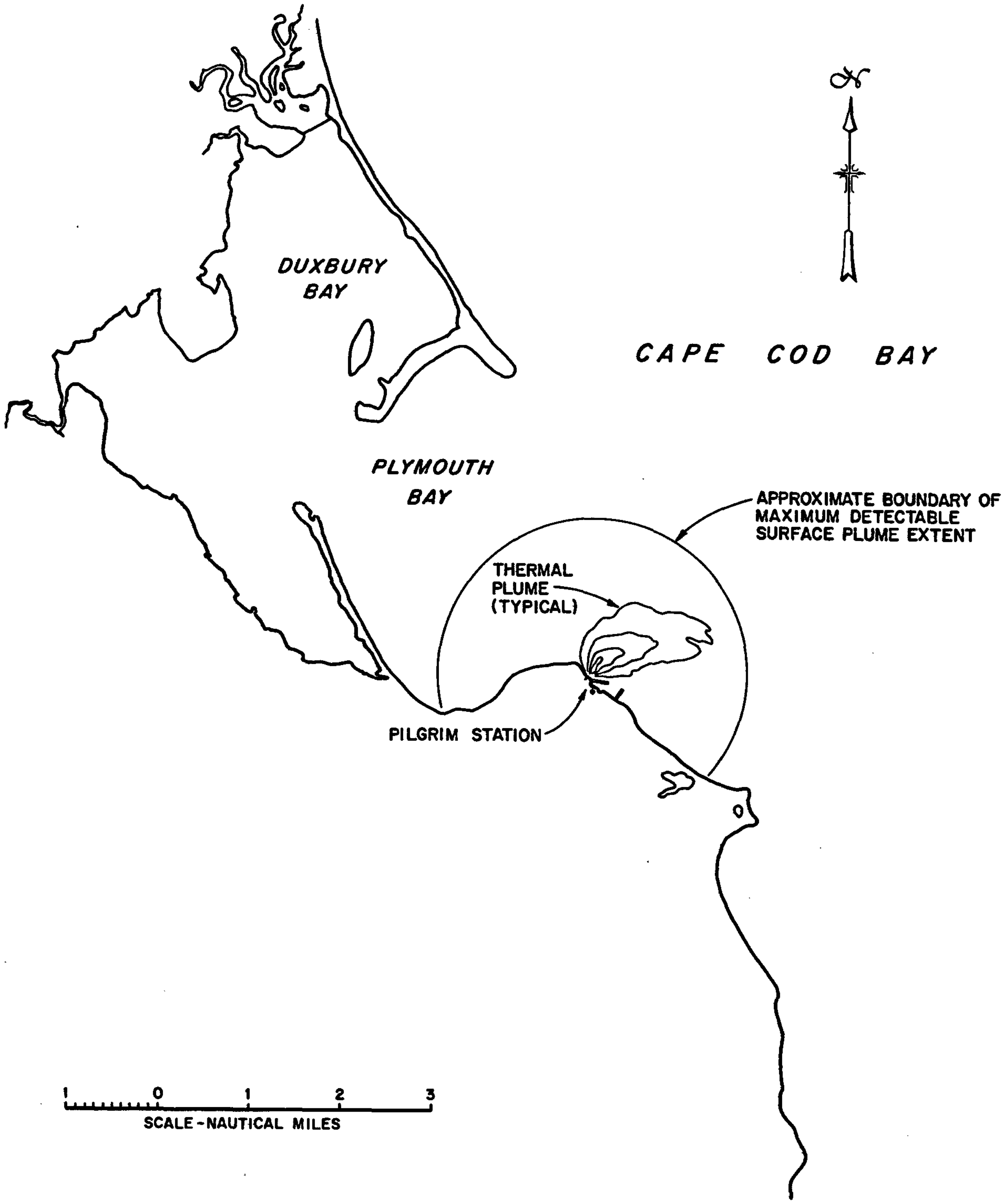

FIGURE 2-25
ASSUMED APPROXIMATE EXTENT OF THERMAL EFFECTS

While the thermal plume would not occupy all of this area at any one time, the figure does indicate the extent of the region in which the thermal plume would be located.

An approximate area of bay bottom which will be subject to direct contact by the thermal plume is shown in Figure 2-26. This figure was derived from the centerline plume temperature profiles shown in Figures 2-21 and 2-23. It was assumed that the distances along the bottom at which elevated temperatures would extend would remain constant regardless of direction. This results in semicircular profiles in that it probably substantially overestimates the size of the affected areas. Because of the momentum of the discharge flow and the jet-induced entrainment flow which will occur along the sides of the discharge jet, it is unlikely that areas along the coast adjacent to the plume will be affected as much as shown. This figure, however, is useful for performing a conservative prediction of the maximum thermal affect on benthic organisms, and will be discussed in Section 6.

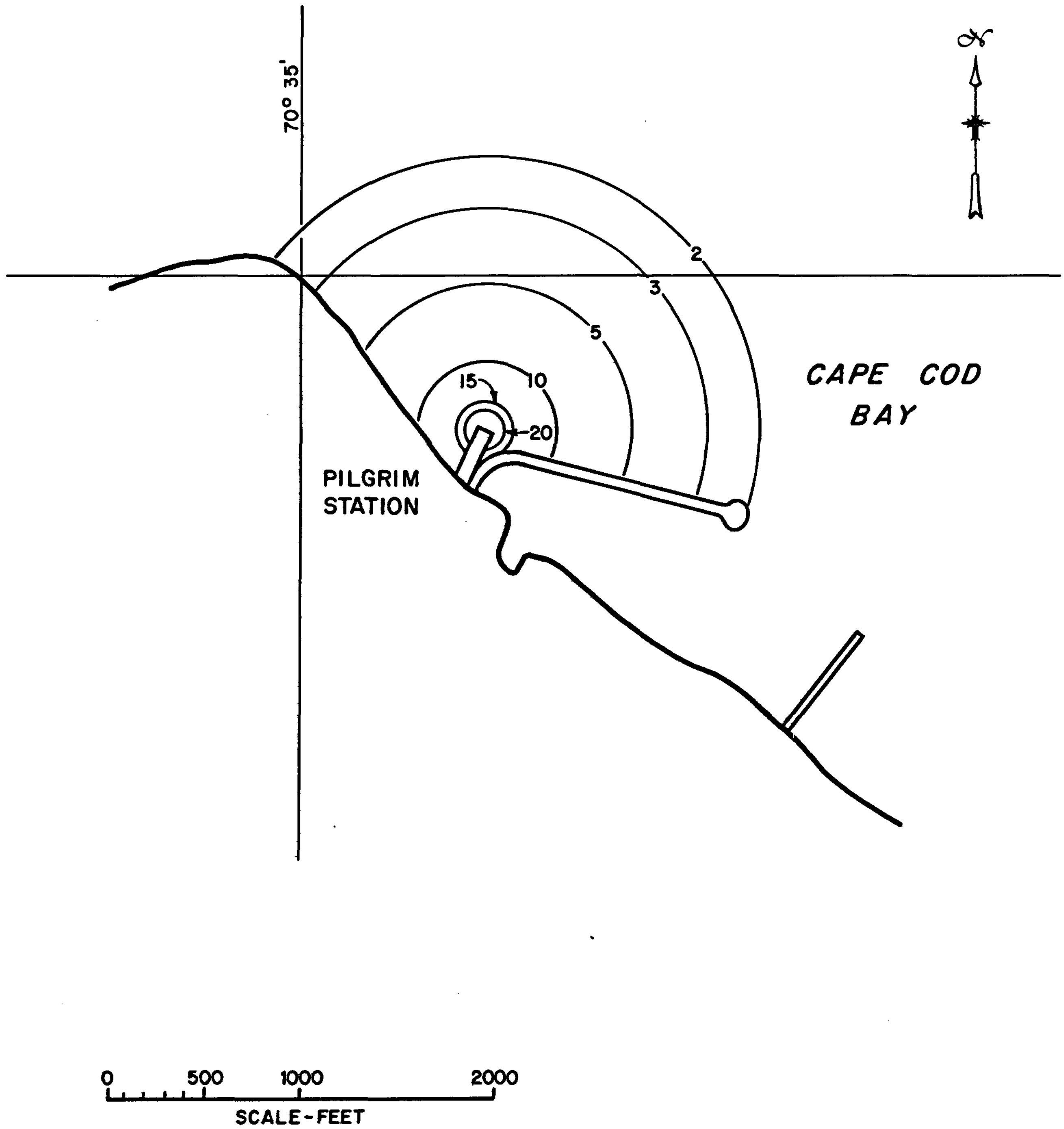

FIGURE 2-26
ASSUMED THERMAL PLUME
BOTTOM ISOTHERMS (°F)

SECTION 3

DESCRIPTION OF AQUATIC COMMUNITIES

3.1 INTRODUCTION

The aquatic biota of Cape Cod Bay is typical of that found in marine environments of north temperate climates. The biotic communities are diverse assemblages more representative of a marine than an estuarine environment.

Cape Cod Bay is a diverse marine environment for several reasons, including the following:

(1) A wide variety of environmental conditions are encountered, including an extensive range of substrate conditions. For example, temperatures in shallow water can range from below 0°C (winter) to 20°C (late summer).

(2) Cape Cod Bay is an area of zoogeographic overlap, and various northern species reach the southern extension of their ranges in this area. An even greater number of southern species range no further north than Cape Cod. The overlap of these zoogeographical types results in increased species diversity for the area.

Winter temperatures are similar in waters north and south of Cape Cod Bay; however, temperatures are significantly different during the summer months. While adults of certain species may survive a wide range of temperatures, temperature limits become very important during the reproductive periods. This is often more important in limiting species distribution. Adult stages of a southern species may survive all year in the bay, but summer temperatures may not be warm enough to initiate breeding. Northern species may not be capable of surviving the warmer temperatures south of the bay. Geographical distribution based on temperature is discussed by Hutchins (1947).

Allee (1922) showed that of 241 littoral animals recorded in this region, 60 percent were not found north of Cape Cod, and 11 percent were not found south. Bousfield (1973) lists 85 southern species of amphipods in the New England area; 46 of these do not extend north of the bay. Fifteen of the 34 northern species do not extend south of the bay.

3.2 BENTHIC COMMUNITY

The marine environment of the Manomet area near Pilgrim Station is characterized by two kinds of substrate, hard rock and sand. Each has its own particular flora and invertebrate fauna. Algae dominate the rocky areas. Most of the animals found there are associated with or are directly dependent upon these algae. The sandy substrate might be further divided into clean inshore sands and silty sands of the offshore region. The transition, however, is gradual, and many species distributions overlap the two conditions.

3.2.1 Macrophytes

Ascophyllum is the dominant intertidal macrophyte at Rocky Point and Manomet Beach; Fucus is dominant intertidally at White Horse Beach (Figure 3-1). Distribution of these species appears to be closely related to substrate types in this area (Boney, 1966). Ascophyllum is more prevalent in rocky areas and Fucus in areas of small stones or rubble.

Irish moss (Chondrus crispus) is a dominant subtidal macrophyte species in Cape Cod Bay and is the chief component of the subtidal flora near Pilgrim Station (Figure 3-1). Depending on depth, Chondrus covers up to 90 percent of the available substrate. Chondrus attains a maximum density between mean low water and 14 feet below mean low water. At depths greater than 14 feet below mean low water, Chondrus density decreases and Phyllophora (P. brodiaei and P. membranifolia) becomes the dominant macrophyte. Laminaria sp., Corrallina officinalis, Polydesrotundus, and Lithothamnion sp., are the remaining conspicuous representatives of the subtidal algal flora.

3.2.2 Benthic Invertebrates

Mytilus edulis, the blue mussel, is the dominant animal found in rocky areas in the immediate vicinity of the station. It is present throughout the year and at all depths studied (intertidal to 30 feet). Three other mollusks are ubiquitous and abundant: Littorina littorea, Lacuna vincta, and Modiolus modiolus. Both Littorina littorea and Lacuna vincta are abundant intertidally and to depths of 30 feet, and are typically associated with benthic macrophytes. The echinoderms Strongylocentrotus droebachiensis, Ophiopholis aculeata, Henricia sanguinolenta, and Asterias sp. are also present.

Encrusting and epiphytic forms are abundant on the rocks and algae where sponges such as Halichondria sp., Haliclona sp., barnacles (Balanus balanoides), and bryozoa (Dendrobeania murrayana, Electra sp., and Crisia eburnea) can be found. The algae provide habitats for a variety of filter feeders, herbivores, carnivores, and scavengers. Common among these are the isopods Idotea daltica, Idotea phosphorea, various gammarids and caprellid amphipods, and the polychaetes, Spirorbi spirorbis, Nereis pelagica, and carnivorous phyllodocids.

The dominant offshore species in rocky areas is the American lobster (Homarus americanus), which inhabits rocky bottom substrates from the shallow subtidal zones offshore to depths in excess of 1,000 feet. Lobsters inhabit the ledges off Rocky

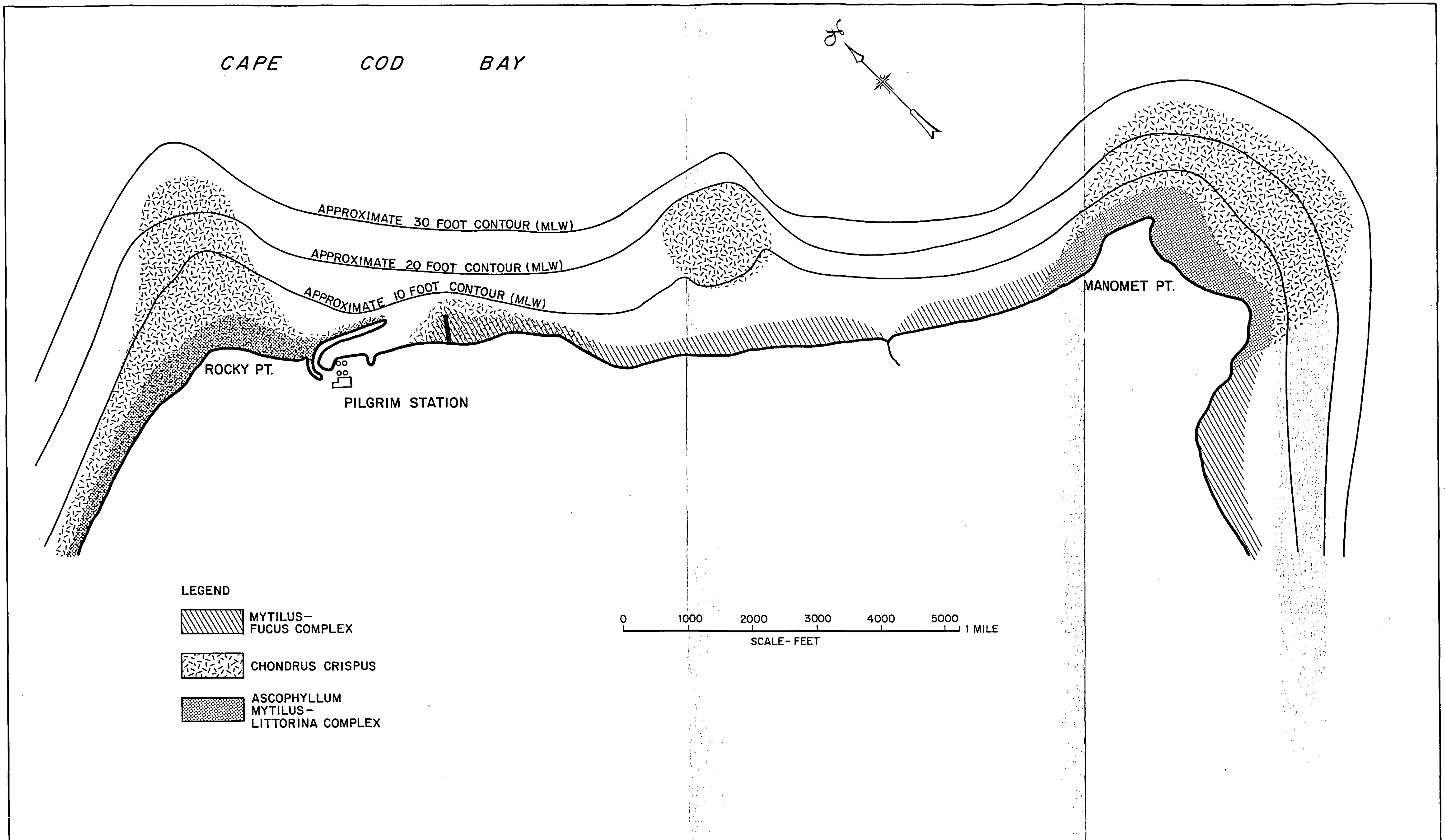

FIGURE 3-1
AQUATIC COMMUNITIES IN VICINITY OF PILGRIM STATION

Point and White Horse Beach, which bracket Pilgrim Station, and off Manomet Point farther to the southeast.

The sand environment shows a gradual transition of clean sands, in which haustorid amphipods are dominant, to offshore silty sands, and the most abundant animals are deposit-feeding polychaetes and bivalves. Acanthohaustorius millsi and Protohaustorius deichmannae are the dominant species in the clean sands. Edotea triloba is also very common inshore as is the bivalve Tellina agilis. Four other species typical of the inshore community are Echinarchnius parma, Nephtys bucera, Spisula solidissima, and Lunatia heros.

The offshore community is characterized by a variety of deposit-feeding bivalves and polychaetes, including Nucula annulata, N. delphinodonta, Ninoe nigripes, Euchone incolor, and Aracidea jeffreysi.

3.3 PLANKTON COMMUNITY

3.3.1 Phytoplankton

The species composition and abundance of phytoplankton in Cape Cod Bay can be expected to vary throughout the year. Temperature, nutrient availability, and wind are major factors affecting the seasonal changes in plankton. Cape Cod Bay is characterized by a diverse phytoplankton community typical of an unpolluted coastal area.

A total of [redacted] were identified from water samples collected in the vicinity of Pilgrim Station in September 1971. Diatoms were the most abundant group and had the highest biomass. Abundant diatom species included Leptocylindricus minimus, Rhizoselenia delicatula, and Cyclotella nana. The phytoplankton community also contained Rhodomonas amphroxeia, a chrysophyte flagellate, and Tetraselmis sp., a green alga. These five species comprised 80 percent of the total phytoplankton cell count. A subsequent study from August 1973, through December 1974, observed seasonal variation not addressed in the 1971 study. The diatom Skeletonema costatum and Leptocylindricus minimus were dominant during much of the sampling period. Skeletonema density increased in the fall, while Leptocylindricus density increased in late winter. Other dominant species included Leptocylindricus danicus, Thalassiosira sp., and Cheatoceros sp. In general, this study indicated different dominant algal species from the 1971 study as a result of seasonal changes.

3.3.2 Zooplankton

Samples collected in 1970 and 1971 from Cape Cod Bay in the vicinity of Pilgrim Station indicated a sparse zooplankton community in winter. Zooplankton densities increase during the summer months. The zooplankton community was strongly dominated by copepods. Centropages typicus was the most abundant winter species. Pseudocalanus elongatus, Temora longicornus, and Acartia clausi were collected throughout the year. Acartia tonsa was unaccountably absent during summer. In a study from August 1973, through December 1974, the dominant species were Acartia clausi, Oithona similis, Pseudocalanus minutus, Acartia tonsa (in summer), and Centropages typicus. The species in this study follow closely those reported for the area by Anraku (1964). These species are representative of the Pilgrim site and are typical of estuaries and coastal marine species found in temperate climates characteristic of Cape Cod Bay.

3.3.3 Meroplankton

From March 1970 to December 1971, eggs and larvae of [redacted] of fish were collected in the vicinity of Pilgrim Station. Atlantic cod, pollock, winter flounder, cunner, tautog, squirrel hake, Atlantic mackerel, and silver hake comprised 96 percent of the eggs and 68 percent of the larvae collected. In collections in 1972, cunner eggs were abundant from May through August, and larvae were abundant from June through August. Winter flounder eggs and larvae were present in April and May. Menhaden eggs were collected in June, while larvae were collected from June through September. Pollock eggs occurred from October to December, and larvae were collected in December. Cod eggs appeared from October to May, while the larvae appeared from November through May. Ichthyoplankton collections in 1974 generally indicated the same seasonality. Labrid eggs (cunner and tautog) were extremely abundant in mid- and late summer. Developing larvae were primarily cunner and, therefore, eggs were thought to be cunner. Gadid eggs (both pollock and cod) again became abundant in mid-November through December. Pollock larvae also appeared in December samples in which they were abundant.

Bivalve and polychaete larvae were the most abundant larval invertebrates collected. Mytilus edulis veliger larvae were abundant in late summer and early fall of 1974 in the vicinity of the Pilgrim Station. Other bivalve larvae were collected periodically throughout the year.

Most fish and invertebrate eggs and larvae collected in the vicinity of Pilgrim Station are indigenous to the area or at least to the Gulf of Maine region.

An extensive cod-spawning ground southeast of the station has been described (Bigelow and Schroeder, 1953). The spawning areas of other fish species in Cape Cod Bay have not been documented.

The eggs and larvae of most species were presumably carried into the region by water currents.

3.4 FISH COMMUNITY

Approximately [redacted] have been identified in the vicinity of Pilgrim Station during monitoring collections from 1969 through 1974. This monitoring program includes both trawl and gill net collections.

Trawling was conducted at three offshore stations in the vicinity of Pilgrim Station. These stations are representative of the benthic fish community of the silty-sand substrate. The most abundant species in trawl catches were winter flounder (Pseudopleuronectes americanus), yellowtail flounder (Limanda ferruginea), windowpane flounder (Scophthalmus aquosus), oceanpout (Macrozoarces americanus), longhorn sculpin (Myoxocephalus octodecemspinosus), and skates (Raja spp.). Winter flounder were present in most trawl samples. They were most abundant in late summer and early fall, and least abundant in mid-winter. Yellowtail flounder, windowpane flounder, longhorn sculpin, and skates have been collected in small numbers throughout most of each of the study years. Comparisons of the trawl data accumulated from June 1969, to December 1972, indicate that both the species and relative abundance at all collecting stations were similar, indicating a relatively stable community.

Gill nets were used to collect both open water fish species and species associated with rocky substrates. Pollock (Pollachius virens), alewives (Alosa pseudoharengus), cunner (Tautogolabrus adspersus), and sea herring (Clupea harengus) were the most abundantly collected species. Pollock, Atlantic cod, cunner, and alewife were common during May and June collections. Pollock and cod abundance also increased from October through December of each year. Sea herring and smelt (Osmerus mordax) occurred in greatest abundance in April, while numbers of cunner were evenly distributed from May through November.

The results of two sportfish creel censuses conducted by Mass. Div. of Marine Facilities at Pilgrim Station indicate generally similar seasonal trends in fish species composition as gill net and trawl collections. Winter flounder, however, were most abundant in the sport fishing catch in spring and early summer, which may indicate that they are inshore and, thus, available to shore fishermen during this time. In addition, bluefish were more abundant in the sportfish catch in late summer than in gill net collections.

3.5 REFERENCES - SECTION 3

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SECTION 4

REPRESENTATIVE SPECIES AND RATIONALE

The aquatic biota of Cape Cod Bay is typical of that found in marine environments of north temperate climates. The biotic communities are more representative of a marine than an estuarine environment. Thus, the concerns of Pilgrim Station are not similar to the concerns of onshore facilities in estuaries, e.g., impact on spawning and nursery areas.

4.1 RATIONALE FOR SPECIES SELECTION

Representative species exhibiting both nearfield and farfield effects were selected for detailed analysis. The choice of these species is based on species affected by Unit 1 operation, or potentially affected by the operation of Units 1 and 2. In most cases, these species are dominant, either numerically or in biomass, which reflects importance in the biological community. Many of these species are of commercial or recreational interest; however, their selection was also based on their ecological importance to their respective communities.

4.1.1 Rare and Endangered Species

There are no rare and endangered species in the vicinity of Pilgrim Station.

4.1.2 Commercially and Recreationally Important Species

There are two major commercial species in the immediate vicinity of Pilgrim Station - the American lobster (Homarus americanus) and a red alga, Irish moss (Chondrus crispus). A commercial fishery also exists for winter flounder (Pseudopleuronectes americanus) and Atlantic menhaden (Brevoortia tyrannus) (Table 4-1). Sport fish in the area include flounder, cod (Gadus morhua), tautog (Tautoga onitis), cunner (Tautogolaburs adspersus), striped bass (Morone saxatalis), mackerel (Scomber scombrus), pollock (Pollachius virens), and bluefish (Pomatomus saltatrix) (Table 4-2).

4.1.3 Dominant Species

Species of phytoplankton and zooplankton will not be used as representative species in this demonstration for several reasons. Natural ecosystems experience wide fluctuations in population size and biomass of organisms of lower trophic levels, such as phytoplankton and zooplankton. These fluctuations are due to several interacting factors, including density-dependent mechanisms such as selective or nonselective predation and density-independent mechanisms such as daily or seasonal changes in physical conditions. These fluctuations severely restrict their use fullness in assessment of impact from minor perturbations. Secondly, short life cycles and indications of rapid regeneration of most planktonic organisms reduce power station impact on this component of the ecosystem when compared to longer-lived species. Thirdly, power station induced mortality of lower trophic level organisms does not prohibit their contribution to the ecosystem as sources of nutrients in detritus.

Dominant benthic species found in the vicinity of Pilgrim Station include the brown algae Fucus and Ascophyllum intertidally, and the red algae, Chondrus crispus, and Phyllophora sp. subtidally (USAEC, 1974). The dominant fauna include the mussel (Mytilus) and periwinkle (Littorina) intertidally, and the lobster and amphipod (Acanthohaustorius) subtidally. Benthic species should not be affected by the operation of Pilgrim Station beyond the immediate discharge area, due to the bouyant nature of the surface discharge. Primarily, benthic species with entrainable planktonic life stages would be affected, since many benthic adults are sessile or have limited mobility. Intertidal species may be affected by nearfield effects, but studies to date have not indicated a measurable impact. Furthermore, intertidal organisms are tolerant of many environmental perturbations (Kinne, 1970; Boney, 1966; and Green, 1971).

Dominant fish species collected near Pilgrim Station in 1974 include winter flounder (collected by trawls) and the pelagic species, pollock, sea herring, cunner, and alewife (collected by gill nets) - USAEC (1974). The density of clupeid species (alewife and sea herring) varied seasonally and annually (1971-1973), while the percentage compositions of resident species were more stable from year to year.

Clupeids, silversides, and rainbow smelt (Osmerus mordax) were the most numerously impinged fish in 1973, and when the station was operating in 1974.

Labrid eggs and larvae (primarily cunner) and winter flounder larvae were the predominant ichthyoplankton taxa entrained as observed by studies from January to December 1974.

4.1.4 Nuisance Species

Two nuisance species have been identified in the vicinity of Pilgrim Station. The sea urchin (Strongylocentrotus drobachiensis) is present in the vicinity of the station. However, its presence does not appear to be a result of station operation, since its habitat is not related to the discharge area. This species is of commercial concern to the Irish moss population as a predator. The sea urchin, however, is a nonselective predator and, thus, represents the same hazard to all macrophytes.

TABLE 4-1

ESTIMATED COMMERCIAL CATCH OR HARVEST (lbs) IN THE VICINITY OF PILGRIM STATION

Species Date	Lobster(3)	Irish Moss(1)	Menhaden(2)	Winter Flounder(3)
1970	782,518	375,000	968,000	
1971	881,279	375,000	6,312,000	
1972	871,485	473,000	11,920,000	1,425
1973	732,866	159,000	43,173,000	3,980*
1974	794,017*	265,000	47,032,000	7,498*

(1) Harvest between Rocky Point and Manomet Point reported in Environmental Report

(2) Total catch reported for the State of Massachusetts to National Marine Fisheries Service

(3) Total commerical catch reported for Plymouth County, Massachusetts, by National Marine Fisheries Service

* Incomplete monthly totals

TABLE 4-2

SPORT FISHING CATCH AT PILGRIM STATION
(TOTAL NUMBER OF FISH)
(1973 - 1974)

	1973[1]	1974[2]
Tomcod	13	7
Atlantic cod	59	139
Mackerel	51	2
Flounder	37	232
Pollock	588	440
Tautog	69	28
Cunner	82	1,294
Striped Bass	648	39
Bluefish	634	760
"Snapper" Bluefish	-	1,176
Ocean Pont	-	6
American Eel	-	4
Scup	-	2

(1) Survey conducted from July through November.
(2) Survey conducted from April through November.

Recently, concern has been voiced over nutrient-enriched, heated water from power stations causing an increase in red tide abundance. Prakash (1967) found that salinity is a more important ecological factor than temperature in controlling the summer abundance of red tide (*Gonyaulax tamarensis*). Analysis of the species composition and abundance of phytoplankton collected from Pilgrim Station intake and discharge has not revealed any increase in *Gonyaulax* sp.

4.2 REPRESENTATIVE SPECIES LIST AND RATIONALE

4.2.1 Irish Moss (*Chondrus crispus*) (Figure 4-1a)

Irish moss is of commerical concern in the area of Pilgrim Station. Table 4-1 indicates the reported commercial harvest of Irish moss in the vicinity of the station. The harvest has fluctuated from year to year (Table 4-1). This species is representative, in many respects, of benthic macroflora in the Pilgrim Station area as a dominant species.

4.2.2 Rockweed (*Ascophyllum nodosum*) (Figure 4-1b)

Ascophyllum nodosum is the most abundant intertidal macrophyte at Pilgrim Station. It is a long-lived, sessile brown algae, and thus a good indicator species of a continuous long-term stress. As an intertidal species, it should reflect any stress from a shoreline discharge such as that of Pilgrim Station.

4.2.3 Amphipod (*Acanthohaustorius millsi*) (Figure 4-1c)

The haustorid amphipod, *Acanthohaustorius millsi*, is an abundant subtidal species collected in the vicinity of Pilgrim Station. It is a burrowing amphipod that prefers a fine sand substrate. As a subtidal species, *A. millsi* is somewhat intolerant of increased temperature. *A. millsi* is thus representative of a temperature-sensitive, subtidal species occupying a sandy substrate.

4.2.4 American Lobster (*Homarus americanus*) (Figure 4-1d)

The American lobster is an important commercial species, is a detritivore, and is a representative of many benthic invertebrates. The commercial catch in the vicinity of Pilgrim Station has remained stable over the past five years (Table 4-1). Lobsters inhabit rocky areas similar to those found in the immediate vicinity of Pilgrim Station. Lobsters may be considered an indicator species of environmental perturbations as they are long-lived. The mysid stage of lobster development is planktonic, occurring in spring. Thus, lobster may be regarded as representative of bivalves and other benthic fauna with entrainable planktonic larval stages.

4.2.5 Blue Mussel (*Mytilus edulis*) (Figure 4-1e)

The blue mussel is an abundant intertidal species collected at Pilgrim Station. It can be described as a habitat-forming organism although it inhabits most substrate types in the vicinity of Pilgrim Station.

The veliger stage of mussel development is planktonic and, thus, susceptible to entrainment. Both initiation of spawning and settling of pediveliger larvae are controlled by ambient temperature conditions (Sherman and Lewis, 1967).

Generally, *Mytilus* is a tolerant species as is evidenced by major industrial problems resulting from *Mytilus* biofouling of water-use systems.

4.2.6 Common Periwinkle (*Littorina littorea*) (Figure 4-1f)

Littorina littorea is an abundant intertidal gastropod collected in the vicinity of Pilgrim Station. This species is an important component of the intertidal community because of its high population densities in many parts of its geographic range. It is an economically important mollusk in western Europe where it is harvested for food (Wells, 1965).

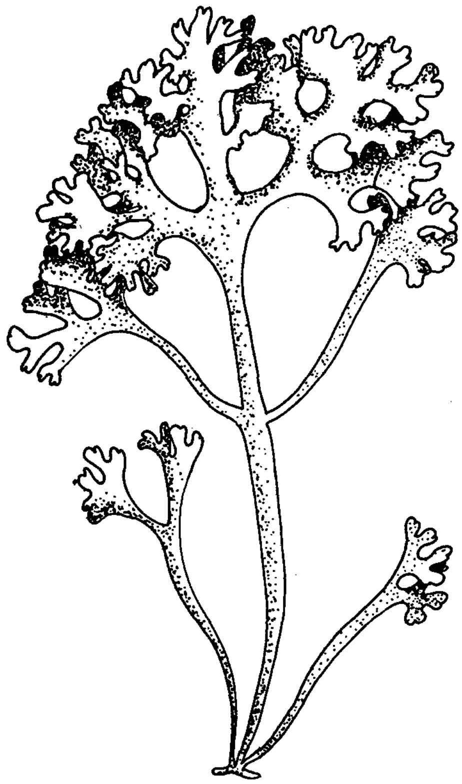
The periwinkle is found on rocky substrates and macrophytes (such as *Ascophyllum nodosum*) both of which are found at the station discharge. It is an omnivorous browser, feeding on detritus and epiphytes.

The egg capsule and veliger larvae stages of the periwinkle are planktonic and, thus, subject to entrainment. Adults are relatively immobile and, therefore, are subject to thermal influence from the onshore discharge at Pilgrim Station.

4.2.7 Atlantic Menhaden (*Brevoortia tyrannus*)(Figure 4-1g)

Menhaden is an open water migratory species which is affected by many generating stations. This species has been affected by both impingement and entrainment at intake structures and entrainment in thermal plumes (Young, 1974). Menhaden are sensitive to extreme environmental conditions and, thus, indicative of stress resulting from environmental perturbations.

Menhaden are representative of most clupeids and other migratory species. Menhaden are planktivorous, feeding on phytoplankton (early life history stages), and zooplankton (late life history stages), and are prey for species such as striped bass and bluefish. Migratory habits of menhaden have been described (Bigelow & Schroeder, 1953). Like other clupeids, menhaden are subject to fluctuating year class strength. Menhaden is a commercial species in Cape Cod Bay (Table 4-1).



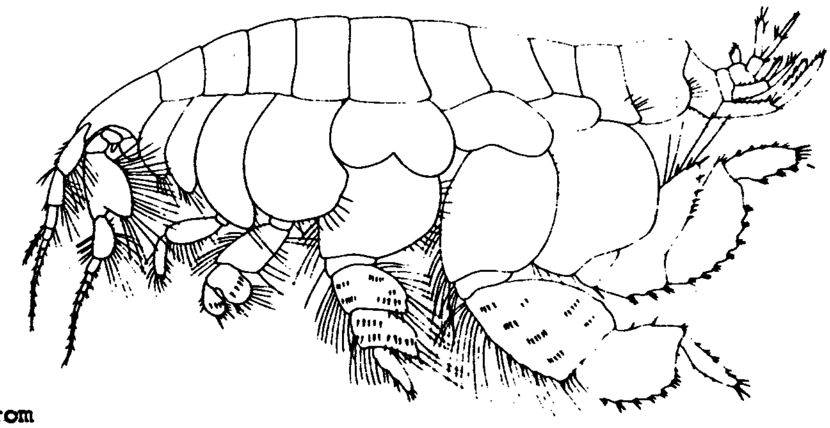
IRISH MOSS, CARRAGEEN

Chondrus crispus

ROCKWEED

Ascophyllum nodosum

FIGURE 4-1A AND 1B
REPRESENTATIVE SPECIES

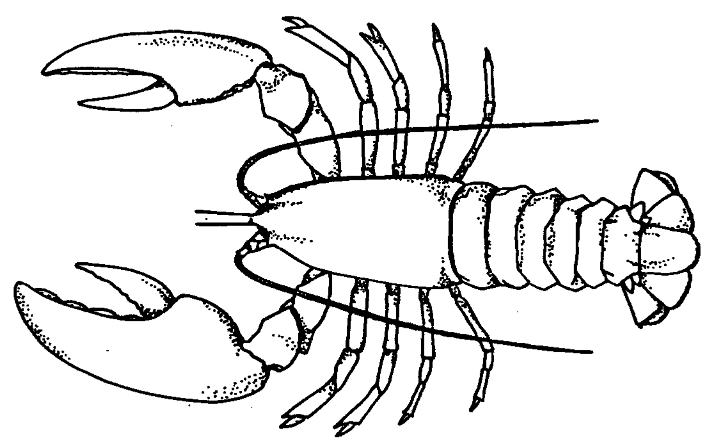


from
The Families and Genera of
Marine Gammaridean Amphipoda

AMPHIPOD

(Representative of

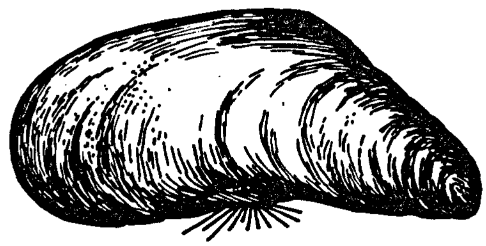
Acanthohaustorius millsi)



American
LOBSTER

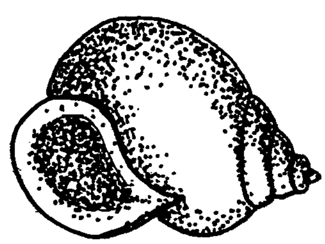
Homarus americanus

FIGURE 4-1C AND 1D
REPRESENTATIVE SPECIES



Blue MUSSEL

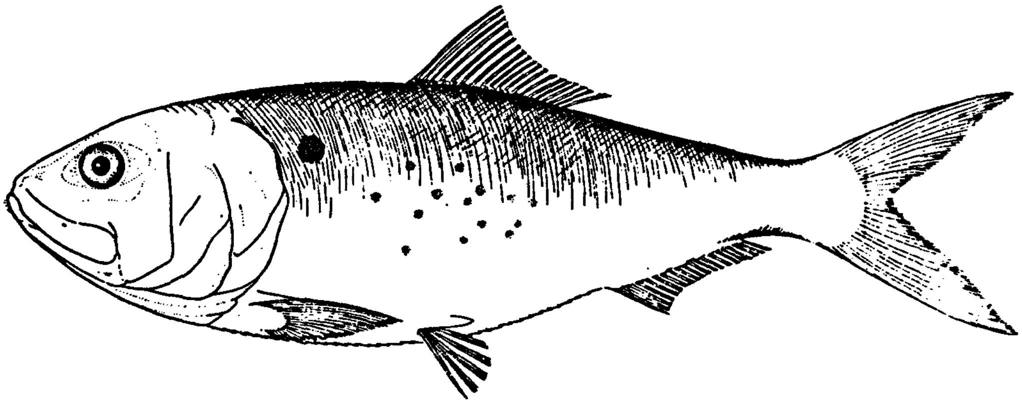
Mytilus edulis



PERIWINKLE

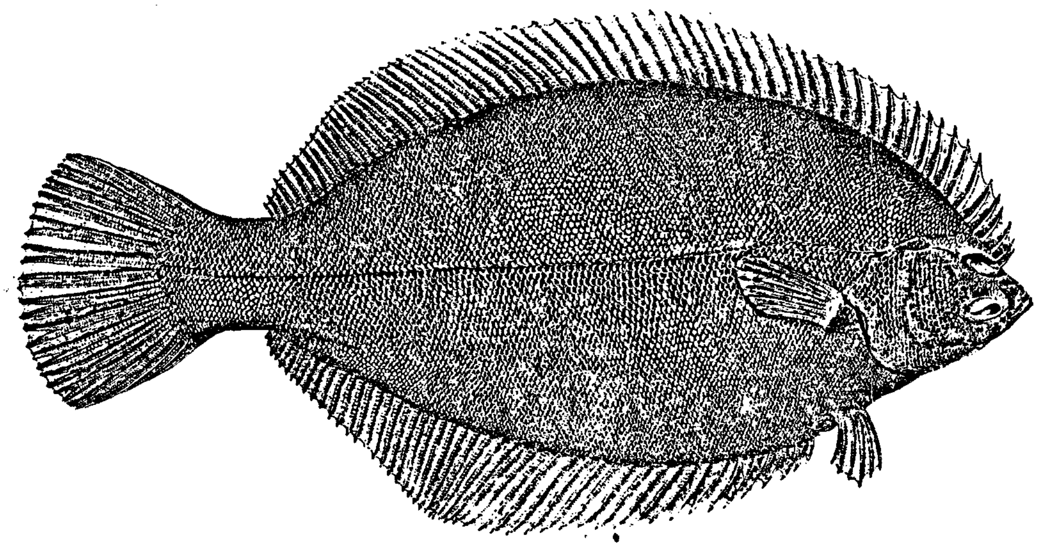
Littorina littorea

FIGURE 4-1E AND 1F
REPRESENTATIVE SPECIES



Atlantic MENHADEN

Brevoortia tyrannus



WINTER FLOUNDER

Pseudopleuronectes americanus

from
Fishes of the Gulf of Maine
Bigelow & Schroeder
1953

FIGURE 4-1G AND 1H
REPRESENTATIVE SPECIES

Menhaden are warm water fish, rarely found in waters less than 50°F; thus, their presence in the cooler waters of Cape Cod Bay is seasonal (Bigelow and Schroeder, 1963). Mortality of menhaden attributable to thermal discharge has been observed at Pilgrim Station.

4.2.8 Winter Flounder (Pseudopleuronectes americanus) (Figure 4-1h)

Winter flounder are commercially important in Cape Cod Bay (Table 4-1) and are the dominant species collected in trawls in the vicinity of Pilgrim Station. They are also of recreational importance in the sport fishery of the area (Table 4-2).

Winter flounder have been affected by many power stations located in estuaries, both through entrainment of planktonic larval stages and impingement of adults (NUSCO , 1973). At Pilgrim Station, winter flounder larvae constitute one of the most numerously entrained ichthyoplankton species; however, few adults have been impinged.

The winter flounder at Plymouth Station is probably a localized population with spawning occurring in the Plymouth-Duxbury estuary (personal communication, R. Fairbanks). This localization is also suggested by the studies of Howe and Coates (1975). Winter flounder are benthic fish usually found at depths between 1-40 meters. Since they prefer a soft, muddy or sandy substrate, they are regarded as a representative of sandy substrates offshore of Pilgrim Station.

4.2.9 Pollock (Pollachius virens) (Figure 4-1i)

Pollock were the most abundant fish species collected by gill netting in the vicinity of Pilgrim Station. Pollock were also an abundant sport fish as reported in the 1973 and 1974 creel census (Table 4-2). Pollock observed in this area were primarily fish of year-class III and IV.

Pollock have a life history similar to cod; both are offshore spawners with planktonic eggs and larvae. Pollock ichthyoplankton are also regarded as representative of cod in that both are subject to entrainment in late fall and early winter. Although pollock have been collected and observed in the immediate vicinity of the power station, both at the intake and thermal discharge, there have been no observed mortalities either through impingement or entrainment in the thermal plume.

4.2.10 Cunner (Tautogolabrus adspersus) (Figure 4-1j)

The cunner is a resident species which inhabits rocky areas. Unlike winter flounder, they probably spawn in the vicinity of Pilgrim Station. Their eggs are planktonic and, therefore, are subject to entrainment. Adults are subject to impingement.

Cunner is of some recreational value as a food fish but is usually not regarded as a sport fish.

Cunner were the most numerously entrained eggs and larvae and are an abundant species in the immediate vicinity of Pilgrim Station. Cunner, Irish moss, and lobster are representative of biotic communities inhabiting rocky substrates such as that found near the station.

4.2.11 Rainbow Smelt (Osmerus mordax) (Figure 4-1k)

The smelt is an anadromous species rarely found more than one mile from the coast. Spawning takes place in spring (April-June) in the upper freshwater reaches of estuaries and rivers. Adults return immediately to saltwater, inhabiting estuaries or marine water just beyond during the summer. Smelt are one of the species impinged at Pilgrim Station.

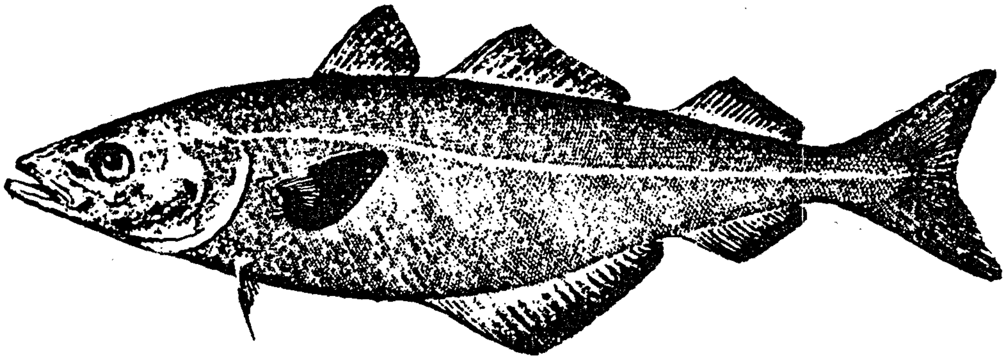
4.2.12 Atlantic Silverside (Menidia menidia) (Figure 4-1l)

The Atlantic silverside is an important forage fish at the Pilgrim site. It inhabits shallow water, generally in large schools. Adults could potentially be affected by the thermal plume and impingement on the traveling screens. The larvae of the silverside could also be entrained at the intake structure. The eggs are adhesive attaching to vegetation in the spawning area and, therefore, entrainment is probably not a concern as indicated by the absence of silverside eggs in the entrainment studies.

4.2.13 Alewife (Alosa pseudoharengus) (Figure 4-1m)

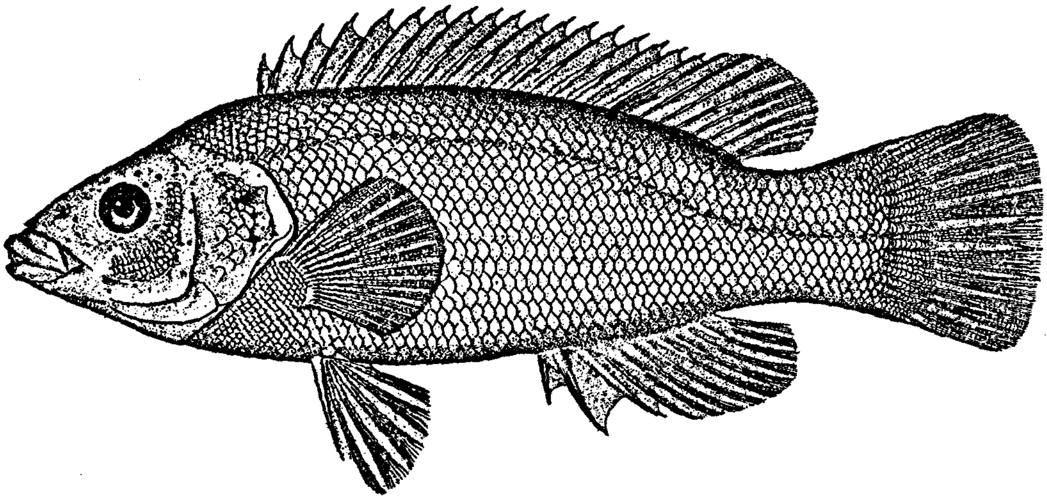
Alewives are one of the forage fish species in the area of the Pilgrim site. They are anadromous, spawning in some of the rivers and streams in the area. In salt water, alewives feed on plankton such as diatoms, other algae and small crustaceans. Alewives serve as food for predaceous fish, birds, and to some extent, man.

Pilgrim Station operational data suggest alewife eggs are not entrained and the larvae are infrequently entrained. Some small alewives are probably impinged on the traveling screens and are grouped into the unidentified clupeid category in the screen-washing program.



~~AMERICAN~~ POLLOCK

Pollachius virens

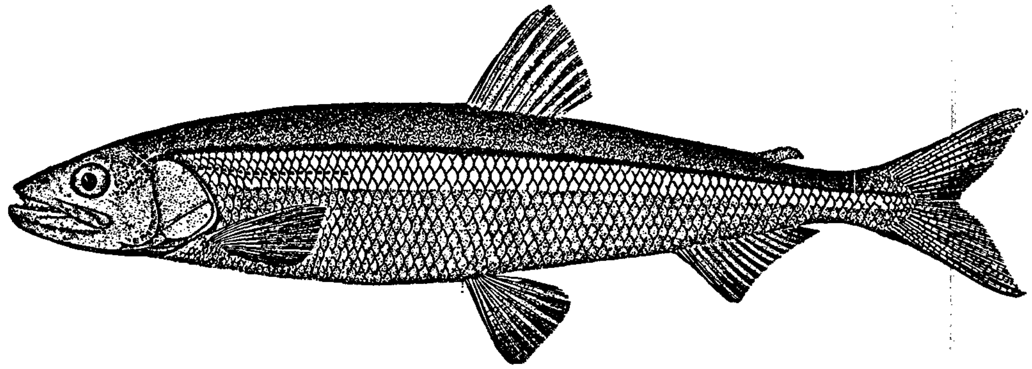


CUNNER

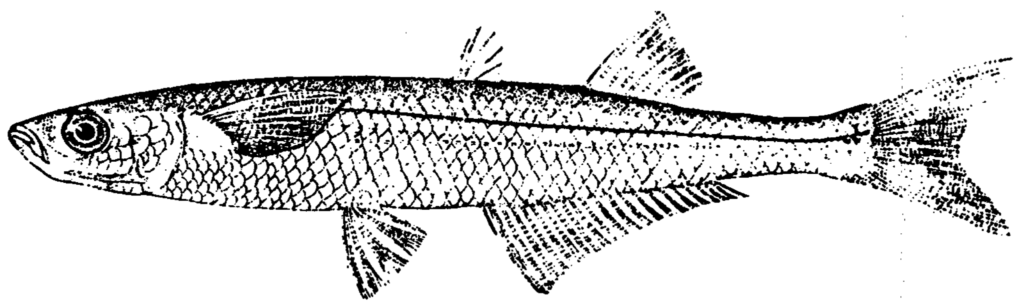
Tautogolabrus adspersus

from
Fishes of the Gulf of Maine
Bigelow & Schroeder
1953

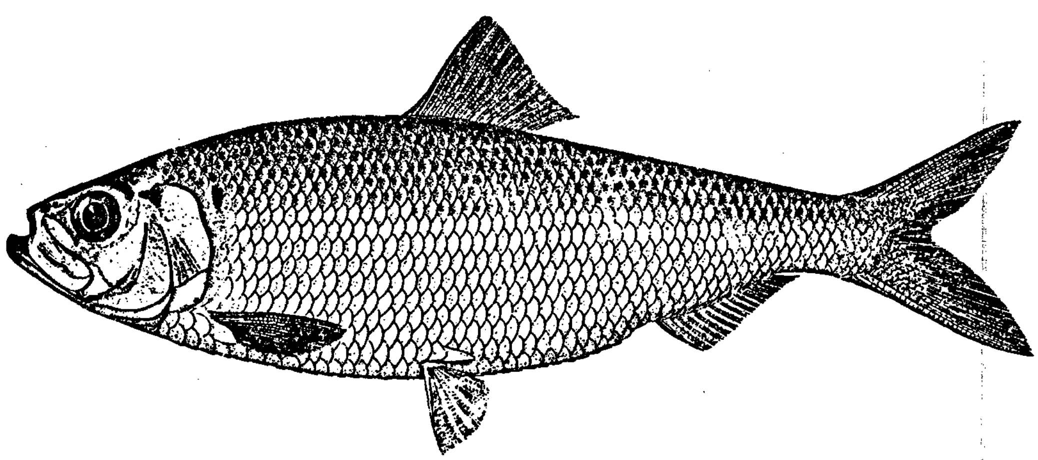
FIGURE 4-1I AND IJ
REPRESENTATIVE SPECIES



Rainbow SMELT Osmerus mordax



Atlantic SILVERSIDE Menidia menidia



ALEWIFE Alosa pseudoharengus

FIGURE 4-1K, 1L & 1M
REPRESENTATIVE SPECIES

from
Fishes of the Gulf of Maine
Bigelow & Schroeder
1953

TABLE 4-3

CHECKLIST SUMMARY OF REPRESENTATIVE SPECIES AND RATIONALE

	Irish Moss	Ascophyllum	Amphipod	Lobster	Periwinkle	Mussel	Menhaden	Winter Flounder	Pollock	Cunner	Smelt	Silverside	Alewife
Dominant Species	X			X		X	X	X	X	X			
Local residents	X	X	X	1	X	X		1	1	X		X	
Migratory				1			X	1	1				X
Commercial Importance	X			X			X	X	X				
Sport Species				X				X	X	X	X		
Community Type													
Estuarine								1			1		
Marine													
Rock Substrate	X	X		X	X	1			1	X			
Silt Substrate			X			1		1					
Open Water							X		1		1	X	X
Habitat Former	X					X							
Intertidal					X								
Subtidal	X	X	X	X									
Trophic Level													
Producer	X	X											
Detrivore			X	X	1	1				1			
Primary Consumer					1	1	1		1		1		
Secondary Consumer							1	X	1	1	1		
Tertiary Consumer									1				
Source of Impact													
Entrainment				P	P	P		A		A	P		
Impingement							P	P	P	P	A		
Thermal Plume	P	P					A						

X - fall in this category.
1 - some life stage falls in this category.
P - potential source of impact.
A - identified as a source of impact on this species at this station.

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SECTION 5

LIFE HISTORIES AND TEMPERATURE TOLERANCE RELATIVE TO REPRESENTATIVE SPECIES

5.1 IRISH MOSS (*CHONDRUS CRISPUS*)

Irish Moss is a benthic marine red alga which inhabits rocky substrates from below low water (including intertidal pools) to a depth of 38 meters. Usually, however, its maximum density occurs from low water to 6 meters below low water. *Chondrus* is found from New Jersey to Labrador with greatest abundance towards the center of this range.

Chondrus reproduces throughout the year with peak reproduction occurring during late spring and summer (Prince, 1971). *Chondrus* reproduces both sexually and asexually. Carpospores are produced in early spring and tetraspores in late summer and early fall. Spores are non-buoyant and thus settling occurs from August through November. The Irish Moss thallus is produced from a perennial holdfast and is usually attached to a rock or ledge outcropping. Shells and small stones are also suitable substrates. A number of morphologically different forms of *Chondrus* have been identified. Morphological differences are generally attributed to certain environmental factors, such as light, wave action, depth, salinity, or predation (Prince, 1971). *Chondrus crispus* is commercially harvested for carrageenan a gelatinous extract used as a suspending agent in the brewing, baking, pharmaceutical, and dairy industries.

An Irish Moss harvest area lies between Rocky Point and Manomet Point, Plymouth. Generally, the density of Irish Moss appeared highest in August, from 1972 to 1974, and lowest in February and May (1972-1974). Maximum density also appeared greatest in areas shallower than 20 feet below mean low water (MLW), especially at Rocky Point.

Upper thermal tolerance limits of *Chondrus* tetraspores and carpospores has been determined. Carpospores have survived 95°F temperature at six minutes exposure when acclimated to ~~20°F~~. 70°F Tetraspores were found to be less tolerant of heat than carpospores. Maximum tolerance was 80°F. At this temperature, however, both carpospores and tetraspores were killed in 4 to 10 days. Maximum growth occurred at 70°F for all developmental stages (Prince, 1971).

5.2 ROCKWEED (*ASCOPHYLLUM NODOSUM*)

Ascophyllum nodosum is an intertidal brown algae usually found in rocky areas protected from intensive wave action (Smith, 1951). It is a widely distributed, north Atlantic species which is found from Labrador to New Jersey. *Ascophyllum* is a long-lived species with an average life span of 12–13 years. Most other macrophyte species have much shorter life spans; for example, Fucus vesiculosus, another brown alga commonly found with Ascophyllum (including at Pilgrim Station) has an average life span of one year (Boney, 1966).

Gametophyte production in Ascophyllum occurs from fall to early spring with most vegetative growth occurring immediately from early spring through late summer.

Ascophyllum is the most abundant macrophyte species at Rocky Point, in Manomet Point, while Fucus is abundant at White Horse Beach. The density (grams dry weight per square meter) appears to be stable from year to year with seasonal variations resulting from decreases in spring (Figure 6–5).

Available information on temperature tolerance of A. nodosum indicates that it can withstand water temperatures as high as 93 to 97°F (Fritsch, 1945). More information is available on other northern species similar to Ascophyllum. Fucus vesiculosis suffered only a slight reduction in photosynthetic activity when exposed to 90°F water after acclimation at 75°F (Boney, 1969).

5.3 AMPHIPOD (ACANTHOHAUSTORIUS MILLSI)

This haustorid amphipod is a subtidal benthic marine species. It is the most commonly occurring species of the family Haustoridae in Cape Cod Bay (Sameoto, 1969a). It is a sand-burrowing amphipod that feeds by filtering fine food particles from the interstitial water of sands.

A previous study in Cape Cod Bay reported A. millsi to have a life span of between 12 and 17 months (Sameoto, 1969a). The same study indicated that females produced only one brood of young and then died. Ovigery appears to be somewhat dependent on water temperature, as 13 percent of females collected were carrying eggs at 45°F, while 54 percent of the females were carrying eggs at 49°F. The number of eggs increased with increasing body weight of females up to 18 eggs per female (the mean is 8 eggs per female) (Sameoto, 1969a).

The density of A. millsi was reported to increase with increasing water depth (Sameoto, 1969a). In the vicinity of Pilgrim Station they are collected in sand substrates at White Horse Beach, and offshore of the discharge location. Density of A. millsi at Pilgrim Station appears to be greatest at 20 feet below mean low water (MLW) rather than at 30 feet below (MLW).

Thermal tolerances for A. millsi have not been well defined for individual life stages. One hundred percent mortality occurs at approximately 97°F, although no mortality was observed during a brief exposure (3 minutes) to water at 95°F. Mortality of intertidal amphipods occurred at higher temperatures (106°F) indicating that intertidal amphipods are less sensitive to thermal increases than subtidal species, such as <u>A. millsi</u> (Sameoto, 1969b).

5.4 AMERICAN LOBSTER (<u>HOMARUS AMERICANUS</u>)

The lobster is a benthic marine crustacean inhabiting coastal waters from the continental slope to the low watermark and ranging from North Carolina to Labrador. Highest numbers of this species occur near the center of this range, off the Maine Coast to Newfoundland, where ambient bottom temperatures normally vary from 28°F to 75°F (McLeese and Wilder, 1964).

Lobster maturation rates vary with water temperature. South of the Gulf of St. Lawrence, sexual maturity occurs when the lobster reaches approximately 1/2 pound in weight and/or 7 inches in length. In contrast, lobsters in the northern part of the Gulf reach maturity at nearly 2 pounds and 12 inches in length. Since a 1-pound lobster is the usual minimum commercial size, many lobsters inhabiting cold water are removed before ever reproducing. (McLeese and Wilder, 1964).

In Cape Cod Bay, lobsters regain 5-7 years to attain legal commercial size, and are approximately 1 pound in weight.

A mature female lays between 5,200 and 50,000 eggs, depending upon the age and size of the individual, from June to September; however, fecundity may decrease in more northern waters (Squires, 1970) (7,000 to 23,000 eggs for northern females). Females retain their eggs for nearly a year, this too being dependent upon temperature; warmer water hastens egg development.

Hatching takes place from mid-June through September for most lobster populations (Perkins, 1972). The first few larval stages of lobster are planktonic. Sherman and Lewis (1967) have reported that the normal hatching process of lobsters occurs from June to August as water temperatures range from 54-59°F.

In the investigations of the lobster fishery of Long Island Sound by Lund and Stewart (1970), the computed survival rates of lobster from larval State I through IV was 0.52. This is extraordinarily high and suggests low predation (which is unusual) but may be the result of low density. Lund and Steward (1970) indicated that during a ctenophore bloom there was a drastic reduction of all planktonic forms - including stage III of the lobster. This occurred in late July of 1966, 1967, and 1969, and August of 1968 and represents the only indicated major reduction of larval forms during the sampling period in Long Island Sound.

Few lobster larvae have been collected in the vicinity of the Pilgrim Station, although there is a sizable adult population.

An on-going program at the Pilgrim Station monitors the lobster catch per pot from Rocky Point to Manomet Point, Plymouth (Figure 6-8). The average catch per pot in the sample period from April through October was approximately 3.7 individuals per pot. Peak abundance during the years 1972 through 1974 was in late August to early October as reported by catch/pot data. The greatest abundance of lobsters occurred at Rocky Point and Manomet Point where the best habitats exist.

Few definitive studies have been written concerning the lethal thermal tolerance of homarids. However, the use of thermal effluents have been suggested for use in the mariculture of lobster and other marine invertebrates. Maintained at an optimum growth temperature of between 71 to 75°F in the laboratory, lobsters have attained commercial size in 2 years after hatching (Hughes, et. al, 1972).

McLeese (1956) recorded the 48-hour thermal tolerance of lobsters acclimated at 25°C (77°F) to be 30.5°C (86.9°F) at 30 percent salinity. The 24-hour TC50 of lobster larvae was determined to be 84.5°F (Battelle Memorial Institute, 1974).

5.5 BLUE MUSSEL (<u>MYTILUS</u> <u>EDULIS</u>)

The common mussel is found in all northern hemisphere temperate marine waters. Hutchins (1947) found the southern limit of distribution corresponded closely with 80°F isotherm monthly maximum temperature. <u>Mytilus</u> <u>edulis</u> is distributed intertidally to 30 feet below mean low water, but reaches its greatest density at the mean tide mark to just below mean low water. <u>Mytilus</u> inhabits tidal flats and is attached to hard substrates including rocks and shells surrounded but not covered by silt and mud. Mussels are also estuarine and occur where normal salinities do not fall below ten parts per thousand. <u>Mytilus</u> is able to withstand short periods of low salinity, as low as four parts per thousand (Hutchins, 1947).

Spawning occurs in late spring when water temperatures reach approximately 57°F and above. Eggs and sperm are liberated at high tides, sometimes in such large volumes that the water becomes opaque. Lubet (1956) found that highest numbers of gametes released corresponded to the new and full moon during the spawning season. Zygotes develop into ciliated veliger larvae which are planktonic for several weeks. Cilia provide the larvae with a small degree of motility. Development of a foot begins during this period, and the larva (pediveliger) begins a benthic existence. The pediveliger is still motile and therefore able to locate a suitable habitat. It attaches itself to a hard substrate with byssus thread. However, if its location becomes unsuitable it can reabsorb the byssal threads and move, to some degree, with remaining cilia.

Most *Mytilus* pediveliger larvae settle to the bottom from mid-June through mid-July in Connecticut (Engle and Losanoff, 1942). Temperatures during settling were between 54.5°F and 66.2°F. An extended season of settlement was recorded by Ralph and Henley (1952), where temperatures in the experimental area never exceeded 66.2°F. Settling substrate usually contain algal filaments and a solid object to which the byssus thread are attached. *Mytilus edulis* were most abundant at White Horse Beach transects during February and May, and lowest in August and November. Intertidal areas had the greatest overall density.

Kennedy and Mihursky (1971) reported the upper lethal tolerance temperature of a species of *Mytilus* to range from 80–105°F. Henderson (1929) recorded the upper tolerance temperature level of *Mytilus* at 105.4°F when acclimated at 59°F. The 24-hour median tolerance was conservatively estimated at 84.2°F. Gonzalez (1972), through field observations and laboratory studies, reported extensive *Mytilus* mortality immediately adjacent to a power plant discharge. Feeding was noticed to ceased at 77°F. Brenko and Calabrese (1969) found minimal survival of *Mytilus* larvae when held at 86°F for 16–17 days. At 77°F, more than 50 percent survived at moderate ocean salinities.

5.6 COMMON PERIWINKLE (*LITTORINA LITTOREA*)

The common periwinkle is a typical intertidal inhabitant of rocky shores in the North Atlantic Ocean. Its range extends from Greenland, down the Labrador coast to New Jersey. The extension of its range from the Maritime Provinces southward has occurred within the last hundred years. Its southern range limit appears to be correlated with summer water temperatures near 70°F (Wells, 1965).

In this species, planktonic egg capsules with developing embryos can be transported considerable distances before hatching. Usually 2 to 4 eggs are contained in each capsule. Free-swimming veliger larvae emerge from the capsules after a development period of about 6 days. These veligers remain planktonic an additional 2 to 4 weeks (Green, 1971; Wells, 1965).

While the average life span for *L. littorea* is approximately 2 years for some populations, other populations may live much longer (Green, 1971). There are apparent differences in breeding cycles of open-coast and estuarine populations, open-coast populations spawning in March and estuarine populations in January. Individuals are sexually mature at a shell height of about 11–12 mm and reproduce for the first time during their second or third winter on the open coast (Fish, 1972). This generally occurs 17 to 18 months after larval settlement (Williams, 1964).

The release of egg capsules occurs gradually over a period of 10 to 12 weeks, and the pelagic phase requires 6 or 7 weeks

(Williams, 1964). At Pilgrim Station, eggs were collected from April through August and larvae from July through August.

L. littorea is an abundant intertidal gastropod collected from rocky substrates near Pilgrim Station. The density in rocky areas ranged from approximately 30 to 1,000 individuals per square meter. The periwinkle is found both on rocky substrates and macrophytes. Although it is omnivorous, it is generally considered a browser. L. littorea usually feeds when submerged by the tide; however, they may feed when not submerged.

Fraenkel (1960) reported the upper lethal tolerance temperature of L. littorea to be approximately 104°F. Newell et al. (1971) reported that the upper lethal temperature was dependent on exposure time and acclimation temperature. They found that L. littorea acclimated to 41 and 51°F water, survived for a shorter time when exposed to water temperatures greater than 86°F than organisms acclimated at 61 and 70°F. McDaniel (1969) reported that the thermal tolerance of L. littorea was also affected by trematode parasitism. Organisms parasitized by Cryptocotyle lingua were less tolerant of temperatures above 102°F than non-parasitized organisms.

5.7 ATLANTIC MENHADEN (BREVOORTIA TYRANNUS)

The Atlantic menhaden is a coastal marine pelagic species and is an important East Coast commercial fish species. It is neither a game nor a food fish, but is primarily used to produce fish meal and oil used in a variety of industrial processes.

The range of menhaden extends from Nova Scotia to Florida, the northern limit being dependent on seasonal changes in water temperature. Previous studies indicated that they are not found in water less than 50°F (Bigelow and Schroeder, 1953). Schools of adult menhaden migrate north along the coast to Cape Cod Bay as water temperature increases from late April through November.

Menhaden are planktivorous, feeding on diatoms, copepods and other planktonic species. Schooling menhaden are responsible for sporadic depletions of plankton as the fish move along the coast. Individuals of the same age class usually school together, and older fish travel farther north with each migration. Menhaden are preyed upon by fish species including bluefish, haddock, pollock, cod, and swordfish. Bluefish are responsible for large kills of menhaden when they drive schools into estuaries and onto beaches. Natural kills of this type have ranged up to 1.5-2 million menhaden (Anonymous, 1974).

According to Henry (1971), menhaden grow rapidly until their fourth year, and growth rate thereafter declines. Utilizing returns from more than 1 million tagged fish, Dryfoos et al (1973), computed the average annual survival rate of menhaden in 1966 to 1968 as 0.22, with a range of 0.13 to 0.37. The average exploitation rates for the years 1966, 1967, and 1968 for New York were 33.6, 47.1 and 55.7, respectively, and the mean instantaneous natural mortality was 0.52.

Little is known of the breeding habits of menhaden. Although some menhaden attain maturity at one year of age, most menhaden are sexually mature in the third year. The number of ova reported per female varies widely in the literature, but the number of eggs increased according to the length of fish. Estimates of 38,000 to 631,000 eggs per female were reported by Higham and Nicholson (1964).

Eggs are buoyant and, thus, planktonic. Menhaden eggs, though rarely collected at Pilgrim Station, were found in June and July.

In ichthyoplankton collections in 1974, Menhaden larvae were first observed in Cape Cod Bay on June 6 and last collected on November 5. Water temperatures during these dates were greater than or equal to 50°F. This is in close agreement with Bigelow and Schroeder's (1953) account of thermal requirements of menhaden.

Leigh wants conformation

The Bureau of Commercial Fisheries in Beaufort, North Carolina, has determined thermal tolerances for menhaden. Yearlings acclimated to 71.6°F and a salinity of 7 ppt survived 89.6°F–90.2°F at 4–6 ppt salinity. The same results are reported for adults and larvae. Lewis and Hettler (1968) determined the upper thermal tolerance of 90.2°F–93.2°F, but found upper thermal tolerance is dependent on acclimation temperature. For example, menhaden have an upper thermal tolerance of 93.2 to 95.0°F when acclimated at 80.6°F (Hoss et al., 1973). A temperature of 85°F was found to be lethal when menhaden were acclimated at 59°F. Battelle Memorial Institute (1972) determined the 24-hour TLm of adult menhaden collected in the vicinity of Pilgrim Station to be 86°F.

5.8 WINTER FLOUNDER (PSEUDOPLEURONECTES AMERICANUS)

The winter flounder is a right-sided, marine, flat fish species commonly found along the Atlantic coast from Labrador to Georgia. Winter flounder are benthic fish that inhabit coastal areas at depths of 1 to 40 meters and prefer a soft, muddy substrate covered by *Zostera marina* or similar vegetation.

Winter flounder average between 12 to 15 inches in length; however some adults attain 2 feet in length. Growth experiments conducted with winter flounder from Charlestown Pond, Rhode Island (Berry, Saila and Horton 1965) indicate a maximum growth increase in length of 293 millimeters between age classes I and V. Growth decreased thereafter to a maximum of 320 mm at age IX for males and 393 mm for females. Maximum length was attained at year XII.

Berry, Saila and Horton (1965) computed the annual total mortality rates as 0.56 and 0.65 for males and females, respectively, from Charlestown Pond, Rhode Island, and 0.51 to 0.58 for males and females, respectively, from Narragansett Bay. However, these high survival rates result from a failure to consider the number of eggs and larvae which are flushed out to sea from large estuarine spawning and nursery areas. Pearcy (1962) calculated survival rates from slopes of biweekly averages for both year classes 0 and I. Monthly survival rates are 69 percent for age class 0 and 92 percent for age group I. Pearcy also found decreasing mortality with increasing age. Saila, as reported in Pearcy (1962), estimated the fecundity of winter flounder at 630,000 eggs. Poole (1969) calculated from tagging returns the survival rate, fishing mortality, annual mortality, and annual natural mortality for winter flounder for 5 years.

Spawning occurs at night between January and May in New England waters. Eggs are demersal and adhesive, usually clumping on the bottom. Incubation requires 15 to 18 days at water temperature of 37 to 38°F. Bigelow and Schroeder (1953) estimate average fecundity at 0.5 to 1.5 million eggs per female. More extensive studies by Topp (1968) estimate fecundity of flounder caught at Ellisville, Sandwich Creek, and White Cliffs, Massachusetts at 435 thousand eggs for a year-class III fish and 3.329 million eggs for a year-class V fish. No gravid year-class II fish were found by Topp.

Winter flounder eggs, because they are demersal, were rarely collected at Pilgrim Station, occurring in April and May samples. However, larvae were abundant, occurring from March through July. Peaks of abundance occurred on April 24, May 8, and June 28.

Trawl samples for winter flounder adults at transects off Rocky Point, Plymouth, indicated presence of the species throughout the year. Highest abundances occurred from early July through October, in 1972, with a similar pattern in 1973 (Figure 6-16). Mean numbers of individuals per trawl during these periods ranged from 67 to 100 in 1972 and 40 to 176 in 1973.

An upper thermal tolerance limit of 89.9°F when acclimated at 76.6°F was recorded by Hoff and Westman (1966). Gift and Westman (1971) estimated TLm's (lethal temperature for 50 percent mortality) at 88.93 to 89.79°F for fish acclimated between 68.9 and 76.6°F. Huntsman and Sparks (1974) recorded the upper thermal tolerance for larvae at 83.6 to 86°F. Lower thermal tolerance limits were found to be 33.8, 34.6 and 42.8°F when acclimated at 44.6, 69.8 and 82.4°F, respectively. However, Bigelow and Schroeder (1953) reported *P. americanus* in water at 28°F.

5.9 POLLOCK (POLLACHIUS VIRENS)

The American pollock is a marine species found along the Continental Shelf from the Gulf of St. Lawrence to New Jersey. Pollock are common in the area of Plymouth and Cape Cod Bay. They travel in large schools, feeding on smelt, young herring, and other small fish and crustaceans, especially shrimp. Young pollock feed on copepods. They feed actively from the surface to depths of 200 meters. Pollock are cool water fish, rarely found at temperatures greater than 60°F; large schools are uncommon if temperatures exceed 52°F. Water temperatures of at least 38°F are needed for adequate incubation of eggs, although adults inhabit waters to 32°F. Spawning begins in December as soon as water temperatures reach 47–49°F. Spawning increases as temperatures fall to 44°F and then decreases as temperatures fall to 36°F. Fecundity is estimated at 225,000 eggs per female, but it can be high as 4 million eggs (Bigelow and Schroeder, 1953).

Eggs are buoyant and nonadhesive. Incubation requires nine days at temperatures of 43°F and six days at 49°F. Larvae remain near the surface for three months after hatching. Growth is approximately 1–2 inches per season during the first year. Year Class I fish attain an average length of 5–6 inches and grow to 12–13 inches by Year II and 17–18 inches by Year-class III. Thereafter, growth rate decreases to 1 or 2 inches/year. The average maximum length is 30 inches (at 9.5 years). Pollack can, however, attain 19 years of age.

At Pilgrim Station, pollock were the most commonly occurring species in gill nets at Rocky Point. Peak abundance was observed in April, May, and June and also in November and December, corresponding with spawning season. Large schools of pollock were also observed near the site by divers.

The pollock's upper thermal tolerance has been determined to be 82.4°F (de Sylva, 1969).

5.10 CUNNER (TAUTOGOLABRUS ADSPERSUS)

The cunner is a marine species found along the western North Atlantic coast from Labrador to the Chesapeake Bay. Cunner prefer rocky areas covered with algae as well as pilings and shipwrecks which serve as refuge areas. These areas are also habitats for small fish and crustaceans, the main prey of cunner.

Cunner are found primarily between 3 and 10 meters but have been caught as deep as 150 meters on Georges Bank. They do not school but do tend to congregate near suitable habitats. Cunner are year-round residents in their range moving into deeper water only during heavy freezes (Green and Farwell, 1971).

Spawning occurs from late spring to summer at water temperatures usually between 55 and 72°F. Eggs are buoyant, transparent, and are nonadhesive. Incubation requires 40 hours at 70–72°F and three days at 55–65°F. Year-class I fish are usually 2.5 to 3 inches and 3 to 4 inches at Year-class II (Bigelow and Schroeder, 1953). Sexual maturity generally occurs during Year-class II, females usually being slightly longer than males.

Cunner were abundant in gill net collections at Pilgrim Station. Cunner larvae were sampled from July 2 to August 13, 1974, peaking in abundance on July 30, 1974. Cunner eggs cannot be separated from other labrids and thus are all grouped together. In 1974 ichthyoplankton collections, Labrid eggs were first observed in early May, were extremely abundant in June and July, and were rare during the remainder of the summer months in Cape Cod Bay.

Kinne (1970) determined the thermal tolerance limits for adult cunner to be 84.2 to 86°F when acclimated at 64.4 to 71.6°F, and 77.0 to 78.8°F when acclimated at 33.8 to 37.4°F. These were the upper lethal temperatures. Lower lethal limits were recorded as 41°F and 32°F when acclimated at 64.4 to 71.6°F and 33.8 to 37.4°F respectively.

5.11 RAINBOW SMELT (<u>OSMERUS</u> <u>MORDAX</u>)

The rainbow smelt is anadromous and rarely found more than one mile from shore or deeper than three fathoms. In addition to marine populations found from Labrador to Virginia, there are landlocked populations existing in lakes of New England, the Maritime Provinces, and the Great lakes.

Adult smelt gather in harbors and in brackish estuaries in the fall. During the following March, when water temperatures increase to 40–42°F, spawning begins in fresh water areas of rivers and estuaries. Peak egg production occurs at water temperatures of 50–57°F, and spawning is completed by May. Fecundity has been estimated by Bigelow and Schroeder (1953) at 40,000 to 50,000 eggs per two ounce female. Sexual maturity occurs during the second winter (McKenzie, 1964).

Smelt are cold water fish, and Van Oosten (1953) reported that smelt prefer water cooler than 59°F in Lake Michigan. de Sylva (1969) found that smelt acclimated from 50-59°F had an upper thermal tolerance of 71-84°F respectively.

Adult smelt were collected in the vicinity of Pilgrim Station in April and November in 1974, while larvae were present primarily in spring.

5.12 ATLANTIC SILVERSIDE (<u>MENIDIA</u> <u>MENIDIA</u>)

The silverside is divided into two subspecies on which occurs along the eastern coast of the United States, (the northern subspecies, M. <u>menidia</u> <u>notota</u>, and the southern subspecies is M.

menidia menidia). The species is found all along the eastern coast. They are found in shallow water, especially during the spawning season.

The diet of silversides consists of copepods, mysids, shrimp, amphipods, cladocera, etc. Silversides are usually found near sandy or gravelly shores.

Spawning occurs from late spring into early summer. In the area of Pilgrim Station, silversides probably spawn once during their life (Bayliff, 1950). Spawning occurs in shallow water where eggs and milt are deposited in strands which cling to vegetation. Bayliff (1950) observed about "300 mature eggs and many smaller, seemingly dead or arrested eggs" in a ripe female.

The silverside probably completes its life cycle in slightly more than one year. Adult silversides reach a length of about 120 millimeters and weight approximately 9 grams (Austin et al., 1973). The longest silverside collected in the study by Bayliff (1950) was 140 millimeters.

The temperature tolerance for adult smelt has been investigated by Hoff and Westman (1966), and Gift and Westman (1971). The relationship between tolerance temperature and acclimation temperature derived from their studies is:

$$y = 40.34 + 0.70x$$

where = y is the upper tolerance temperature in degrees Fahrenheit, and x is the acclimation temperature in degrees Fahrenheit.

The residual standard deviation is 4.98 and the correlation between these variables is 0.87.

Silversides are an important forage fish in the area. They have been observed in the stomachs of bluefish, striped bass, grey squeteague, sea bass, scup, Atlantic mackerel, Atlantic bonito, cunner, silver hake, Atlantic cod, tomcod and squirrel hake, (Bayliff 1950).

5.13 ALEWIFE (ALOSA PSEUDOHARENGUS)

Alewives are one of the forage fish species near the Pilgrim site. They are anadromous, spawning in rivers and streams in the area. In Massachusetts, spawning generally occurs between the middle of April to the beginning of June (Belding, 1921).

Eggs adhere to the stream bottoms. The incubation of fertilized eggs requires 48 to 96 hours at 72°F. Young-of-the-year alewives reach a size of 2 to 4 inches by the fall when they move from the breeding grounds to the open ocean (Belding, 1921).

Adults return to the rivers and streams to spawn in their fourth and fifth years in Connecticut (Marcy, 1969). Approximately 75 percent of the females and 68 percent of the males first spawned at age 4. The maximum age for the alewives was estimated at 8 years. Limited studies indicate that alewives return to the stream in which they were born to spawn (Belding, 1921).

The fecundity of alewives has been estimated at 48,000 to 360,000 eggs per female with an average of 229,000 eggs per female. The sex ratio during spawning was approximately 1 to 1 when averaged over the entire period; however, the beginning of the spawning run is characterized by the dominance of males (Kissel, 1974).

Mortality through the life cycle has been studied for alewife populations. Kissil (1974) calculated that one young alewife migrated seaward for every 80,000 eggs spawned in fresh water. Edsall (1970) observed the percent of eggs which hatched was related to temperature. Maximum hatching success occurred at about 60°F, and declined at higher and lower temperatures.

Alewives are planktivorous. They feed on diatoms and other algae, as well as the microcrustaceans of the zooplankton (Belding, 1921; Bigelow & Schroeder, 1953). Alewives serve as forage fish both in the ocean and during their migration and spawning activities in fresh water. The weakened conditions of adults after spawning probably makes them more susceptible to predation and disease.

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SECTION 6
IMPACT ASSESSMENT

6.1 PROCEDURES FOR ASSESSMENT OF THE POWER STATION'S EFFECT ON SELECTED SPECIES

Impact to each of the selected species is assessed by the following strategy:

Data collected from ecological studies at the Pilgrim site are reviewed with respect to the operating history of Unit 1 (See Appendix B for listing of field and laboratory studies). The density of each of the selected species entrained, entrapped, or otherwise affected by the thermal component of the discharge or plant shutdown is then compared with available estimates of species population densities. Information on life history, geographic distribution, and thermal sensitivity is also considered to assess the sensitivity of the species population to any effect of power station operation. Predictions of the effects of Units 1 and 2 combined are made for the thermal plume, entrainment and entrapment for all representative species based on these considerations.

Analyses of impact are also based on hydrographic information provided in Section 2. Pertinent hydrographic information includes: (1) estimates of the maximum size of the thermal plume contacting the bottom (for assessment of potential thermal effects for benthic species). The effects of the maximum mid-depth and surface plume are also considered for assessment of impact on pelagic species. (2) the projected maximum intake flow for Units 1 and 2 combined (for assessment of entrainment and entrapment impacts).

A quantitative prediction of impact is presented for representative species judged to potentially sustain some mortality from plant operation. The particular model used for prediction depends upon the information available to quantify the population and the information available to quantify the perturbation. The models presented below are used for the quantitative predictions.

Populations for which the age specific mortalities and fecundities are estimated, can be simulated by a computerization of the Leslie (1945) model. This model is:

$$N_{t+1} = \underline{A}\, N_t, \qquad (1)$$

where N is a 1-by-x vector corresponding to the number of organisms (n_i) in each of x life stages, and each life stage has an equal development time:

$$N_t = \begin{bmatrix} n_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ n_x \end{bmatrix}_t \qquad (2)$$

The x-by-x $\underline{A}$ matrix is the projection matrix which describes the transition of the population from time t to t+1

$$A = \begin{bmatrix} F_1 & F_2 & \text{———} & F_{x-1} & F_x \\ P_1 & 0 & \text{———} & 0 & 0 \\ 0 & P_2 & \text{———} & 0 & 0 \\ 0 & 0 & \text{———} & 0 & 0 \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & & \cdot & \cdot \\ 0 & 0 & \text{———} & P_{x-1} & 0 \end{bmatrix} \qquad (3)$$

where

F_i is the number of female offspring born to a female of age i,

P_i is the probability that an organism of age x will survive to age x+1,

and

$$P_i = e^{-d_i}, \qquad (4)$$

where

d_i is the instantaneous death rate of organisms of age i.

The finite rate of population growth (R) is calculated from the $\underline{A}$ matrix as the maximum characteristic root of the characteristic equation with the stable age distribution represented as the characteristic vector accompanying the largest root (Leslie, 1945).

$$R = \text{max char root } \underline{A} \qquad (5)$$

The instantaneous population growth rate (r) is:

$$r = \log_e R \quad (6)$$

One method of investigating impact attributable to the power station is to estimate the elements of the $\underline{A}$ matrix from field and literature values for the affected population. The value of r can then be calculated. The P_i or the probabilities of survival to the next age can then be converted to instantaneous age-specific death rates. The instantaneous mortality rate due to entrainment can be added to the age-specific death rate and the new instantaneous death rates converted to a new age-specific probability of survivorship. The maximum characteristic root and the associated characteristic vector of the second $\underline{A}$ matrix represent the instantaneous population growth rate and the stable age distribution of the impacted population.

Instantaneous rates of population growth with and without entrainment can be compared as can the stable age distributions. This represents comparison of the theoretical potential of the population under the assumptions of exponential growth and is therefore most conservative as there is no density dependence in the population. A computer program, EIGENPOP (Stone & Webster, 1975), was developed to numerically solve the characteristic roots and vector. This program is based on the EISPAC routines contained in Reinsch and Wilkinson (1971).

The analysis of the year-to-year variation in population size is made by simulating the population represented by the Leslie (1945) model. A computer program (POPI) (Stone & Webster, 1975) was also developed which simulates the Leslie model. This program calculates the probability of survivorship to the next age as the combination of the instantaneous rates of natural, fishing, and power station-related mortality. Any of the elements in the $\underline{A}$ matrix can be constants or functions of the population density. The population is then simulated with and without the effect of the power station. The change in population size or any selected population parameter represents the impact associated with the power station on fish eggs and larvae.

The population methods presented thusfar require a great deal of information for the affected population. Because of the nature of these parameters, it is difficult to estimate them for field studies, and many times they do not exist in the literature. A simplistic approach is to translate the number of organisms lost into the number of adults that would have resulted assuming no compensatory mechanisms (e.g., density-dependent parameters) in the population.

If the population is in equilibrium, in one generation the fecundity of a breeding pair will be reduced to 2 breeding adults.

$$2 = S \cdot F \quad (7)$$

where

S is the survival from egg to adult,
F is the fecundity of a breeding pair during their life,

or

$$S = 2/F \tag{8}$$

If the affected life stage is larvae, then the survival from egg to larvae (S_e) is multiplied by F to give the survivorship from larvae to adult (S_1).

$$S_1 = \frac{S}{S_e} = \frac{2}{S_e F} \tag{9}$$

The number of affected larvae (N_1) is multiplied by S to give the number of adults (N_a) that would have resulted, assuming no density dependence.

$$N_a = S_1 N_1 \tag{10}$$

The number of adults can then be compared to some reference such as catch statistics for commercial or sport species. This is a meaningful comparison when sufficient information is not available for the more extensive analysis.

6.2 IRISH MOSS (CHONDRUS CRISPUS)

Irish moss is a subtidal species occurring from mean low water to about 30 feet below mean low water. It is, therefore, exposed to temperature fluctuations but not to the degree of intertidal species. The primary station-related impact to Irish moss could result from the thermal plume because it is a sessile organism. Entrainment may occur, although Chondrus does not have buoyant spores. Impact assessment for Units 1 and 2 combined can best be determined by looking at the historical data from Unit 1.

6.2.1 Thermal Plume

Several studies have been conducted to determine the impact of station operation of Pilgrim Unit 1 on the local Irish moss population. These include investigations of commercial harvest and effort, benthic monitoring studies, and short-term intensive surveys reported by Boston Edison Company.

The commercial harvest of Irish moss declined in the vicinity of the station in 1973 (Table 6-1). The effort expended also decreased, since low total harvest was primarily caused by low density of Irish moss. This reported decrease in the harvest and effort also occurred in areas outside the influence of the station operation (unaffected areas). Therefore, affected and

TABLE 6-1

IRISH MOSS HARVEST STATISTICS: 1971*, 1972, 1973 and 1974
(Semi-Annual Report No. 3, 1974; Section II B)

	Landing (lbs-wet wt)				Harvest Effort (hrs)				Harvest Rate (lbs/hr)			
Area	1971	1972	1973	1974	1971	1972	1973	1974	1971	1972	1973	1974
1	92,637	133,402	57,045	105,110	411.4	571.1	343.4	446.4	225.2	232.8	166.1	125.5
2	78,060	110,246	45,310	91,290	443.7	776.3	345.8	391.9	175.9	142.0	131.0	232.9
3	10,719	17,295	4,140	11,730	55.7	90.6	22.8	77.8	192.4	190.9	181.6	150.8
4	23,252	31,402	7,695	10,795	113.6	155.9	41.3	39.7	204.7	201.4	186.3	271.9
5	82,724	78,567	18,815	28,515	406.8	374.9	102.3	139.7	203.4	209.6	183.9	204.1
6	39,925	56,881	24,995	17,230	170.7	233.9	128.8	79.0	233.9	243.2	193.7	218.1
7	14,727	17,004	30	215	87.6	80.3	0.1	1.3	168.1	211.8	300.0	165.4
8	33,429	28,368	605	25	114.9	108.1	1.4	0.3	290.9	262.4	432.1	83.3
Total	375,473	473,165	158,595	264,910	1,804.4	2,393.1	985.6	1,176.1	208.1	197.7	160.9	225.2

* 1971 values do not include approximate 2-week period prior to 6/18/71.

unaffected areas were compared to determine station effects (Figure 6-1).

Total harvest and effort decreased in 1973 at the station intake and discharge when compared to Manomet Point (unaffected area) (Figure 6-2). However, this trend continued through 1974 when the station was not operating and the total harvest was high. The same annual trend was observed when comparing another control area, Warren Cove, to Manomet Point. In addition, at a site adjacent to the discharge area (Rocky Point), there was no decrease until 1974 when the station was not operating. These comparisons indicate that although there was a decrease in harvest at the station, a decrease also occurred in areas not directly influenced by the station. Therefore, plant operation is not considered a contributing factor resulting in lower Irish moss densities.

Irish moss density (dry weight/m²) in benthic studies, collected both preoperationally and postoperationally, have not indicated a power station effect. An additional intensive short-term survey, conducted in 1973 and 1974, has indicated that the quality of Irish moss is decreasing in both control and impact areas from Warren Cove to Manomet Point. There was no noticeable difference in size, weight, and condition of Irish moss between control and discharge areas except at the end of the discharge canal where Chondrus was absent from an area with a 50-foot radius.

Since there has been little difference in Irish moss density at control and both the intake and discharge areas in over a year and a half of station operation, it appears that the station has not affected the mature plants of Irish moss.

The predicted effects of the thermal plume (Appendix A) from Units 1 and 2 on Irish moss are shown in Figure 6-3. The various isotherms are superimposed over the 10-foot mlw contour and the distribution of Irish moss. In summer, under conditions of highest ambient temperatures, Chondrus reproduction will be excluded from a small area (2.1 acres) outside the discharge canal based on hydrothermal conditions. Thus, Chondrus will be excluded from this area. Growth, including maximal vegetative and sporeling growth, should be optimal in an area of approximately 6 acres during summer. During remaining seasons, growth should be stimulated (allowing for seasonal differences) within an area of approximately 10 acres. Since Chondrus is a sessile organism and is excluded from an area of 2 acres during one season (summer), it will be excluded from that area on a yearly basis. Therefore, Chondrus growth should be stimulated for an area of approximately 8 acres.

The area observed to be devoid of Chondrus from Unit 1 operation (50-foot radius) will increase to a 110-foot radius with the additional of Unit 2. This represents a worst case condition of the combined plume. This independent prediction of effects based on literature thermal tolerance data and hydrothermal predictions is very similar to operational observations, since Chondrus was observed to be thriving directly outside the observed barren area, (50-foot radius) during Unit 1 operation.

6.2.2 Entrainment

Entrainment of Irish Moss spores was observed in the fall of 1973. Thermal tolerance tests, however, indicated that significant mortality (30 percent) of spores on passage through the station cooling system would occur only when ambient water temperatures were greatest, in late summer when spore density is low.

6.2.3 Entrapment

(Not applicable)

6.2.4 Cumulative Impact

Most of the possible impact of station operation on Irish moss should result from the thermal plume. This localized effect will result in the elimination of Irish moss immediately adjacent to the discharge area (2.1 acres). No impact will result from entrapment, as no life stages are susceptible to entrapment. Although entrainment can occur, thermal tolerance tests on Irish moss indicate no impact of consequence from entrainment. Station operation will result in a negligible effect on the total Irish moss population in the Warren Cove - Manomet Point area and on the commercial harvest. In fact, stimulated growth adjacent to the discharge may offset losses in the immediate vicinity since the area of stimulated growth is 4 times as large as the barren area predicted.

6.3 ROCKWEED (ASCOPHYLLUM NODOSUM)

Ascophyllum nodosum is an intertidal species and therefore is naturally exposed to large temperature fluctuations. However, as an intertidal species, it has a life history strategy which compensates for these fluctuations. A continuous thermal stress, however, may result in stress during reproductive periods.

A. nodosum is a sessile organism. Therefore, primary station-related impact to *A. nodosum* should result from the thermal plume. Entrainment may occur, although the spores are probably nonbuoyant. Impact assessment for Units 1 and 2 combined is determined by observing the operational impact of Unit 1.

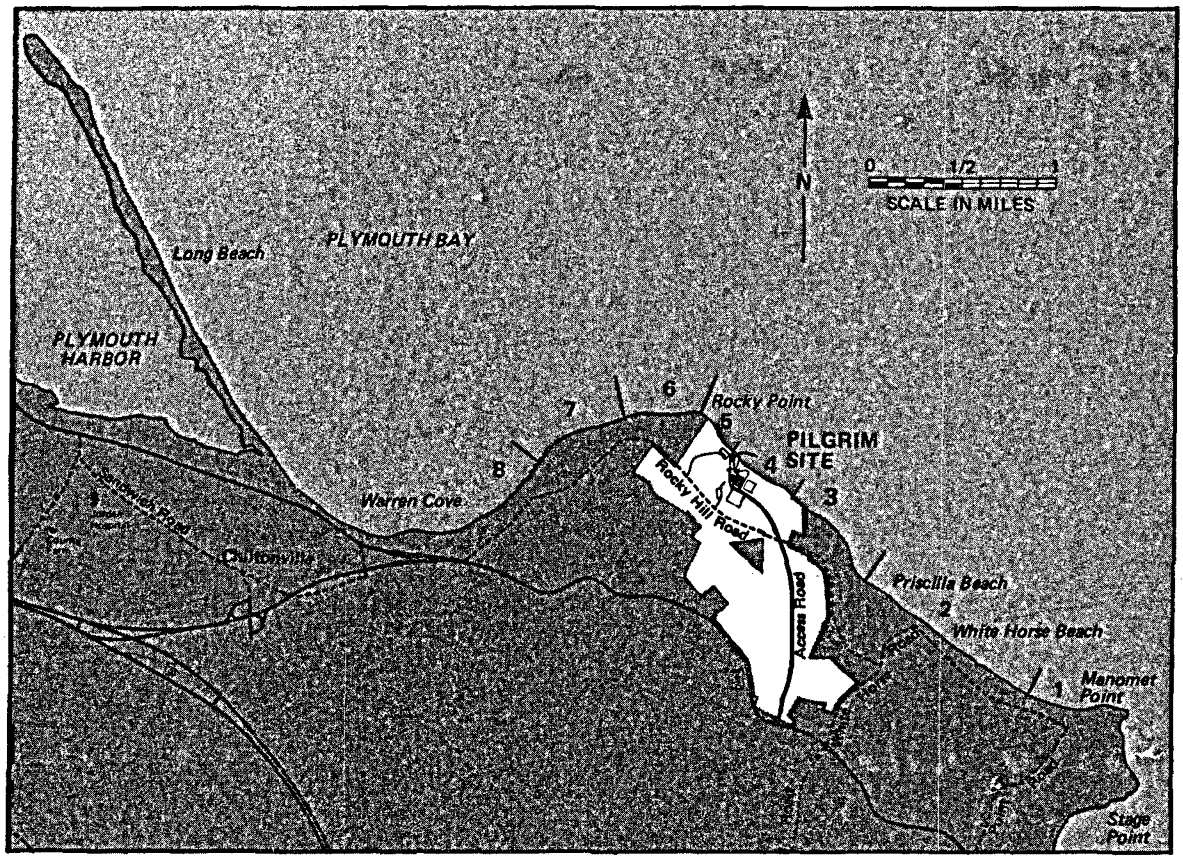


FIGURE 6-1.
IRISH MOSS HARVEST AREAS
IN CAPE COD BAY
IN VICINITY OF PILGRIM STATION

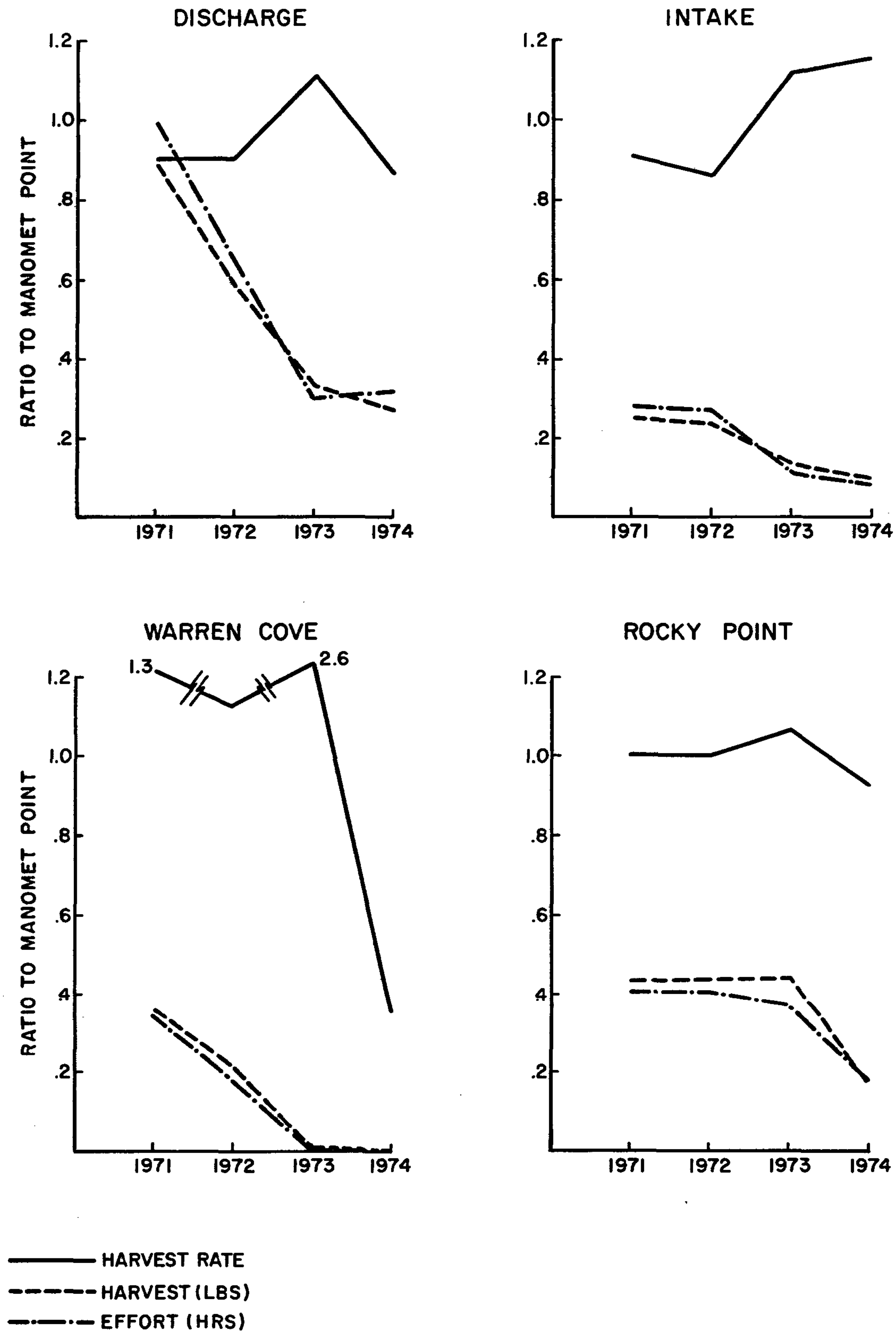


FIGURE 6-2

COMPARISON OF ANNUAL IRISH MOSS HARVEST STATISTICS AS RELATED TO MANOMET POINT

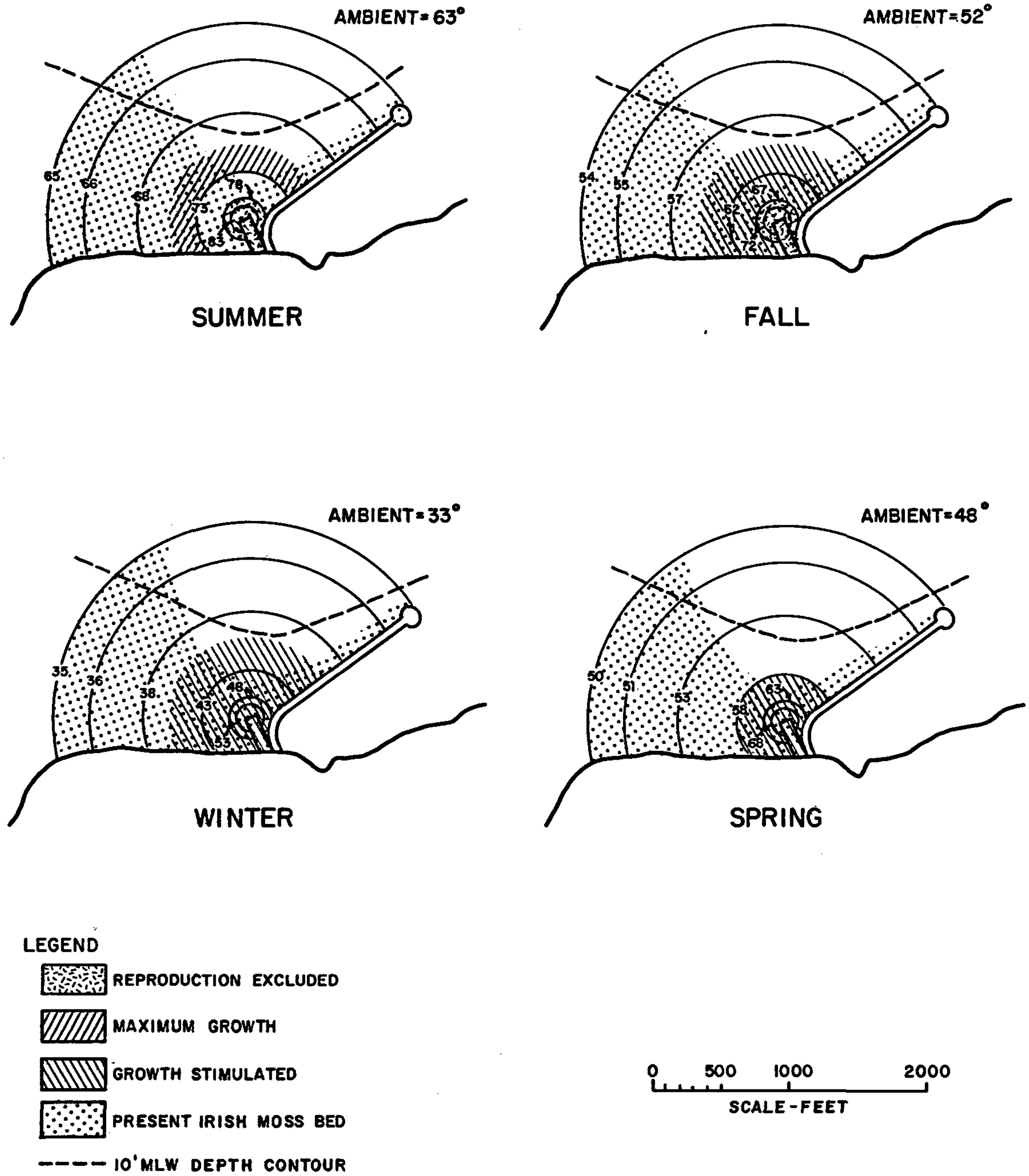


FIGURE 6-3

POTENTIAL THERMAL PLUME EFFECTS
IRISH MOSS

6.3.1 Thermal Plume

A benthic monitoring program in the vicinity of Pilgrim Station has determined seasonal density for A. nodosum, both preoperationally and postoperationally, at various transects (Figure 6-4). The mean intertidal densities (dry weight/m^2) at Rocky Point (discharge area, Transect G-1) and Manomet Point (unaffected area, Transect G-5), are summarized in Figure 6-5.

The density of A. nodosum appears to be somewhat stable from year-to-year, with natural decreases in density occurring in spring. The densities at Rocky Point and Manomet Point were markedly similar, preoperationally. Although the densities differed postoperationally at both locations, the pattern at Rocky Point was consistent with the preoperational trend. This suggests that there has been no detectable effect of Unit 1 operation on Ascophyllum.

As discussed in Section 5.2, limited information on the thermal tolerance of Ascophyllum makes prediction of the effects of the combined Units 1 and 2 thermal plume difficult. The maximum plume temperature outside of the discharge canal will not reach 93°F during any season. Therefore, acute mortality should not occur.

The thermal plume may have some effect during reproductive periods; however, since Ascophyllum thermal tolerance during these periods has not been described, this effect is unknown. Population density data collected both preoperationally and postoperationally have not, however, indicated a station-related effect.

6.3.2 Entrainment

Zygotes of A. nodusum are nonbouyant and adhesive and thus are not expected to be subject to entrainment. No A. nodosum zygotes have been collected in entrainment samples.

6.3.3 Entrapment

Not applicable.

6.3.4 Cumulative Impact

No station impact on A. nodosum is expected to occur through entrapment on entrainment, since no life stage of this species is susceptible to these sources of impact. The only potential source of impact expected is the thermal plume. The upper lethal temperature of A. nodosum (93°F) will not be reached in the discharge plume; so little, if any, mortality is expected. Reproductive periods occur from fall through spring when discharge temperatures are low; thererfore, no impact is expected during these periods.

6.4 AMPHIPOD (ACANTHOHAUSTORIUS MILLSI)

Acanthohaustorius millsi is a subtidal burrowing amphipod found offshore of Pilgrim Station. As an offshore species, A. millsi is less subject to power station effects than inshore species. The component of power station impact that will most affect A. millsi is the thermal plume. No A. millsi have been collected in entrainment samples, and the species is too small to be entrapped. Impact assessment for Units 1 and 2 combined can again be determined to some degree by using the known impact of Unit 1.

6.4.1 Thermal Plume

Results of the Unit 1 benthic surveillance study have been reviewed (preoperationally and postoperationally) to determine the impact of station operation on A. millsi. Mean densities at 20 feet below mean low water (mlw) at the discharge location (Transect G-1, Figure 6-4) and White Horse Beach (control) (Transect G-4) are compared in Figure 6-6. Densities of A. millsi are highly variable at the unaffected (White Horse Beach) and discharge locations. There are several factors which may contribute to this variability. A. millsi is motile and can thus avoid sampling devices. Also, the preferred habitat at the discharge sampling area is somewhat limited because of the extent of rocky areas. This would also contribute to the lower density at the effluent station, as compared to White Horse Beach. With reduced preferred substrate, collections at the discharge would be more subject to variability through clumping, and thus a nonuniform distribution of organisms. This type of variability commonly occurs in short-lived univoltine species, such as midges, found in fresh water lakes and streams.

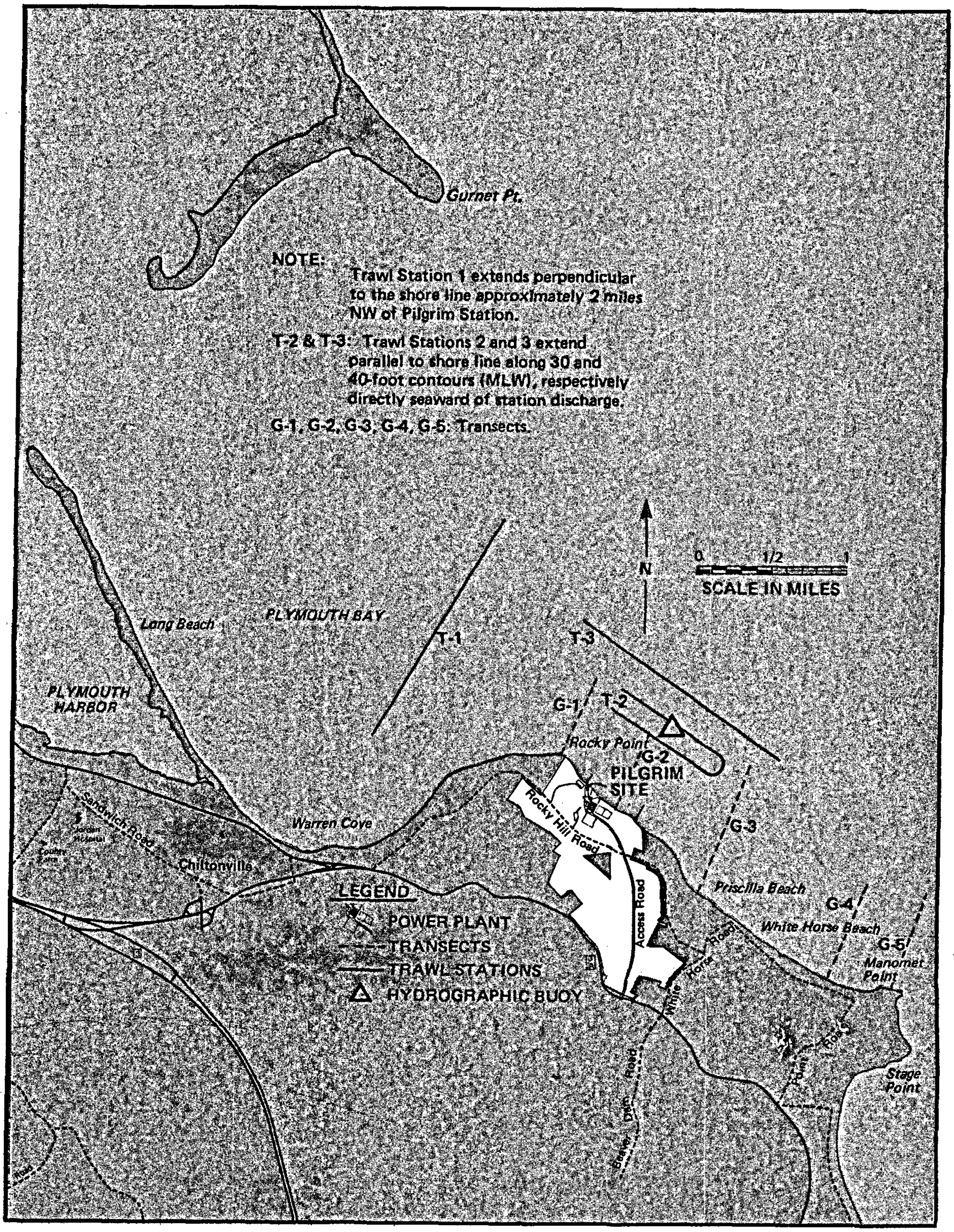
The thermal plume will rarely contact the bottom in the area of 20 feet below mlw. When it does contact the bottom, only the two- and three-degree isotherms will reach this area. The habitat inshore of this area subject to higher temperature increases does not appear to be suitable for A. millsi, as it is primarily a rocky substrate. The thermal tolerance of A. millsi appears to be high, although it is a subtidal species. Temperatures as high as 97°F are necessary for complete mortality, and the temperature-mortality range appears to be small (Sameoto, 1969). Therefore, no impact is expected, since temperatures will not reach 97°F in the two- and three-degree isotherms.

6.4.2 Entrainment

Not applicable.

6.4.3 Entrapment

Not applicable.



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Environmental Report - Unit 2

FIGURE 6-4.

LOCATION OF SAMPLING STATIONS FOR ECOLOGICAL MONITORING PROGRAM

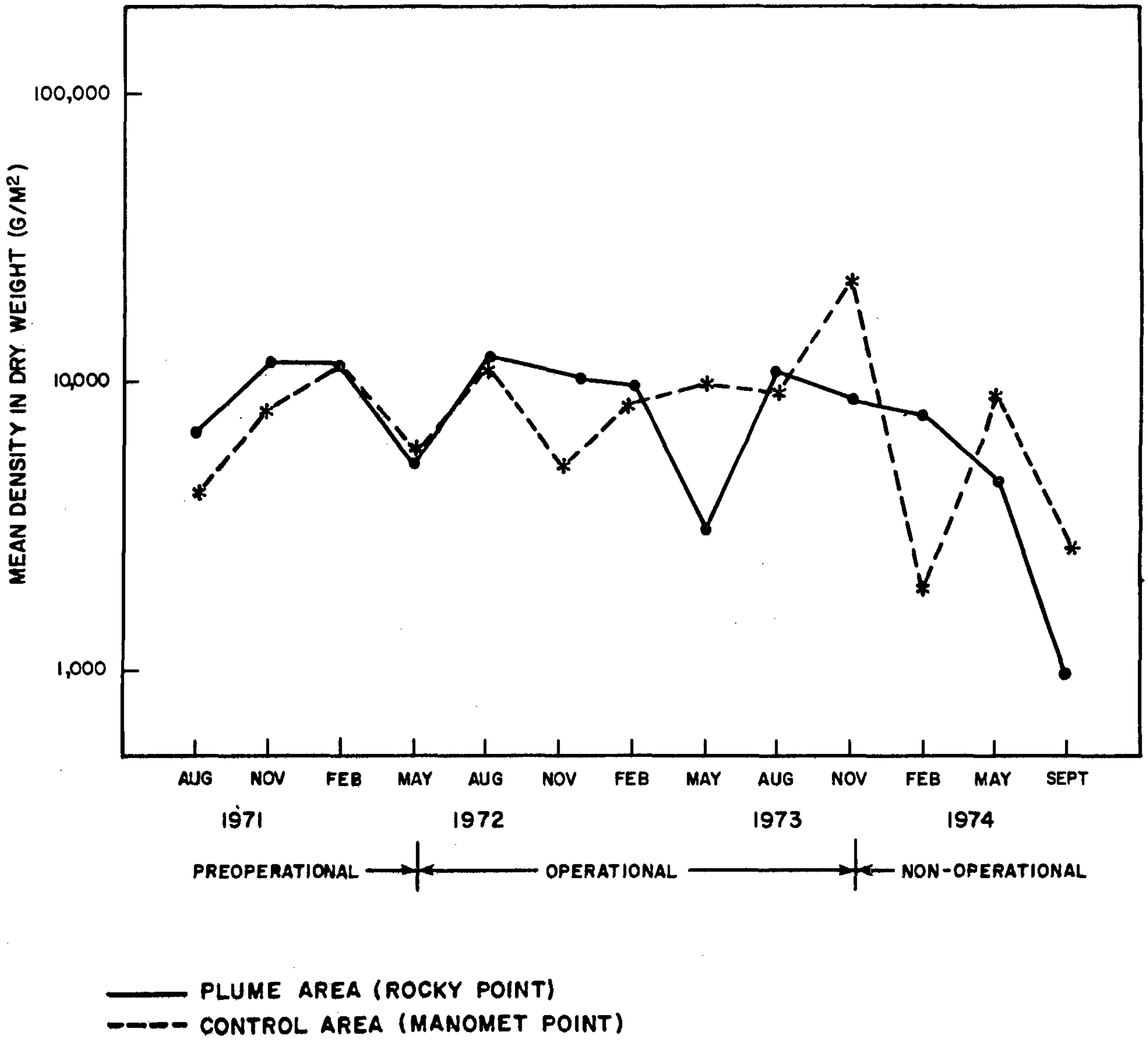

FIGURE 6-5
MEAN INTERTIDAL
ASCOPHYLLUM NODOSUM
DENSITY IN. DRY WEIGHT (G/M^2)

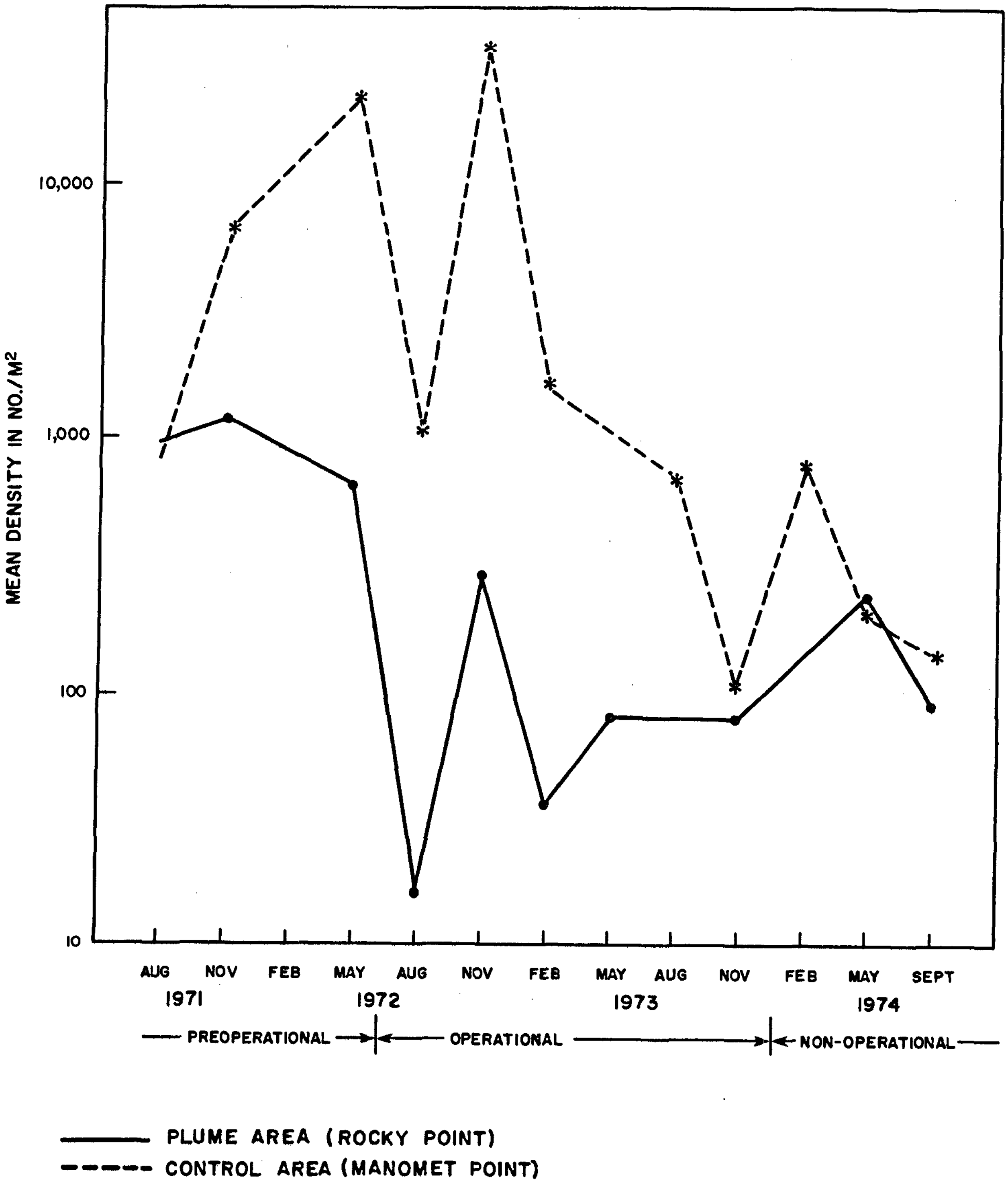

FIGURE 6-6
MEAN DENSITY OF
ACANTHOHAUSTORIUS MILLSI
AT 20 FEET BELOW MLW

6.4.4 Cumulative Impact

No station impact on <u>A. millsi</u> is expected to occur through entrapment or entrainment as no life stage of this species is susceptible to sources of impact. The only potential source of impact is the thermal plume. The only suitable habitat for <u>A. millsi</u> in the discharge area is at 20-foot mlw, which is beyond the major influence of the predicted thermal plume. Therefore, there should be no impact on <u>A. millsi</u> as a result of the operation of Units 1 and 2.

6.5 AMERICAN LOBSTER (<u>HOMARUS AMERICANUS</u>)

The lobster is a subtidal, mobile benthic species found offshore of the Pilgrim Station. As an offshore species, lobster are less subject to power station effects than inshore species. Monitoring studies at the site have indicated that the local population of lobster is not a self-sustaining population and relies on spawning elsewhere in Cape Cod Bay. Morrisey (1971) indicated that there was some movement of egg-bearing females from the northeastern shore of Cape Cod to this area. Only 238 of 4,616 lobsters handled during studies through 1973 were egg-bearing females. Thus, the local population in the vicinity of Pilgrim Station is a nonsustaining population.

Impact assessment for Units 1 and 2 is determined relative to data on the impact of Unit 1 on the lobster.

6.5.1 Thermal Plume

Two monitoring studies have been conducted preoperationally and postoperationaly to determine the impact of station operation on lobster. A harvest-per-pot study monitored lobster catch within grid areas (Figure 6-7) in the vicinity of the station. Figure 6-8 shows the catch per pot for grids in the discharge area and catch per pot at Manomet Point (control area). There is little difference between the catch per pot at areas, both preoperationally, operationally, and seasonally, indicating no power station effect. Generally, a greater total catch occurred in the discharge area although it is not reflected in Figure 6-8. Additionally, the effort (number of pots checked) increased with the season.

A second study monitored lobster migration in control and affected areas. The discharge area did not seem to present an unmanageable stress on lobster, as the patterns of migration were similar from Rocky Point (discharge area) and Manomet Point (control area).

The seasonal effects of the predicted thermal plume (Appendix A) from Units 1 and 2 are shown on Figure 6-9. Based on thermal tolerance data for lobster (Appendix A), permanent residence of adult and juveniles will be excluded from the area (2.1 acres) immediately adjacent to the discharge canal during the summer months. The area immediately outside this exclusion area will maintain temperatures (68–77°F) allowing maximum growth for adults and juveniles during the summer months. During the other seasons, the temperature should be stimulatory for increased growth in the summer exclusion area (15-degree isotherm). Growth of lobster to harvestable size has been shown to be reduced from seven to two years in some heated waters (Hughes et al., 1972). Lobster are mobile and can thus migrate to the thermal plume when temperatures are suitable and migrate out of the thermal plume if temperatures are less than optimal.

6.5.2 Entrainment

Although lobster larvae have been collected in the vicinity of the station, they have not been collected in entrainment samples at Unit 1. This may be attributed to techniques used for lobster larve collection in entrainment monitoring or that the larvae are not subject to entrainment. Entrainment effects will therefore be based on densities of lobster larvae collected near the station and thus represent conservative estimates of entrained larvae.

30 days

100 day

Lobster larvae are sparsely distributed and congregate at the water surface (Personal communication, R. Fairbanks). Two separate collections were conducted in 1974 resulting in a mean density of 0.95 larvae/1,000 cubic meters from June-August, and a mean of 2.96 larvae/1,000 cubic meters from June-July. For purposes of entrapolating potential entrainment effects the more conservative (2.96 larvae/1,000 cubic meters) was used.

The number of individuals not attaining adulthood due to larval entrainment can be calculated using the density of larvae collected near the station, the calculated flow through Units 1 and 2, and known fecundity values. The depth of the water column at which these collections were made is approximately three meters. Therefore, to make the clumped distribution (Stage 4 larvae clumping at water surface) fit a uniform distribution, the distribuiton was calculated to be 0.99/1,000 cubic meters for the total water column.

$$2.96 \text{ larvae}/1{,}000\text{m}^3 \div 3 \text{ meters} = 0.99 \text{ larvae}/1{,}000\text{m}^3$$

The number of larvae potentially entrained per year was calculated by the following equation:

$$0.99 \text{ larvae}/1{,}000\text{m}^3 \times 30 \text{ days (period of occurrence)} \times 6.87 \times 10^6 \text{ m}^3/\text{day (2-unit intake volume)} = 204 \times 10^3 \text{ larvae/year}$$

Assuming 100 percent mortality on passage through the station and using a mortality factor of 99 percent from eggs to Stage 4 larvae, this results in the equivalent of 2.04×10^5 eggs entrained per year. An estimate of loss of harvestable adults

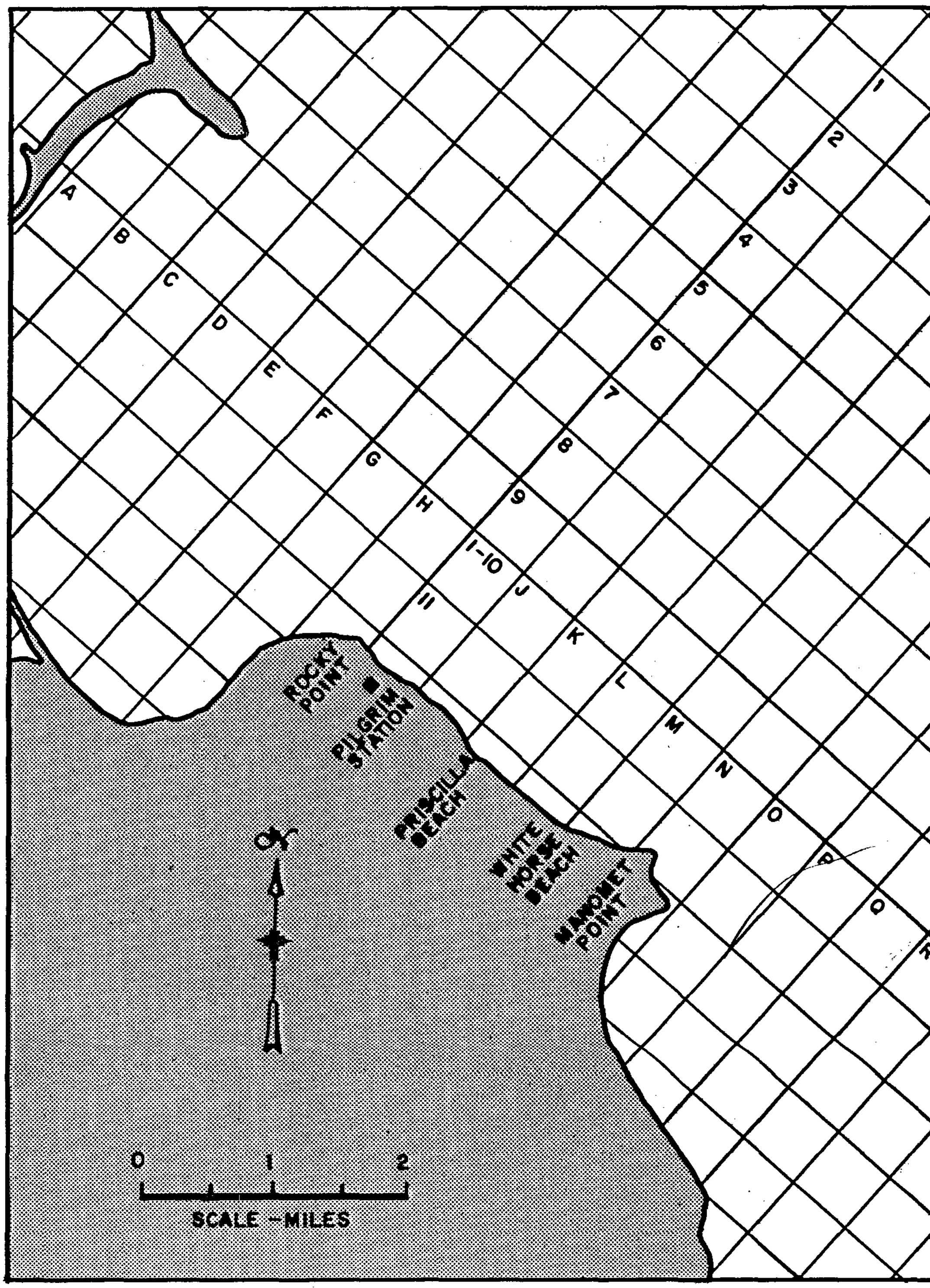

FIGURE 6-7
LOBSTER POT SAMPLING GRID

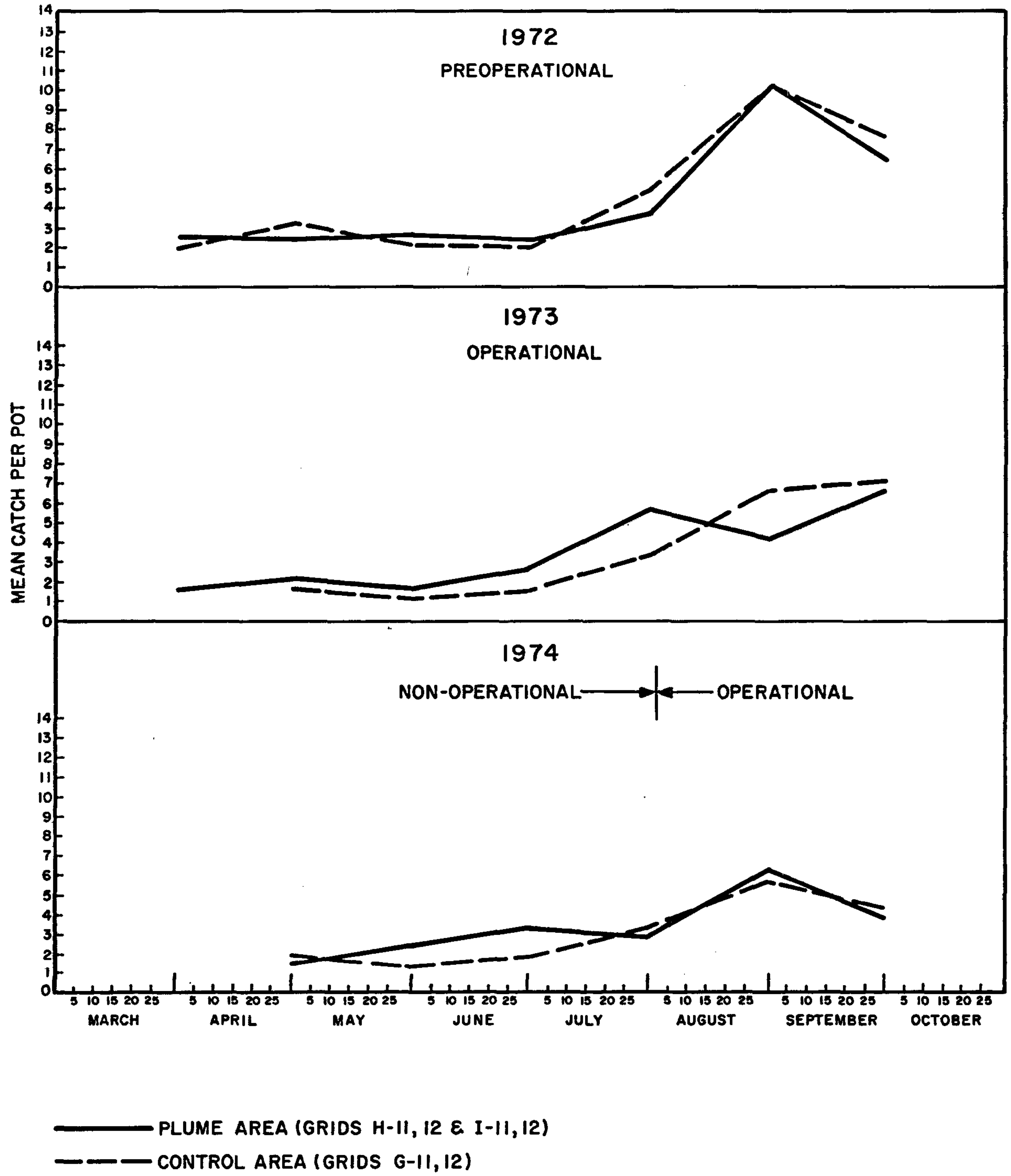

FIGURE 6-8
MEAN LOBSTER CATCH PER POT

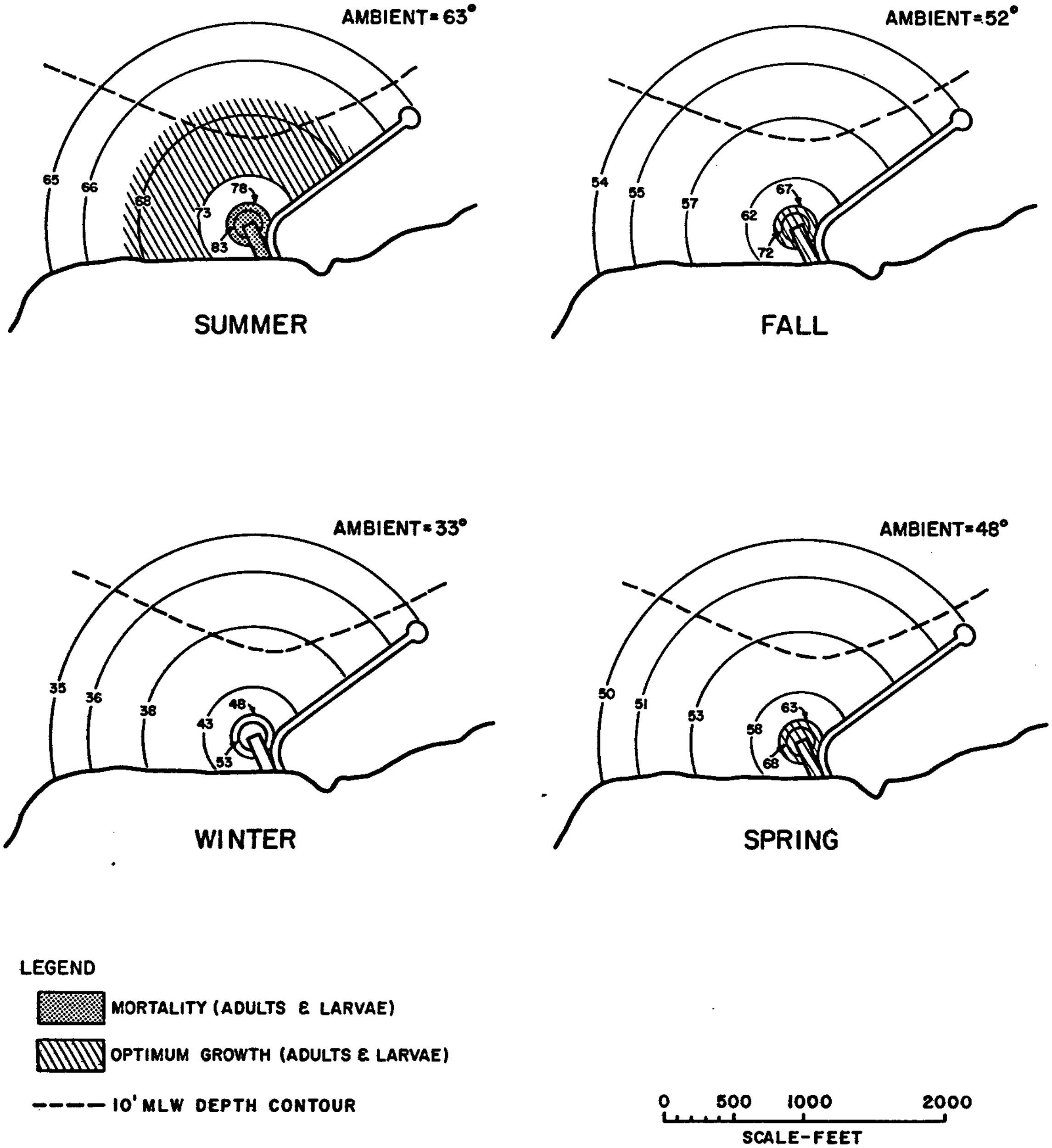

FIGURE 6-9

POTENTIAL THERMAL PLUME EFFECTS
LOBSTER

(N_a, Section 6.1) can be made based on average harvest size (1.2 lb) and fecundity (10,000 eggs/female) for this year class (Saila et al., 1969).

$$N_a = 204 \times 10^5 \text{ eggs/year} \times 10^{-4} \text{ female/egg} \times 2 = 4080 \text{ adults/year}$$

Theoretically, the number of harvestable lobster lost with 100 percent mortality through the station would be between 2640 and 4080 lobster/year, based on the results of the two studies. This represents between 0.4 and 0.6 percent of the average yearly harvest of lobster for Plymouth County (Beals et al., 1970).

These estimates represent very conservative estimates as lobster larvae have not been observed in entrainment collections.

6.5.3 Entrapment

To date, no lobsters have been collected on intake screens during Unit 1 operation. Lobster entrapment is not expected to result in the future because of low intake velocities (less than 1 fps for both units).

6.5.4 Cumulative Impact

No station impact on lobster is expected to occur through entrapment as intake velocities are low. Potential station effects on lobster can result from the thermal plume and entrainment. Based on thermal tolerances, during the summer months, adult and juvenile lobsters will be excluded from 2.1 acres immediately adjacent to the discharge canal. During the rest of the year, growth should be stimulatory within this area. Since lobsters could avoid less than optimal temperatures, no mortality as a result of the predicted thermal plume is expected.

Although no larvae have been observed in entrainment monitoring for Unit 1, the potential for loss of larvae through entrainment exists. Based on nearfield larval densities in Cape Cod Bay, as many as 2.04×10^5 larvae could be entrained per year. Assuming 100 percent mortality on passage through the station, this could result in the loss of 4080 harvestable adults per year or 0.6 percent of the Plymouth County annual harvest.

Based on these predictions, the effect of the operation of Units 1 and 2 on the lobster population of Cape Cod Bay will be negligible.

6.6 MUSSEL (MYTILUS EDULIS)

Mytilus edulis is adapted to many environmental conditions, including varying temperatures and exposure to partial drying. Station impact would result from the thermal plume on adult organisms and entrainment of planktonic larvae. Potential impact of Units 1 and 2 is assessed using the known impact of Unit 1 on M. edulis.

6.6.1 Thermal Plume

A station-related benthic monitoring program has determined preoperational and postoperational seasonal mussel concentrations. Figure 6-10 indicates the density of Mytilus or M. edulis intertidally at Rocky Point (discharge area) and Manomet Point (unaffected area). Intertidal densities are analyzed, as the greatest densities of Mytilus occurred intertidally.

Although the populations fluctuated over time at both Rocky Point and Manomet Point, there was a gradual increase. In general, there was no detectable difference between preoperational and operational densities, except in August 1971 and February 1974. In both cases, the station was not operating; so they are not the result of station-related effects. Mytilus was more abundant at Rocky Point than at Manomet Point. Therefore, there appears to be no effect of Unit 1 operation on Mytilus populations.

The seasonal effects (based on Appendix A) of the predicted thermal plume from Units 1 and 2 are shown in Figure 6-11. The greatest density of Mytilus occurs within the 10-foot mlw contour shown. A higher ambient temperature (maximum seasonal surface temperature) is used in the discussion of Mytilus than the previous sub-tidal species to be more representative of the intertidal environment. Under conditions of maximum ambient temperature (summer season), the thermal plume may result in some mortality within the 15-degree isotherm (2.1 acres) as was the case for lobster sub-tidal species. In addition, during maximum ambient temperatures (summer), temperatures in an area of 10 acres may result in cessation of feeding in Mytilus. At the edge of the plume, temperature conditions will be optimum for settling of larvae. It is assumed then that larvae (veliger or pediveliger) will settle in the outer edges of the thermal plume.

In the fall, the areas for maximum settling will be closer to the discharge, and feeding could be ceased in the immediate discharge area (1 acre). In winter and spring, settling could still occur within the 10-degree isotherm.

It appears that the station will result in a localized plume effect of yearly population shifts of Mytilus inshore in winter and offshore in summer.

6.6.2 Entrainment

Bivalve veliger larvae have been collected in entrainment samples at Unit 1 for a period of 210 days from April to November (1974). During this period, however, most bivalve larvae were not

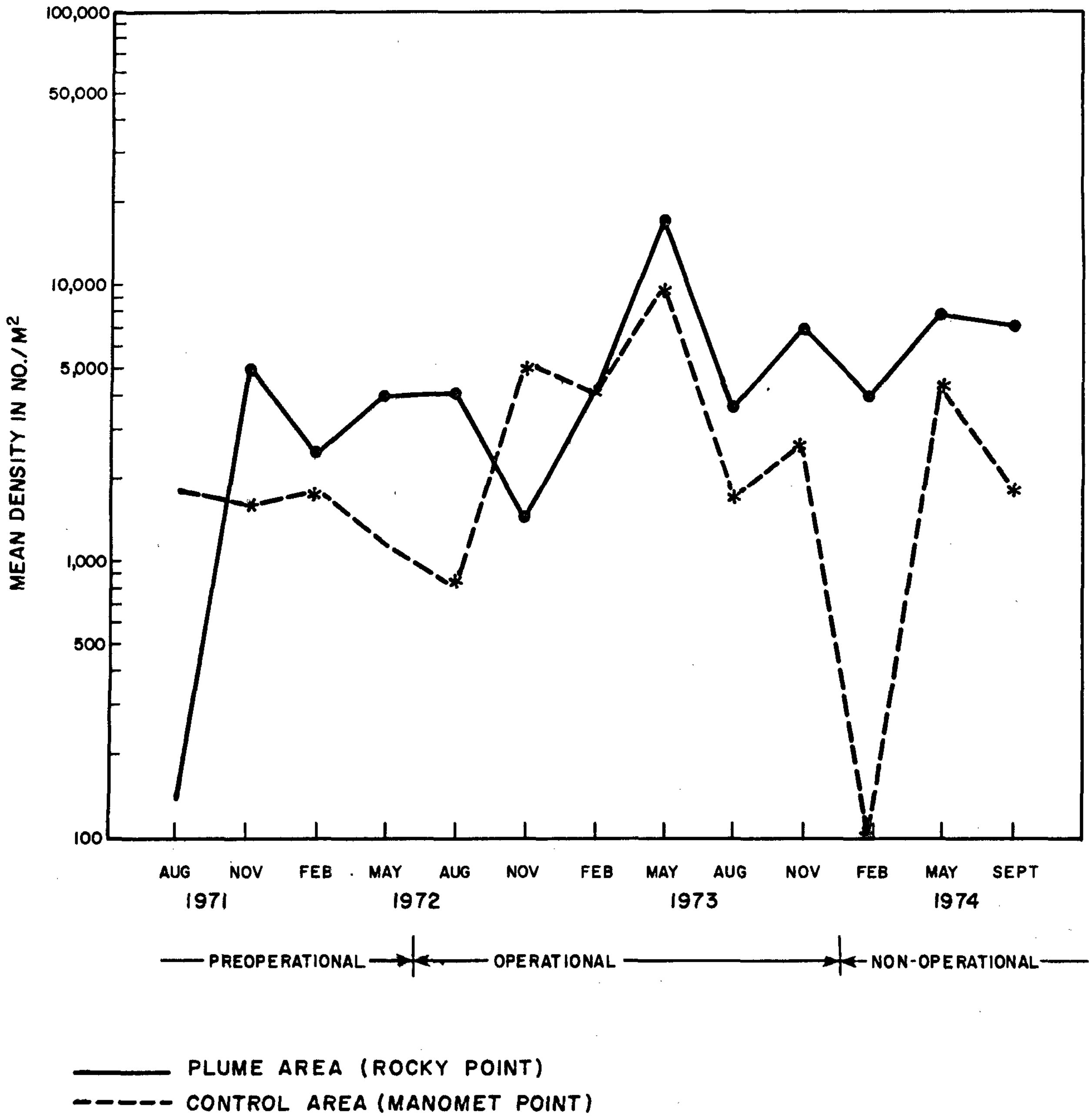

FIGURE 6-10
MEAN INTERTIDAL *MYTILUS* DENSITY

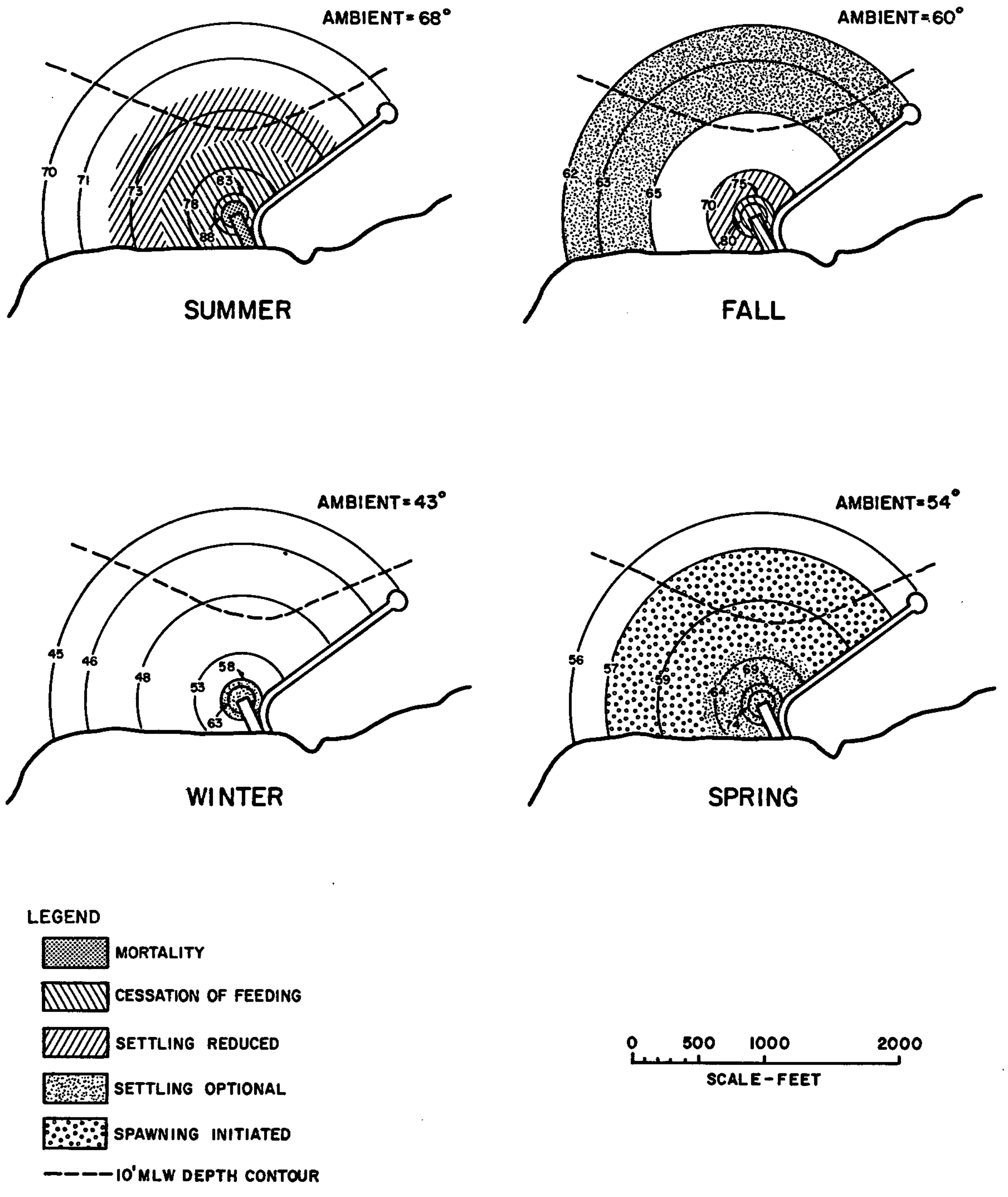

FIGURE 6-11

POTENTIAL THERMAL PLUME EFFECTS
MUSSEL

identified to species. The estimated annual number of bivalve larvae entrained in Unit 1 is:

1632 larvae/m^3 (mean number per sample) x 210 days x 1.8×10^6 <u>m^3/day</u> = 6.17×10^{11} larvae/year

To extrapolate the effects of two-unit operation, this estimate was multiplied by the ratio of the flow for Units 1 and 2 to the flow of Unit 1 (3.75). The maximum annual number, based on the projected flow through Units 1 and 2 combined, would be 2.31×10^{12} larvae entrained. This estimate assumes that all bivalve larvae collected are <u>Mytilus</u> and is, therefore, highly conservative.

Additionally, entrainment mortality studies at Unit 1 have indicated 80 percent survival of bivalve larvae on passage through the station.

This conservative estimate of larval loss is used to extrapolate to adult loss.

Purchon (1968) indicated that mortality over 99.9 percent was normally compensated for by bivalves in general. Applying this assumption to <u>Mytilus</u>, the entrained larvae might produce 2.31×10^9 adults. The average density of adult <u>Mytilus</u> for all stations and all seasons is 4,700 organisms/square meter. Therefore, the equivalent of 4.9×10^5 square meters or 121 acres could theoretically be devoid of <u>Mytilus</u>.

Theoretically, the equivalent of 6.17×10^8 adults or 32 acres should be devoid as a result of Unit 1 operation, when in reality no detectable change in <u>Mytilus</u> density at the station has occurred as a result of Unit 1 operation. Based on low mortality of larvae on passage through Unit 1, the fact that all bivalve larvae are assumed to be <u>Mytilis</u> and the negligible effect of entrainment resulting in adult population decreases at Unit 1, the estimate of 2.31×10^9 adults/year lost is extremely conservative.

6.6.3 Entrapment

Mussels are commonly collected from intake screens; however, they are not considered entrapped species since they actively colonize the screens rather than being passively swept onto them.

6.6.4 Cumulative Impact

No detrimental station impact on <u>M. edulis</u> is expected to occur through entrapment as this species readily colonizes intake screens. However, potential station-related effects on <u>M. edulis</u> can result from the thermal plume and entrainment.

Based on thermal tolerances, some mortality will occur within the 15-degree isotherm (2.1 acres). In addition, during brief periods in the summer, mussels within an area of 10 acres adjacent to the discharge canal may cease feeding. This will probably not result in mortality. During the other seasons, the temperatures within these areas will be optimal for larval settling.

Entrainment of _M. edulis_ larvae will occur through Units 1 and 2. The predicted number of larvae entrained is 2.31×10^{12} larvae per year based on entrainment monitoring at Unit 1 and the combined Unit 1 and 2 flow. A conservative estimate of the acreage of adult loss through larval entrainment mortality (assumed to be 100 percent) is 121 acres. A more reasonable and yet conservative estimate of adult acreage loss (based on the effects of Unit 1 operation and preliminary entrainment mortality studies) is 20 percent of the above estimate or 24 acres.

Based on the above estimates, the large area of Cape Cod Bay, and rapid colonization of _M. edulis_, the cumulative impact of Unit 1 and 2 operation on the Cape Cod Bay population of _M. edulis_ (approximately 26 acres) will be negligible.

6.7 COMMON PERIWINKLE (LITTORINA LITTOREA)

Common periwinkle is a dominant intertidal gastropod at Pilgrim Station. It is a tolerant organism adapted to varying temperatures and partial drying. Power station-related impact could result from the effect of the thermal plume on adults and entrainment of planktonic eggs and larvae. As in previous discussions, the potential impacts of the combined Units 1 and 2 discharge are described by relating results of monitoring studies at Unit 1 to the predicted Units 1 and 2 discharge data.

6.7.1 Thermal Plume

A preoperational and postoperational benthic monitoring program has indicated trends in seasonal periwinkle densities. Figure 6-12 indicates the density of L. littorea intertidally at Rock Point (discharge area, Transect G-1) and Manomet Point control area, Transect G-5). Intertidal densities are analyzed as the greatest densities of Littorina occurred intertidally.

Figure 6-12 indicates that the Littorina population of Manomet Point is more stable over time than at Rock Point. There is a decline in population size at Rock Point from 1971 to 1973. It is unlikely that this is attributable to power station operation since this trend continued when the station was not operating.

The seasonal effects of the combined thermal plume based on a temperature tolerance (Appendix A) of Units 1 and 2 on Littorina are shown in Figure 6-13. The greatest density of L. littorea occurs within the 10-foot mlw contours shown. During maximum ambient temperature (summer), some mortality may occur within the 15-degree isotherm.

6.7.2 Entrainment

Gastropod eggs and larvae have been collected in entrainment collections for Unit 1 during 1974. Littorina eggs were collected from April through August and larvae were collected from July through November. During these periods most gastropod larvae were not identified to species. Therefore, all gastropod larvae entrained were assumed to be L. littorea. The annual number of Littorina eggs entrained in Units 1 and 2, based on Unit 1 collections and projected flow rates, are:

$$282.7 \text{ eggs/m}^3 \times 140 \text{ days (period of occurrence)} \times 6.87 \times 10^6 \text{ m}^3\text{/day} = 2.72 \times 10^{11} \text{ eggs/year}$$

The annual number of larvae entrained is:

$$180.3 \text{ larvae/m}^3 \times 126 \text{ days} \times 6.87 \times 10^6 \text{ m}^3\text{/day} = 1.56 \times 10^{11} \text{ larvae/year}$$

The projected number of larvae entrained is high in relation to the egg density. This could be due to high survivorship from egg to larvae (in this case, 57 percent), which is unlikely. A more reasonable explanation is that the veliger larvae collected at the station may not be from the immediate station area as the larvae are planktonic for a 6-week period, while the eggs are in the water column for only 6 days. The larvae could thus be from an extended area. To represent a conservative estimate of localized impact, the larval number entrained will be included in assessing impact. Assuming a 0.1 survivorship of eggs to larvae, a total of 1.83×10^{11} larvae would be entrained per year ($2.72 \times 10^{10} + 1.56 \times 10^{11} = 1.83 \times 10^{11}$ larvae/year).

This conservative estimate of larval loss is used to extrapolate to adults. Purchon (1968) indicated that mortality of some molluscans of over 99.9 percent was normally compensated for in general. With this assumption applied to L. littorea, the entrained eggs and larvae might produce 1.83×10^{8} adults. The average density of adults for all stations at which L. littorea occurs is approximately 400 organisms per square meter. Therefore, the equivalent of 4.58×10^{5} square meters or approximately 113 acres could theoretically be devoid of Littorina. This estimate is probably very conservative as the operation of Unit 1 would have presumably affected the populations at Manomet Point to some degree, but there was no noticeable effect in postoperational studies, all gastropod larvae were assumed to be L. littorea, and better than 80 percent survivorship of entrained gastropod larvae was observed (Section 6.6.2).

6.7.3 Entrapment

Not Applicable

6.7.4 Cumulative Impact

No station impact on L. littorea is expected to occur through entrapment as no life stage of this species is susceptible to this source of impact. Potential station-related effects on L. littorea can result from the thermal plume and primarily entrainment.

Based on thermal tolerances, twenty percent mortality will occur in the summer within the 15-degree isotherm (2.1 acres). Entrainment of both periwinkle eggs and larvae will occur through Units 1 and 2. Based on entrainment monitoring at Unit 1 and the combined Unit 1 and 2 flow, 2.7×10^{11} eggs and 1.56×10^{11} larvae per year will be entrained. A conservative estimate of the acreage adult loss through entrainment mortality (100%) is 113 acres. A more reasonable and yet conservative estimate of adult acreage loss (based on the effects of Unit 1 operation and preliminary entrainment mortality studies) is 20 percent of the above estimate or 23 acres.

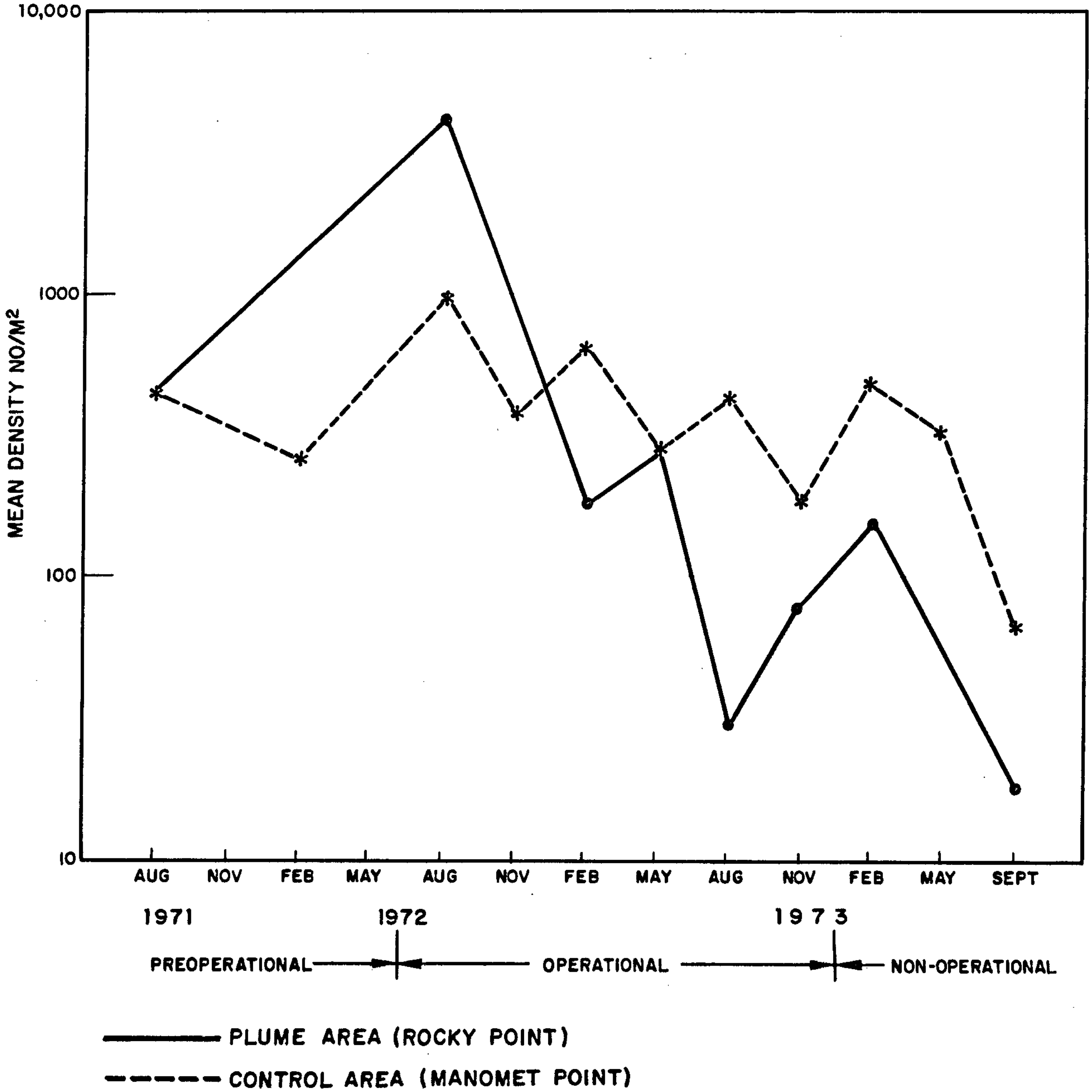

FIGURE 6-12
MEAN INTERTIDAL DENSITY OF
LITTORINA LITTOREA (NO. PER M^2)

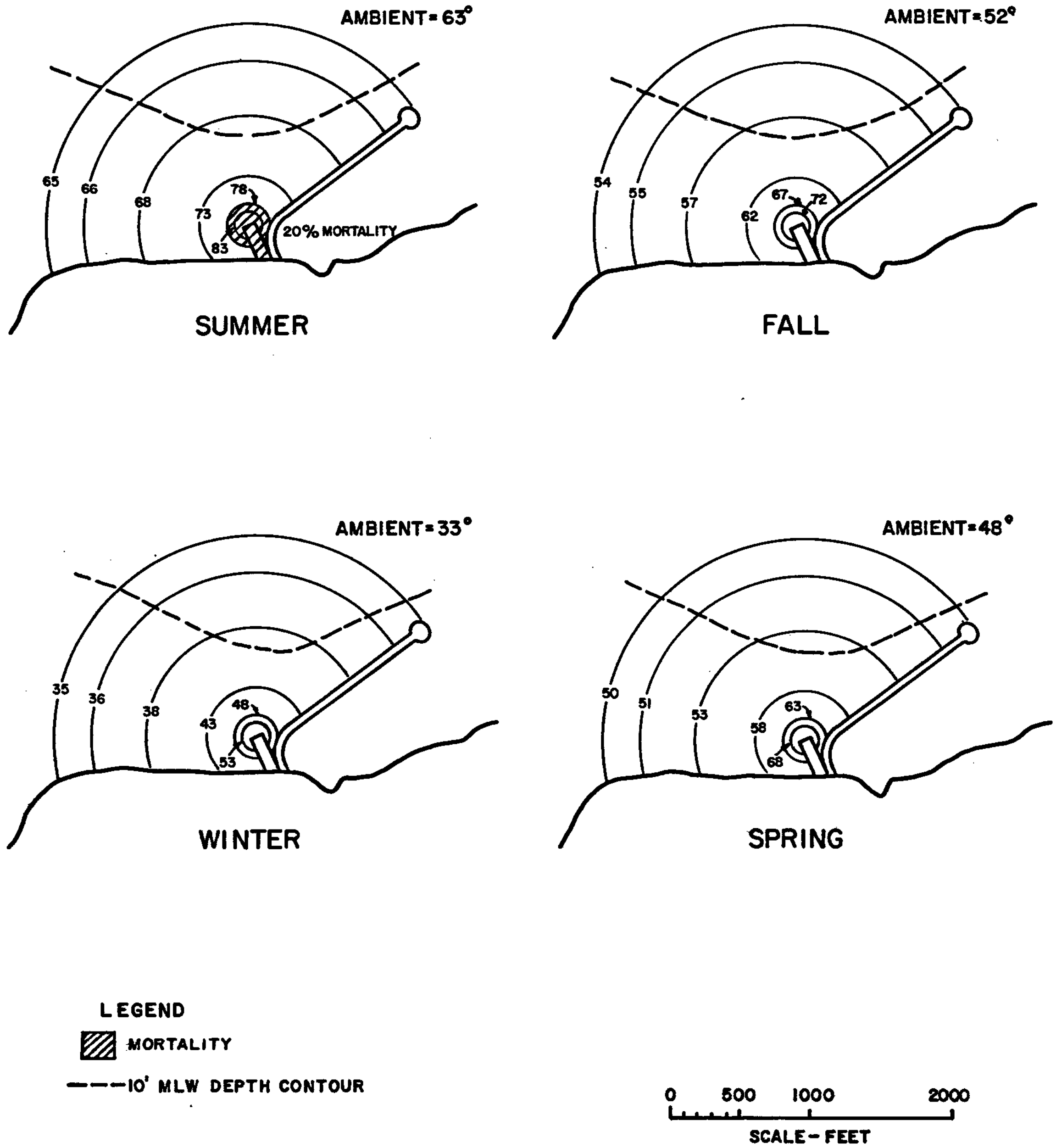

FIGURE 6-13

POTENTIAL THERMAL PLUME EFFECTS PERIWINKLE

Based on the above conservative estimates, the large area of Cape Cod Bay, and rapid colonization of L. littorea the cumulative impact of Unit 1 and 2 operation on the Cape Cod Bay population of L. littorea (approximately 25 acres) will be negligible.

6.8 ATLANTIC MENHADEN (BREVOORTIA TYRANNUS)

The effect of the operation of Units 1 and 2 on the Atlantic menhaden (Brevoortia tyrannus) population is predicted by a population simulation model. Sources of impact to this population include entrainment of larvae, impingement of yearlings and the effects of the thermal plume, such as gas bubble disease to adults. The basis for the analysis of impact is a population dynamics simulation model initially developed by Schaaf and Huntsman (1972). The model was used to simulate menhaden populations for a 50-year period. The analysis also included additional sources of mortality representing the power station operation effects. Results of both simulations were compared with respect to population size and the projected yield to the commercial fishery.

6.8.1 The Model

The menhaden life cycle model used for this analysis allows prediction of future population structure. A Ricker (1958) stock and recruitment function from Schaaf and Huntsman (1972) was used to predict the number of fish in age-class I (R) from the total number of spawners (S) the previous year:

$$R = S \exp (1626 - S/10^6)/654 \qquad (1)$$

The stock and recruitment function is the density-dependent component in this population dynamics model. A graph of the function is depicted in Figure 6-14. For spawning densities below 6.54×10^8, an increase in the spawning stock results in an increased number of recruits. For spawning densities above 6.54×10^8, an increase in the spawning stock results in a decreased number of recruits.

The instantaneous natural mortality and fishing mortality were assumed to be constant for all ten age-classes. The instantaneous fishing mortality of age-class I was calculated as 66 percent of the fishing mortality of the other ages (Table 6-2). The simulations were run with a natural mortality rate of 0.37, as developed by Schaaf and Huntsman (1972). The instantaneous fishing mortality rate of 0.8 was used. Schaaf and Huntsman (1972) determined that this fishing mortality rate results in annual commercial catches of 400,000 to 500,000 metric tons.

Yield to the commercial fishery was calculated using the exploitation formula:

$$U = F(1-e^{-Z})/Z, \quad (2)$$

where

U is the exploitation rate,
F is the instantaneous fishing mortality, and
Z is the total mortality rate from all sources.

The yield is calculated in metric tons by using average weight at each age-class from the data of Reintjes (1969) and is presented in Table 6-2. The number of fish which incur mortality from the power station is also calculated using formula 2 by substituting the instantaneous mortality rate due to the power station for F.

The effect of the power plant was simulated by first calculating a mortality rate due to power-plant-related events (e.g. entrainment, entrapment, and plume effects) The number of larvae entrained at Unit 1 during 1974 was calculated by integrating the densities observed in the entrainment studies throughout the year. An estimated 4.1×10^7 larvae were entrained between June and December of 1974. No larvae were collected during the remaining portion of the year. To extrapolate the effects of 2-unit operation, this estimate was then multiplied by the ratio of the flow for Units 1 and 2 to the flow of unit 1 (3.75).

To estimate the mortality rate which would result from this loss, the number of larvae produced by the simulated population was calculated.

The age specific fecundity for menhaden was estimated from the weight fecundity relationship of Higham and Nickolson (1964). The age specific mean weight from Reinjes (1969) was then used to obtain the age specific fecundity (Table 6-2). The equilibrium population was multiplied times the fecundity to obtain an estimate of the number of eggs produced. It was assumed that 1 in 10 eggs hatch. This results in an estimated 1.45×10^{13} larvae. The estimate of entrainment mortality is:

$$Me = -\ln\ (1-(1.53 \times 10^8/1.45 \times 10^{13})) = 1.06 \times 10^{-5} \quad (3)$$

The effect of impingement of menhaden on the traveling screens was estimated from the screen-washing data collected in 1973. These data represent a complete year of collection and generally agree with the other data collected in the screen washing program. The screen-washing data does not distinguish between clupeid species; therefore, it is conservatively assumed for this analysis that all clupeids are menhaden. It is also assumed these fish are age-class I, since they are unidentifiable as menhaden.

An average of 0.853 clupeids per hour were impinged during 1973. Assuming the power station runs continuously for a year, 7,473 would be impinged. The extrapolation to 2-unit operation assumes fish are impinged in proportion to the rate of flow. This would

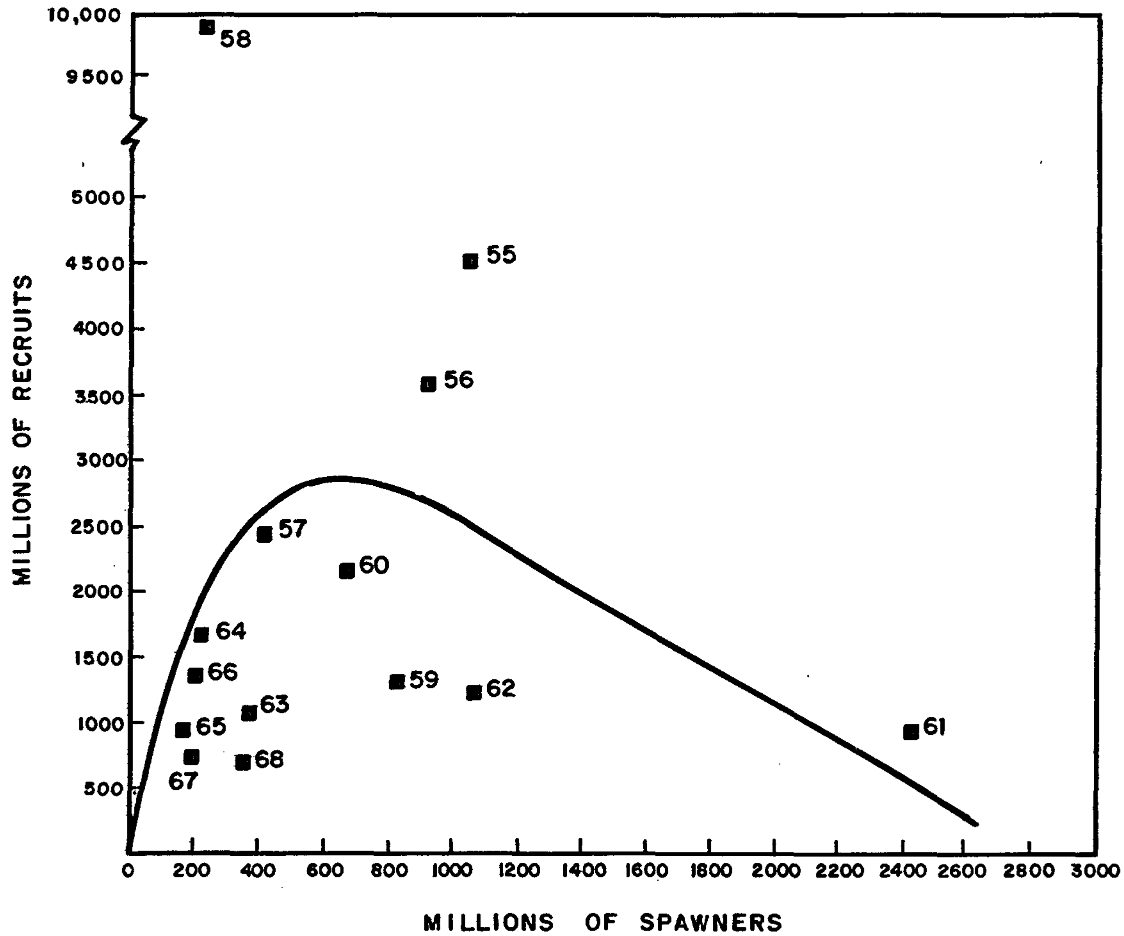

FIGURE 6-14
THE RICKER STOCK AND RECRUITMENT FUNCTION FROM SCHAAF AND HUNTSMAN (1972)
(DATA POINTS REPRESENT YEARLY ESTIMATES OF FISH ABUNDANCE)

TABLE 6-2

PARAMETERS OF THE MENHADEN POPULATION SIMULATION MODEL

Age-Class	Initial Population Size ($x10^6$)	Instantaneous Natural Mortality	Instantaneous Fishing Mortality	Average Weight (grams)	Fecundity
1	1,480	0.37	0.53	115.60	-
2	1,472	0.37	0.80	245.61	-
3	363	0.37	0.80	406.96	239,845
4	493	0.37	0.80	545.04	345,976
5	69	0.37	0.80	625.73	408,269
6	15	0.37	0.80	691.89	459,237
7	3	0.37	0.80	720.56	481,330
8	1	0.37	0.80	762.24	513,420
9	1	0.37	0.80	762.24	513,420
10	1	0.37	0.80	762.24	513,420

result in 28,023 clupeids impinged each year. The estimated additional mortality to the population would be:

$$MI = -\ln (1-2.802x10^4/2.8159x10^9) = 9.95x10^{-6} \qquad (4)$$

The effect of gas bubble disease-related mortality is conservatively predicted by calculating the additional mortality that would have resulted from a kill of the size which occurred at Pilgrim Unit 1 in April 1973, and imposing this additional mortality each year. Since this mortality does not occur every year as evidenced by 1974 and 1975 data, this estimate is most likely an over-estimate.

The 1973 fish kill has been estimated to be about 43,000 age-III fish. In 1975, a smaller fish kill estimated at about 5,000 menhaden took place. The additional mortality to the equilibrium-simulated population based on the higher 1973 kill would be:

$$Mg = -\ln (1-4.3x10^4/3.5x10^8) = 1.23x10^{-4}$$

The mortalities attributed to the power station are added singularly and in combination to the total mortality rate and the population re-simulated. The number of fish which suffer mortality due to the power station and the percent of the equilibrium population affected were also calculated from the simulation.

The initial population structure and size for the simulation analysis was calculated based on the data from Schaaf and Huntsman (1972) for the year 1955. This estimate of population size was calculated from the number of fish in the commercial catch and the 1955 age-specific exploitation rates (Table 6-2). The exploitation rate for age-class I was two-thirds the average exploitation rate for fish ages II to V. For fish VI years and older the average exploitation rate was used.

6.8.2 Results of Thermal Plume, Entrainment, and Impingement

The population simulation of menhaden with the parameters listed in Table 6-2 revealed a population which reached an equilibrium size of $4.48x10^9$ individuals and a stable age distribution (Table 6-3). At equilibrium and an annual fishing mortaltiy rate of 36 percent, the yield to the commercial fishery is $3.94x10^5$ metric tons.

The results of imposing additional mortality to the population to simulate the effect of entrainment, entrapment and the thermal discharge are presented in Table 6-4. The result of imposing an additional mortality due to entrainment is a population which comes to an equilibrium and is reduced in size by 0.00275 percent from the non-impacted population.

The simulation of entrapment and the thermal effect reveal similar levels of reduction in population size of 0.00073 percent and 0.00156 percent, respectively. These simulations also produced populations which reached an equilibrium.

The combined effects of all three sources of power plant mortality were simulated. The resulting population had a stable equilibrium and a population size 0.00485 percent below the non-impacted population.

6.8.3 Cummulative Impact

The simulation performed using the population dynamic model of Schaaf and Huntsman (1972) reveals a population which is regulated only by the stock and recruitment function. The other population parameters which include age specific individual weight, natural and fishing mortalities are constants regardless of population density.

Any perturbation to the population within several orders of magnitude of that estimated for the Pilgrim Nuclear Power Station, Units 1 and 2, results in a change in the equilibrium population density, but not the stability of the equilibrium. It is difficult to predict the reduction in the Massachusetts menhaden catch as a result of the operation of Pilgrim Units 1 and 2, since Massachusetts does not represent a biological subunit of the North Atlantic Menhaden population. An estimate in the reduction in Massachusetts catch could be made for the fish which were killed by entrainment, entrapment and the effects of the thermal plume if these were assumed to all be translated into reductions in the Massachusetts catch.

These losses due to power station events may be compared to the yield to commercial fisheries. The landings of menhaden in all Massachusetts ports and the dollar value of the landings are presented in Figure 6-14. A loss of 43,000 age-III fish which was estimated for the 1973 fish kill would have represented 0.11 percent of the 1973 Massachusetts catch or an approximate dollar value of $944.

An estimate of the reduction in the commercial fishery catch as a result of power station operation (due to all 3 sources of mortality) was made for a constant rate of fishing mortality. The reduction in the North Atlantic catch in the impacted population vs. the non-affected population is about 104,073 fish per year.

If it is further assumed that the reduction in Atlantic menhaden population size of 0.00485 percent is represented by fish weighing about one pound each, the weight of this loss is then 46 metric tons. This corresponds to about 0.57 percent of the 1973 Massachusetts catch, or a dollar value of about 2,285.

TABLE 6-3

SIMULATED EQUILIBRIUM OF MENHADEN POPULATION

Age-Class	Population Size ($\times 10^6$)	Age Distribution	Yield (Metric Tons)
1	2,815.9	0.629112	125,270
2	1,144.8	0.255780	146,030
3	355.32	0.079386	75,096
4	110.28	0.024639	31,201
5	34.227	0.007647	11,122
6	10.623	0.002373	3,812
7	3.2970	0.000737	1,234
8	1.0233	0.000229	405
9	0.3176	0.000071	125
10	0.0986	0.000022	39
Total	4,475.9	1.000000	394,334

TABLE 6-4

RESULTS OF SIMULATION OF MENHADEN POPULATION

Condition	Additional Mortality	Population Size	Yield (metric tons)	Number of Fish Killed	% Reduction Population
Without Power Plant	0	$0.44758794 \times 10^{10}$	394,335	0	0
Entrainment (larvae)	1.06×10^{-5}	$0.44757565 \times 10^{10}$	394,324	56,750	0.00275%
Impingement (age-class I)	9.95×10^{-6}	$0.44758467 \times 10^{10}$	394,330	18,567	0.00073%
Thermal Plume (age-class III)	1.23×10^{-4}	$0.44758098 \times 10^{10}$	394,321	25,759	0.00156%
Total	all the above	$0.44756623 \times 10^{10}$	394,306	104,073	0.00485%

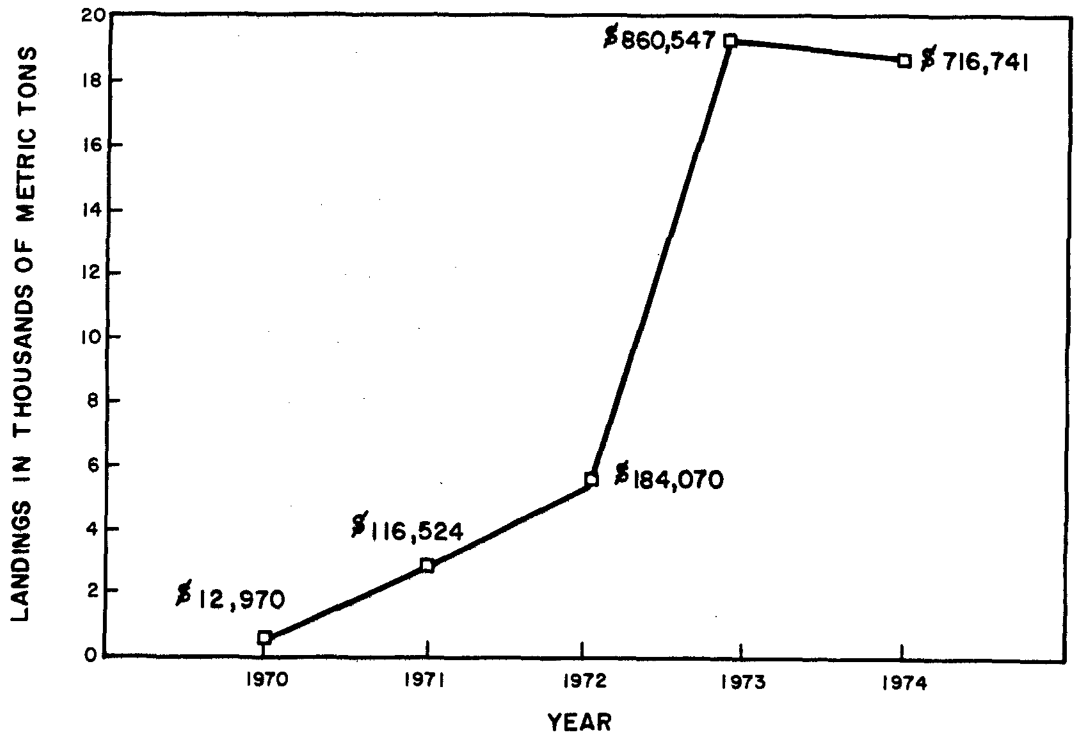

FIGURE 6-15
MENHADEN LANDINGS FOR ALL MASSACHUSETTS PORTS
(FROM U.S. DEPARTMENT OF COMMERCE CURRENT FISHERIES STATISTICS; TOTAL LANDINGS AND DOLLAR VALUE OF EACH YEAR'S CATCH)

6.9 WINTER FLOUNDER (PSEUDOPLEURONECTES AMERICANUS)

The predicted effect of the operation of Pilgrim Units 1 and 2 on the local winter flounder population during the 40 years the station is expected to operate is based on several conservative assumptions. The population which is affected is assumed to be a closed population with no migration to or from neighboring populations. This assumption is conservative since additional mortality is restricted to the local population without benefit of migration into or out of the area.

The local winter flounder population is assumed to only reproduce in the Plymouth-Duxbury Harbor. Howe and Coates (1975) reported that winter flounder north of Cape Cod showed limited movement from inshore grounds with 90 percent of the recaptures within the localized area where tagging was conducted. Since there are no estimates of the size of the breeding winter flounder population for the Plymouth-Duxbury area, the estimates of breeding population density made by Saila (1961) for Rhode Island were used. The density times the area of the estuary at mean low water gave an estimate of the breeding winter flounder population.

The second assumption is that the winter flounder found in the immediate vicinity of the Pilgrim station are recruited into the local winter flounder population. This assumption is the basis for predicting entrainment impact to the local winter flounder population.

6.9.1 The Model

The winter flounder life cycle model used for this analysis was based on the model developed by Hess, Sissenwine and Saila (1975). A Ricker (1958) stock and recruitment function was parameterized by the method described by Hess, et al (1975). This function predicts the number of recruits of fish in age-class I (R) from the total number of eggs produced the previous year (E):

$$R(E) = E \exp(-10.09-(-0.154\times10^{-11})E) \qquad (1)$$

This stock and recruitment function is the only density-dependent component of the model. For egg densities in the population below 6.15×10^{10}, and increased number of eggs results in an increased number of yearlings. For egg densities greater than 6.15×10^{10}, an increase in eggs results in a reduced number of yearlings per egg.

The life cycle of the winter flounder is assumed to have twelve age classes. The instantaneous natural mortality and fishing mortality rates for age-class II and older were assumed to be constant. Age-class I fish were assumed to have no mortality from fishing and a natural mortality rate of 1.928 (Table 6-5).

The yield to the commerical fishery was calculated by assuming a constant age-specific weight from Hess et al (1975). The yield was calculated in metric tons using the fishing mortality and weights in Table 6-5.

The effect of the power plant was simulated by first calculating the additional mortality associated with the power plant. The effect of entrainment was simulated using the mathematical models for circulation and dispersion developed by the staff of the Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics at MIT. A description of the circulation model, CAFE, can be found in Wang and Connor (1975), and a description of the dispersion model DISPER, can be found in Leimkuhler (1974).

The results of simulations of the center of mass for particulars in various locations are presented in Figure 6-16a for a southwest wind and Figure 6-16b for a northeast wind.

An initial concentration of 2×10^9 larvae was loaded at uniform concentration throughout the Plymouth-Duxbury Harbor over the course of two tidal cycles. A sink was modeled at the node closest to the Pilgrim intake. Larvae were removed in proportion to the concentration at the sink. Flow was assumed to be 2,560 cfs representing Units 1 and 2 operation.

The simulation was run with and without the power plant sink. The percent reduction in the number remaining in the harbor due to the sink compared to the original cohort reaches a maximum of 0.01 percent after about 6 days. The difference in the larvae remaining in the harbor after 6 days with and without the sink compared to the number remaining in the harbor is about 0.1 percent. Since both numbers are small, the larger value of 0.1 percent is chosen as a conservative estimate of the additional mortality due to entrainment of larvae. A more detailed discussion of this work is contained in Pagenkopf et al. (1975).

An estimate of mortality associated with impingement was made by extrapolation from Unit 1 screen-washing data. Extrapolation for 2-unit operation, an estimated 769 flounder would be impinged per year. These are assumed to belong to age-class II. The estimate of impingement mortality rate becomes:

$$MI = -\ln\ (1.-769/73347)=0.0104 \qquad (3)$$

6.9.2 Results of Thermal Plume, Entrainment, and Impingement

The effect of the thermal discharge can best be illustrated by the data gathered in the field studies. Winter flounder populations have been monitored preoperationally and postoperationally in the vicinity of the thermal plume and at Warren Cove (control area). Figure 6-16 shows the densities of winter flounder at both stations. In most cases, population

TABLE 6-5

PARAMETERS OF THE WINTER FLOUNDER SIMULATION MODEL

Age-Class	Initial Population Size	Instantaneous Natural Mortality	Instantaneous Fishing Mortality	Average Weight (Grams)	Fecundity
1	511,099	1.928	0.0	25.7	0
2	73,374	0.66	0.45	105.2	0
3	21,142	0.66	0.45	222.3	260,000
4	8,077	0.66	0.45	356.1	443,000
5	2,662	0.66	0.45	489.2	637,000
6	878	0.66	0.45	607.3	813,000
7	289	0.66	0.45	707.9	970,000
8	95	0.66	0.45	793.7	1,107,000
9	32	0.66	0.45	861.4	1,217,000
10	11	0.66	0.45	913.9	1,301,000
11	3	0.66	0.45	954.2	1,367,000
12	1	0.66	0.45	988.3	1,424,000
	617,636				

?

?

Mass. landings broken down by harbor?

TABLE 6-5A

RESULTS OF WINTER FLOUNDER SIMULATION OVER A 40-YEAR PERIOD

(Based on the Model of Hess et al, 1975)

	Additional Mortality	Population Size	% Reduction
Non-affected population	0	610,830	0
Entrainment	0.001	606,890	0.65 (1.75%)
Impingement	0.0104	575,330	5.81
Entrainment and Impingement	both	574,950	5.87

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:
FIGURE 6-16:
"WINTER FLOUNDER TRAWL CATCH"

WITHIN THIS PACKAGE... OR, BY SEARCHING USING THE DOCUMENT/REPORT FIGURE 6-16

D-05

FIGURE 6-16A.
DEPTH-AVERAGED PARTICLE PATHS; VELOCITIES TAKEN FROM "CAFE" USING TIDE AND 10-KNOT SOUTHWEST WIND
(FROM PAGENKOPF ET AL., 1975, FIG. 8)

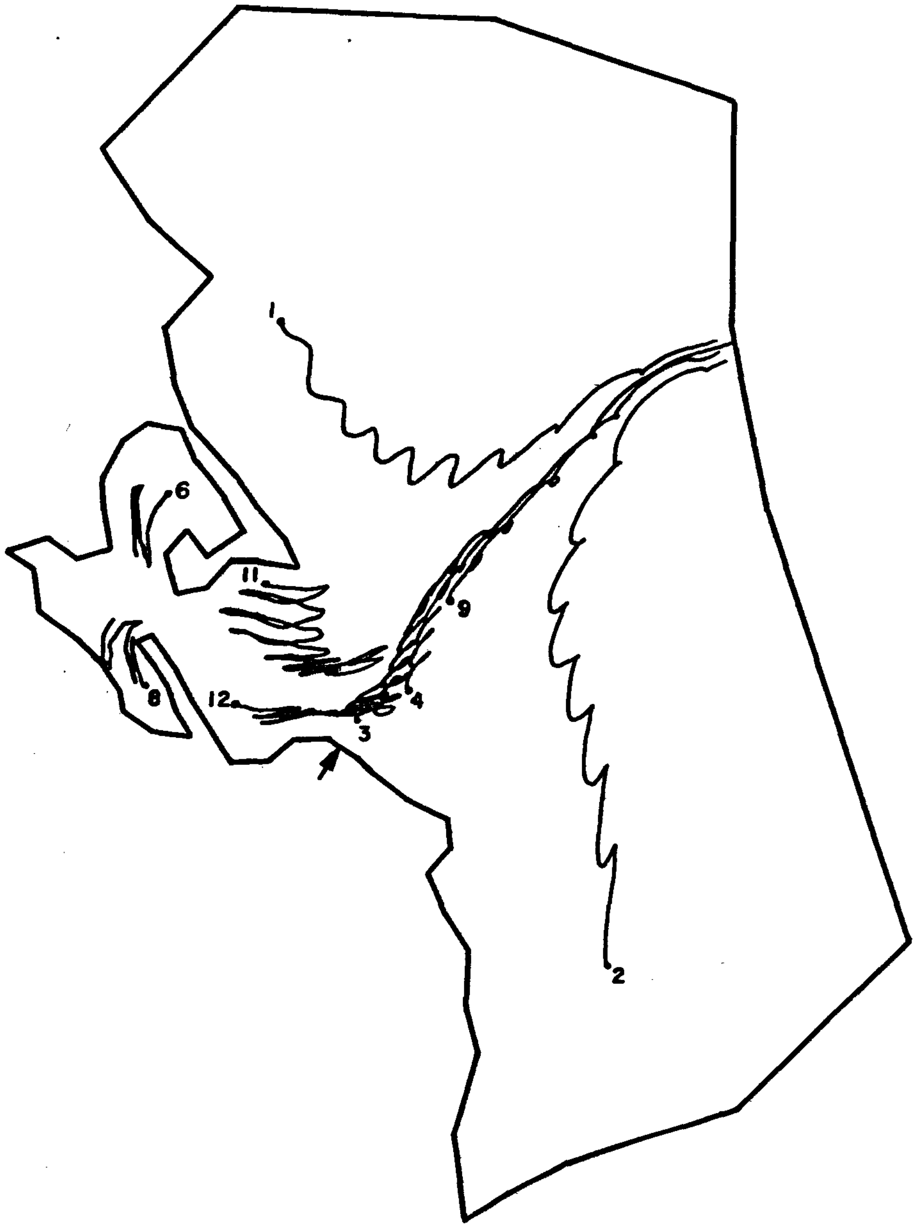

FIGURE 6-16B.
DEPTH-AVERAGED PARTICLE PATHS;
VELOCITIES TAKEN FROM "CAFE"
USING TIDE AND 20-KNOT
North ~~SOUTH~~EAST WIND
(FROM PAGENKOPF ET AL., 1975, FIG. 14)

density was similar at both stations, both preoperationally and postoperationally. Reduction in the plume area population occurred in January, 1974, which coincided with station shutdown, but it probably was the result of sampling variability as it occurred briefly. In addition, the Warren Cove population was reduced in July and October of 1974 and, although the station was operating, there was no reduction in the vicinity of the plume.

Thermal tolerances are given in Appendix A. For the most part, thermally related mortality occurs at temperatures higher than those of the thermal plume. Since the plume is buoyant and flounder is a benthic species, only the immediate discharge area will be affected. In summer, larval mortality can occur in the immediate discharge area (one acre). Since this is an area of active station plume flow, only winter flounder larvae which have passed through the station should occur in this area and thus would be entrained organisms. These organisms were assumed to be killed by entrainment.

The simulated winter flounder population maintains its initial population size and age distribution (Table 6-16). The yield to the commerical fishery for the simulated population would be 6.5 metric tons per year.

The imposition of additional mortality due to entrainment of larvae produces a population which is reduced by 0.65 percent of the original population in 40 years.

The imposition of additional mortality associated with the impingement of winter flounder was simulated. The resulting population reached a level 5.8 percent below the unaffected population in 40 years.

The combined effects of both impingement and entrainment was also simulated. The population was depressed by 5.9 percent over the unaffected population in 40 years.

The effect of termination of power station operation was investigated by using the impacted population as the initial population for an additional simulation without the effects of the power station. After 40 years of recovery, the population had recovered 2.3 percent of the 5.9 percent it was reduced in 40 years of plant operation.

6.9.3 Cumulative Impact

The simulation performed in this analysis for winter flounder reveal a population which is regulated only by the stock and recruitment function. The other parameters which include age-specific individual weight, natural and fishing mortalities are constants regardless of population density.

The effect of the thermal plume on winter flounder is expected to be minimal based on Unit 1 operating data. The effect of the entrainment of larvae and the impingement of adults is predicted to reduce the population by 5.9 percent in 40 years.

The reduction in population size as a result of power station events may be compared to the commercial fisheries catches. The average catch from 1970 to 1973 for both lemon sole and black back flounder, as reported by Massachusetts Landings for all ports, was 6.850 metric tons per year. The predicted reduction in the winter population would result in a loss of 0.40 metric tons from the commercial catch, assuming the population would be harvested at the same rate.

6.10 POLLOCK (POLLACHIUS VIRENS)

Pollock is a predatory schooling fish species which is present at Pilgrim station during certain seasons of the year. Pollock could be subject to station impact through the thermal plume, entrainment of eggs and larvae, and impingement.

The relative abundance of pollock in the vicinity of the station, as measured by gill net collections, is listed in Table 6-6 and monthly variations are shown in Figure 6-17. The relative abundance of pollock increased during station operation and decreased when the station was down (Table 6-6). This could be due to two factors:

(1) Natural migrations inshore in spring and fall with patchiness in collection techniques (this is common with gill net collections of schooling species). In other words, natural variability coincident with station operation.

(2) It could be due to predation of pollock on migratory prey species drawn near the station. The decrease in sea herring and alewife densities in gill net collections occur when pollock density is greatest (Table 6-6). During station operation, there are more prey species and thus more predatory species in the area.

6.10.1 Thermal Plume

There is little quantifiable evidence concerning the effect of the thermal plume on pollock. Visual observations indicate that pollock stay on the edge of the plume, feeding, and do not appear to be affected by the plume (R. Fairbanks, personal communication). Thermal tolerance data (Appendix A) indicate that pollock mortality could occur within the 20 degree isotherm (less than 1 acre) during the summer months. Pollock avoid the immediate plume areas thus no mortality is expected.

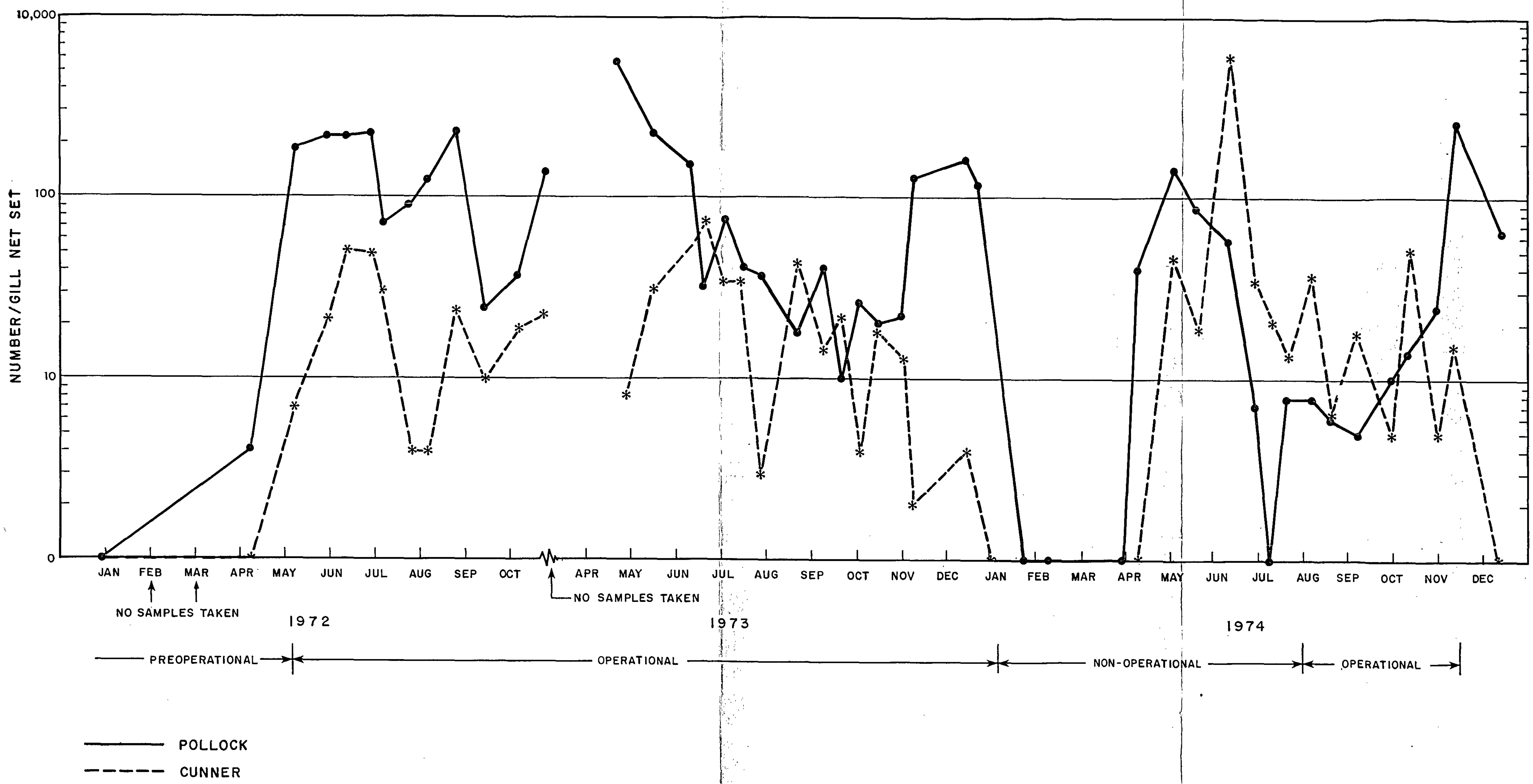

FIGURE 6-17
NUMBERS OF POLLOCK
COLLECTED IN GILL NETS AT ROCKY POINT
IN THE VICINITY OF PILGRIM STATION

TABLE 6-6

SPECIES COMPOSITION OF GILL NET COLLECTIONS

Species	1971 Number	1971 %	1972 Number	1972 %	1973 Number	1973 %	1974 Number	1974 %
pollock	950	37.5	1558	68.7	1707	58.9	750	29.8
cunner	265	10.4	242	12.7	337	11.6	340	13.5
sea herring	199	7.8	20	0.9	74	2.6	267	10.6
alewife	620	24.4	141	6.2	244	8.4	522	20.7
blueback herring	30	1.2	2	0.1	90	3.1	15	0.6
Atlantic mackerel	195	7.7	65	2.9	100	3.5	44	1.7
striped bass	7	0.3	18	0.8	105	3.6	11	0.4
Atlantic cod	199	7.8	184	8.1	154	5.3	142	5.6
tautog	10	0.4	8	0.3	20	0.7	18	0.7
Atlantic menhaden	25	1.0	9	0.4	31	1.1	88	3.5
northern kingfish	2	0.1	1	<0.1	0	0.0	0	0.0
four spot flounder	1	<0.1	0	0.0	0	0.0	0	0.0
hickory shad	1	<0.1	0	0.0	0	0.0	0	0.0
bluefish	1	<0.1	2	0.1	6	0.2	119	4.7
butterfish	12	0.5	0	0.0	1	<0.1	7	0.3
winter flounder	5	0.2	5	0.2	6	0.2	3	<0.1
Atlantic tomcod	7	0.3	3	0.1	1	<0.1	0	0.0
silver hake	4	0.1	1	<0.1	7	0.2	151	6.0
scup	0	0.0	3	0.1	3	0.1	4	0.2
rainbow smelt	1	<0.1	1	<0.1	4	0.1	35	1.4
hake	2	0.1	3	0.1	7	0.2	1	<0.1
hardtail	0	0.0	0	0.0	0	0.0	2	0.1
black sea bass	0	0.0	0	0.0	0	0.0	1	<0.1
banded rubberfish	0	0.0	0	0.0	0	0.0	1	<0.1
TOTAL	2536		2266		2897		2521	

6.10.2 Entrainment

Pollock eggs and larvae are planktonic and therefore are subject to entrainment. No eggs or larvae were collected in a year of entrainment monitoring. As with lobster larvae, although none were entrained, some pollock larvae have been collected in the vicinity of the station. These larvae are probably the result of minor offshore spawnings in Cape Cod Bay.

Few pollock larvae were observed in ichthyoplankton collections in 1974 and even fewer in 1972. The average density approximately a mile offshore was 0.28 larvae per 100 cubic meters in the 1974 spawning season, and 0.003 larvae per 100 cubic meters in 1972. Based on the combined projected intake flow rate through Units 1 and 2, this could result in from 3.7×10^4 (1972 collections) to 3.6×10^6 (1974 collections) larvae entrained per year. The fecundity of pollock has been reported as high as 2 million eggs per year per female with an average of 225,000 eggs per female per year (Bigelow and Schroeder, 1953). Assuming 90 percent mortality from egg to larvae and using the model described in Section 6.1, this results in the equivalent of from 4 to 316 adults lost through entrainment of ichthyoplankton. Again, this represents a hypothetical worse case since no pollock eggs or larvae have been observed to be entrained in Unit 1.

6.10.3 Entrapment

Some pollock have been entrapped on the intake screens at Unit 1. A total of 12 pollock were collected in 2,096 hours (1973) or at an entrapment rate of 0.005 pollock per hour. In 1974 three pollock were impinged in 1,464 hrs (0.002 pollock/hr). Projecting the 1973 estimate for Units 1 and 2 yields an estimate of 0.019 pollock entrapped per hour. This entrapment rate results in a total of 189 pollock entrapped per year.

6.10.4 Cumulative Impact

No station impact on pollock from heat or cold shock is expected to occur through the thermal plume as behavioral observations indicate that pollock position themselves outside the plume. The estimated number of adult pollock potentially removed from the population through entrainment and entrapment, varies from 189 adults (no entrainment), 193 adults (based on 1972 offshore ichthyoplankton collections) to 505 adults (based on 1974 offshore collections).

An assessment of the impact of this removal on the total pollock population can be made based on commercial harvest. Commercial fishing records only give harvest estimates based on eviscerated fish. The average annual harvest for Massachusetts (1970-1973) is 11.2 million pounds. Adult pollock potentially affected by the station were assumed to be equivalent to a 5-pound eviscerated fish. Therefore, the potential station-related loss would represent 1.0×10^{-4}, or 2.2×10^{-4} percent, respectively, of the Massachusetts commercial landings of pollock, and therefore would be negligible.

6.11 CUNNER (TAUTOGOLABRAS ADSPERSUS)

Cunner, is an abundant local fish species found in the vicinity of Pilgrim station. The relative abundance of cunner was stable from year to year, both preoperationally and postoperationally (Table 6-6) in the gill net catch. Although there was some population variability from month to month (Figure 6-17) due to variability in catch and movement offshore in winter. The 1974 sport catch (Table 6-7) indicates the same trend as the gill net catch with cunner predominating in summer and fall. Therefore, cunner could expect to be most affected by station operation in summer and fall. Cunner could be affected by the thermal plume, entrainment of eggs and larvae, and entrapment.

6.11.1 Thermal Plume

Since the cunner population has been stable both preoperationally and postoperationally, it appears that Unit 1 has had little effect on the cunner population. Based on temperature tolerance data in Appendix A, the thermal plume should not result in overt mortality of cunner beyond the discharge canal. During periods of maximum ambient temperature, (summer) cunner will probably not reside within the ten-degree isotherm. Optimum spawning and adult growth should take place outside this area during the summer months. In the fall, temperatures immediately outside the discharge canal will be optimal for growth. In spring, temperatures immediately outside the discharge canal will be optimal for spawning and for the incubation and hatching of eggs.

6.11.2 Entrainment

Cunner eggs and larvae have been collected in entrainment samples in 1974. Cunner eggs, however, cannot be differentiated from other labrid eggs; therefore, all labrid eggs were assumed to be cunner. This is reasonable, as most labrid larvae were cunner. The estimated density of labrid eggs entrained in Units 1 is: 0.016 eggs/m^3 x 120 days/year x 1.8×10^6 m^3/day = 3.46×10^6 eggs/year. The estimated density of cunner larvae entrained is: 9.3×10^{-5} larvae/m^3 x 120 days/year x 1.8×10^6 m^3/day = 2.01×10^4 larvae/year. To extrapolate the effects of 2 unit operation, these estimates were multiplied by 3.75.

Assuming 0.1 survivorship of egg to larva, the equivalent of 1.64×10^7 eggs would be entrained per year.

The fecundity of cunner has been estimated to be about 100,000 eggs per female per season (Williams et. al, 1973). Using the

TABLE 6-7

SPORT FISHING CATCH AT PILGRIM STATION
1974

	April	May	June	July	August	September	October	November	TOTALS
Tomcod	-	-	2	-	-	4	1	-	7
Atlantic Cod	17	24	15	6	1	-	72	4	139
Mackerel	-	2	-	-	-	-	-	-	2
Winter Flounder	60	70	70	26	6	-	-	-	232
Pollock	208	90	95	25	8	4	10	-	440
Tautog	-	2	2	12	4	4	4	-	28
Cunner	-	9	178	240	157	466	244	-	1,294
Striped Bass	-	-	-	4	3	-	32	-	39
Bluefish	-	-	-	8	68	615	69	-	760
"Snapper"* Bluefish	-	-	-	-	1,036	140	-	-	1,176
Ocean Pout	6	-	-	-	-	-	-	-	6
American Eel	-	-	4	-	-	-	-	-	4
Scup	-	-	-	2	-	-	-	-	2

*young-of-the-year

assumption of the population being in equilibrium (Section 6.1) this results in the equivalent loss of 274 adult cunners.

6.11.3 Entrapment

Ninety-nine cunner were entrapped on intake screens at Unit 1 in 2,096 hours of monitoring or 0.047 cunner/hour from April through November 1973. Projected for Units 1 and 2, the entrapment rate would be approximately 0.22 cunner per hour or 1,036 cunner per year. The average sport fish catch rate at Pilgrim Station is also 0.2 fish per hour. This estimate is probably a conservative estimate for cunner as cunner are easily caught and therefore the numbers caught are considerable. The effects of entrapment are therefore assumed to be negligible.

6.11.4 Cumulative Impact

No mortality is anticipated to result from the thermal plume since lethal temperatures will not be reached outside the discharge canal. Units 1 and 2 should result in cunner mortality only through entrainment and entrapment. A conservative estimate of the total number of adults potentially removed from the population per year is 1,310 adults per year. Based on the high relative abundance of cunner in this area (Table 4-2 and Figure 6-17), the potential loss of 1,310 adults per year is expected to have a negligible effect on this population.

6.12 RAINBOW SMELT (OSMERUS MORDAX)

The effect of the operation of Pilgrim Units 1 and 2 on the smelt population in the area is predicted from published life history information and plant monitoring data. The sources of impact to the population include entrainment of larvae and impingement of adults. The maximum temperature predicted in the immediate area of the discharge is less than 94°F during the summer. This temperature is near the upper maximum temperature tolerance presented in Appendix A for smelt. It is therefore assumed that adult smelt will be excluded from the immediate area of discharge. From the combination of the area of exclusion and the mobility of the adults, this source of impact is judged to be negligible and will not be quantified in the present analysis.

Marine populations of this species generally spawn upstream of the tidal influence and the eggs are adhesive. While there is a net downstream movement of larvae, McKenzie (1964) reports that larvae are carried back and forth under the influence of the tide. After a few days, the larvae become negatively phototactic which results in higher densities near the bottom during the day. It may be concluded from this strategy that larvae are retained in the brackish estuary and those which are washed out of the estuary have a lower probabibility of being recruited into the adult population.

Refer to Section 6.9 for a discussion of the effect of the Pilgrim Station on populations in the Plymouth-Duxbury Harbor. The analysis presented in Section 6.9 is for winter flounder; however, the effect on the larval smelt population would be of a similar nature, since both populations breed in the Plymouth-Duxbury area. The smelt breed in the rivers while the flounder breed closer to the mouth of the estuary; therefore, the predictions for winter flounder larvae entrainment will be over-estimates for smelt.

6.12.1 The Model

Presently, there is no published population dynamics life cycle model for smelt. A paper by McKenzie (1964) was used to obtain statistics for the development of a life table for use in the present analysis. While the statistics were gathered for the smelt population of the Miramichi River in New Brunswick, comparision with the work of Warfel, Frost and Jones (1943) in Great Bay, New Hampshire, and Rothschild (1961) in Dean Brook, Maine, suggest the values are applicable to other populations. It is therefore assumed that this life table is applicable to the population which could be affected by Pilgrim Station.

The life table for smelt is presented in Table 6-8. The survivorship for ages 2 through 5 and the estimates for fecundity were taken from Mckenzie (1964). The survivorship for age 1 was assumed to be the same as for larvae to age 1 and the survivorship for age 6 was assumed to be the same as age 5. The number of eggs produced by fish from ages 2 to 5 was calculated using the McKenzie (1964) estimates of fecundity. A function for egg survivorship was developed from McKenzie.

$$L = 89.91-0.00023\ (E)$$

where:

L is larval density per ft^2 of surface area, and
E is egg density per ft^2 of surface area.

From this life table, the mean length of a generation was calculated:

$$T = \frac{xlxMx}{lxMx} = \frac{32049.95}{9919.42} = 3.23 \text{ years,} \qquad (1)$$

where
x is age in years,
lx is the survivorship of age x, and
Mx is the number of eggs produced by a female of age x.

The estimate of fishing mortality was taken from the Miramichi smelt fishery since no other estimate was available. This

TABLE 6-8

LIFE TABLE FOR SMELT

Age	(lx) Survivorship	Fishing Mortality	(Mx) Fecundity	Sex Ratio	Weight (grams)
Eggs	0.024	0	0		
Larvae	0.043	0	0		
1	0.044	0.04	0		8
2	0.452	0.04	11,348	0.77	14
3	0.136	0.04	19,705	0.77	17
4	0.098	0.04	31,327	0.75	22
5	0.027	0	42,532	0.76	32
6	0.027		54,153	0.50	

fishery uses trap nets. McKenzie (1964) estimated a 4 percent annual harvest for ages 2 through 4. Therefore, a fishing mortality of 0.04 per year was used in the simulation.

An estimate of the density of breeding smelt in the Plymouth-Duxbury Harbor in the late fall was made from data collected by the Massachusetts Department of Marine Fisheries in 1971. Smelt were collected in a 30-foot shrimp trawl in 5-minute tows at 1 to 2 knots. The area swept by this trawl was estimated to be approximately 1,411 m^2. Smelt were most consistently collected during November when an average of 10.33 individuals (standard error of 2.84) were collected per trawl.

It was assumed that this trawl had an efficiency of 50 percent and, on the average, it sampled one half of the water column. It is also assumed that the adult smelt have a uniform distribution with depth. This yields an estimated density of breeding adults in the harbor of 0.0027 per ft^2 of surface area at mean low water.

The density of eggs in the Jones River, where the Massachusetts Department of Marine Fisheries collects smelt eggs, has been estimated between 800 to 1,600 per square inch during each period of collection. It was assumed for conservatism, that the average density of eggs was about 1,000 eggs per square foot over the area which spawning takes place.

The number of eggs produced each season (E) can be estimated:

$$E = X \cdot R \cdot T, \tag{2}$$

where

X is the standing crop of eggs per square foot,

R is the area of the river which eggs are deposited, and

T is the turnover rate for eggs.

The breeding adult population (A) which resides in the harbor during the fall is:

$$A = Y \cdot H, \tag{3}$$

where:

Y is the standing crop of adults per square foot, and

H is the area of the harbor.

The turnover rate for adults is assumed to be one. The relationship between the number of eggs (E) and adults (A) in the population is:

$$E = A \cdot F \cdot S, \tag{4}$$

where:

F is the fecundity, and

S is the sex ratio.

Substituting equation 3 into 4, and setting this equal to equation 1:

$$F \cdot Y \cdot H \cdot S = X \cdot R \cdot T. \tag{5}$$

Equation 5 can be solved for the turnover rate T:

$$T = \frac{H}{R} \cdot \frac{F \cdot Y \cdot S}{X} \tag{6}$$

Estimates of the adult density Y and the egg density have been made. The average fecundity from Table 6-8 is 14,770, the adult density is 2×10^{-3}, and the egg density is 10^3 per square foot. The turnover rate becomes:

$$T = \frac{H}{R} \cdot \frac{1.5 \times 10^4 \times 2 \times 10^{-3} \cdot .7}{10^3} = \frac{H}{R} \cdot 2.1 \times 10^{-2} \approx \frac{H}{R} 10^{-2}$$

The estimate of the number of eggs in the population becomes:

$$E = X \cdot R \cdot T = X \cdot R \cdot \frac{H}{R} \cdot 10^{-2} = X \cdot H \cdot 10^{-2} \tag{7}$$

The area of the harbor (H) has been estimated as 1.95×10^7 square meters at mean low water. Therefore, the number of eggs is estimated as:

$$E = X \cdot H \cdot 10^{-2} = 10^3 \cdot 1.95 \times 10^7 \cdot 10.764 \cdot 10^{-2} = 2 \times 10^9$$

The initial population structure for the simulation is presented in Table 6-9. The estimate of the number of larvae entrained results from an extrapolation from the densities of smelt entrained at Unit 1. Based on these densities and the combined flows of both units, an estimated 8.51×10^7 larvae would be entrained per year. It is conservatively assumed that this loss would have been recruited to the adult population.

The simulated population has 1.869×10^{10} larvae at equilibrium. The calculation of entrainment mortality is:

$$Me = -\ln\left(1 - \left(8.51 \times 10^7 / 1.869 \times 10^{10}\right)\right) = 0.00456 \tag{8}$$

The number of smelt impinged each year was estimated from the Unit 1 screen-washing data for 1973. The extrapolation for 2-unit operation assumes the fish are impinged in proportion to the

TABLE 6-9

INITIAL POPULATION STRUCTURE FOR SIMULATION

Age	Number
Egg	2.09898×10^{9}
larvae	5.0376×10^{7}
1	2.166×10^{6}
2	9.5310×10^{4}
3	4.3080×10^{4}
4	5.8589×10^{3}
5	5.7417×10^{2}
6	1.5503×10^{1}

flow. It is estimated that 5,313 smelt would be impinged per year. It is assumed that all these fish are of age 2.

The simulated population has 3.5361×10^7 age 2 fish at equilibrium. The calculation of impingement mortality is:

$$M = -\ln(1 - (4560/3.5361 \times 10^7)) = 0.000129. \qquad (9)$$

6.12.2 Cumulative Impact

The effect of this loss of young fish on the adult population was investigated by adding the mortality attributable to entrainment and impingement to the simulated population. The effect of the thermal plume was not considered in this analysis due to the negligible nature of the effect.

The population was resimulated, including the mortalities associated with power station operation. The population size and the yield to the fishery were depressed by 0.5 percent compared to the non-impacted population. The impacted population came to equilibrium as did the non-impacted population.

The simulation of the smelt population revealed a population which reached an equilibrium size of 8.57×10^8 fish from age 1 to 6. The yield to the fishery, assuming an annual mortality of 0.04, was calculated as 1.94×10^6 fish, or 29 metric tons per year.

6.13 ATLANTIC SILVERSIDE (MENIDIA MENIDIA)

The impact of operation of Pilgrim Units 1 and 2 on silversides is predicted from temperature tolerance data, entrainment data and screen-washing data. Published life history data on silverside was researched to obtain fecundity, sex ratio, and length of life information.

6.13.1 Results of Thermal Plume, Entrainment, and Impingement

Temperature tolerance information is presented in Appendix A, and the relationship between acclimation and tolerance temperatures is presented in Section 5.12. Based on these data, silversides can be anticipated to be excluded from about 11 acres in the immediate discharge area. It is expected that many of the fish will simply move to other areas to avoid the thermal plume, due to their motile behavior. The effect of this impact will not be quantified in the present analysis.

Larval silversides were collected on three dates in the entrainment studies during 1973. Integrating the density of larvae collected provides an estimate of 2.809×10^6 larvae entrained for 2-unit operation. The equivalent number of adults was estimated by assuming the fecundity is 300 eggs per female, and that 1 in 10 eggs hatch (Bayliff, 1950).

$$N = 2.809 \times 10^6 \times (2/300 \times 0.1) = 187,267 \text{ adults per year}$$

Assuming an adult silverside weighs about 10 grams, (Austin, et al., 1973), the loss of this many adults would be equivalent to a loss of 4,125 pounds per year.

The loss due to impingement has been estimated from data collected in the screen-washing program for Unit 1 in 1973. The predicted loss for both Units 1 and 2 is 8,070 fish per year. Assuming again these fish weigh 10 grams each, this results in a loss of 178 pounds per year.

The combined effect of entrainment and impingement is predicted to be 195,337 fish per year, or about 4,303 pounds per year. Since this species is not of commercial value in Massachusetts, no comparisons with commercial catch can be made. Anderson and Power (1950) reported that in 1946 in New York State 126,300 pounds of silversides were commercially caught. The availability of silversides may also be indexed by the number caught in seines. Bigelow and Schroeder (1953) reported that up to 3,500 were caught in a single seine haul from the southern side of the Gulf of St. Lawrence. Warfel and Merriman (1944) reported as many as 1,938 in a 30-foot seine which was fished for about 100 feet parallel to shore in water less than 4 feet deep.

6.13.2 Cumulative Impact

The effect of the thermal plume is expected to be minimal to silversides based on the abundant nature of the species and the area from which they could potentially be eliminated (11 acres). An estimated 187,929 and 8,070 adults could be lost from entrainment and impingement, respectively. These losses assume no compensatory mechanism in the population and are therefore an over-estimate of the impact to this species. Although there are no direct estimates of the population size in the area, the abundant nature of this species would suggest a minimal impact to the population from this additional source of mortality.

6.14 ALEWIFE (ALOSA PSEUDOHARENGUS)

The impact of the operation of Pilgrim Nuclear Power Station, Units 1 and 2, is predicted from published life history information and station operation data. The sources of possible impact from station operation include the thermal plume, entrainment of larvae, and mortality of adults on the traveling screens.

6.14.1 Results of Thermal Plume, Entrainment and Impingement

Based on the studies of de Sylva (1969) presented in Appendix A, and the predicted areas of various isotherms in Section 2, it is predicted that alewives will be excluded from about 3 acres in the immediate area of the discharge. The studies of Huntsman

(1946) indicate alewives are able to tolerate a temperature of 88.6°F, which is near the predicted summer maximum surface temperature at the discharge area.

From the above-mentioned information and the mobile nature of fish, it is anticipated that most alewives will avoid the thermal plume. Since this should not constitute a problem, it will not be quantitatively considered in the present analysis.

Calculation of entrainment impact was made by assuming the average fecundity is 229,000, the sex ratio is 1 to 1 (Kissil, 1974), alewives reproduce 3 times in their life (Marcy, 1969), and the survival of eggs is no less than 1 in 10 (Edsall, 1970). For further details on life history information, see Section 5.13.

The number of larvae predicted to be entrained with 2 units operating at the Pilgrim site was predicted from Unit 1 entrainment studies conducted in 1973. Integrating the densities collected over the entire year and extrapolating for 2 units, 4.7643×10^7 larvae would be entrained annually.

Extrapolation of larvae lost through entrainment to adults lost is made with the method outlined in Section 6.1. The estimated number of adults which could have resulted from entrainment losses is:

$$N = N.S = 4.7643 \times 10^7 \cdot 2/(3 \times 229{,}000 \times 0.1) = 1387 \text{ adults/year}$$

The losses due to impingement are predicted from data collected in the Unit 1 screen-washing program in 1973. Since the fish collected in this program are small, they are only identified as clupeids. As with other clupeids considered in this report, it is conservatively assumed that, all clupeids impinged are alewives. The predicted number impinged each year is 28,023.

The combined effects of impingement and entrainment should be less than 29,410 fish per year for 2-unit operation. This analysis assumes no compensatory mechanisms in the population which would be reduced by this number. The analysis also does not consider other species than alewives collected in the clupeid category in the screen-washing program.

To give some perspective to this number of fish, Kissil (1974) reported 184,151 and 140,203 (average, 162,177) alewives in Bride Lake, Connecticut, which has an area of 18.2 hectares. If the same breeding density were to occur in the areas near the Pilgrim station, this would be equivalent to removing spawning adults from 3.67 hectares, or 9.06 acres.

The weight of adult alewives can be roughly calculated at about one-half pound. Bigelow and Schroeder (1953) reported that in

Cape Cod Bay and the Merrimack River in 1896, 526,500 fish were caught, which had a total weight of 293,671 pounds. This is about 0.56 pound per fish. Using this average weight, the 29,410 fish would weigh 16,470 pounds. This would have been 6 percent of this catch. Unfortunately, no recent catch statistics for the local alewife fishery are known to exist.

6.14.2 Cumulative Impact

The effect of the thermal plume is expected to be of a minimal nature to the population. With no compensation in the population, 1387 and 28,023 adults could be lost from the population annually due to entrainment and impingement, respectively. The effect of this additional mortality is expected to be of a minimal nature to the population.

6.15 REFERENCES - SECTION 6

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SECTION 7

SUMMARY OF ENVIRONMENTAL IMPACTS AND CONCLUSIONS

7.1 INTRODUCTION

The impact to the marine environment as a result of the operation of Pilgrim Station, Units 1 and 2, has been predicted by investigating 13 representative important species. These selected species are distributed at all trophic levels from primary producers to highest level carnivore. Species in all habitats which might be affected by station operation were considered. Species selection was based on dominance, commercial importance, sensitivity and potential of incurring impact.

The impact to the fish populations in the area is analyzed by a population simulation where sufficient population dynamics data is available for parameterization. The effect of station operation is predicted by comparing simulation results with and without the effects of power station operation. For those species on which no population simulation was performed, the number of adults which could have resulted from station-related loss was predicted. This prediction was compared to some index of population size.

The predictions of impact represent very conservative predictions because the following criteria were generally used:

(1) Maximum station flow rates and temperatures are used to estimate numbers of organisms affected.

(2) The nearfield density of planktonic stages of representative species is used to predict potential entrainment of organisms at Units 1 and 2 even though they may not have been observed in the entrainment collections at Unit 1.

(3) One hundred percent mortality is assumed in calculations of most mortalities of entrained organisms, even though it is likely that mortality estimates would be lower under normal operating conditions during certain times of the year.

(4) Conservative estimates of biological parameters such as fecundity and survivorship of particular species are made when literature values are not available.

(5) In many cases, estimates of impact did not include compensation (density dependence) within populations.

7.2 SUMMARY OF INDIVIDUAL SPECIES IMPACT

The primary impact of Units 1 and 2 will have a minimal effect on Irish moss in the immediate vicinity of the thermal plume. The density of Irish moss may be reduced within 2.1 acres in the area of the thermal plume. However, growth outside of this area is expected to increase as a result of the slightly elevated water temperature. Entrainment of spores may occur, but mortality on passage through the station is expected to be low. No station-related impact is expected to occur due to entrapment.

No station-related impact is expected to occur to rockweed as a result of entrainment or entrapment. some mortality may occur, attributable to the thermal plume, but it is expected to be negligible.

No station-related impact is expected to occur to A. millsi as a result of entrainment or entrapment. Negligible impact is expected from the thermal plume as A. millsi will not be exposed to lethal temperatures.

The impact of the thermal plume on lobster should be minimal since lobsters are relatively mobile and can avoid areas of high temperature. Entrapment of lobster should not occur because intake velocities are low. Entrainment of lobster larvae could occur although it was not observed at Unit 1. Conservative estimates of adult lobster potentially lost through larval entrainment represents less than 0.6 percent of the annual lobster harvest of Plymouth County.

No station-related effect is expected to occur to the mussel as a result of entrapment. The potential impact of Units 1 and 2 on the common mussel will result from the thermal plume and entrainment. Some mortality will occur within 2.1 acres of the discharge area during the summer months. Utilizing conservative estimates of mortality and number of larvae potentially entrained, it was predicted that the number of adults lost would approximate the density of mussels from an area of 24 acres. However, considering that mussel densities both pre and postoperationally at Unit 1 are similar, this indicates that an overestimate of potential effects was made. Because of the extremely large numbers of mussels in the area of Cape Cod Bay, it is believed that any effect potentially attributable to the operation of Units 1 and 2 would be negligible.

The potential impact of Units 1 and 2 on the periwinkle will be similar to that of the mussel. Some mortality will occur within 2.1 acres of the discharge area during ths summer months. Additional entrainment of larvae could result in the loss of L. littorea from an area as large as 23 acres. However, as with the mussel, effects attributable to Unit 1 were not obtained post-operationally, and the large abundance and distributions in Cape Cod Bay would indicate that potential effects would be negligible.

The effect of the thermal plume on Atlantic menhaden has been observed to result in mortality due to gas-bubble disease. This source of mortality, plus those associated with entrainment and entrapment, were predicted by a population simulation. The result of all 3 sources of mortality is a reduction of 0.00485 percent below the non-impacted population. Since the effect of the station on the North Atlantic menhaden population is expected to be negligible, the population should not be adversely affected.

The effect of the thermal plume on winter flounder is expected to be minor due to the benthic nature of the species. The effect of entrainment and impingement were investigated by a simulation of the local population. The conservative prediction is a 5.9 percent reduction in the local winter flounder population in 40 years of station operation, assuming very little compensation within the population. If the population is allowed to recover for 40 years after station operation, it recovers within 2.3 percent of its original population size. Fluctuations in the size of the population predicted as a result of station operation should not adversely affect the balanced indigenous flounder population.

Pollock may experience some mortality within the 20° isotherm (less than one acre). Pollock have been observed feeding at the edge of the Unit 1 plume. Pollock may suffer some loss due to entrainment and entrapment with a predicted 189 to 505 fish loss from the population due to these events. This potential loss is about 2.2×10^{-4} percent of the Massachusetts landings for this species. Mortalities of such magnitude as a result of station operation would not adversely affect the balanced indigenous pollock population.

Cunner feed on small fish and crustaceans. They move offshore in winter and spring and move close to the station in summer and fall. Since cunner can avoid lethal temperatures, no effect is expected due to temperature. Cunner eggs and larvae are entrainable and conservative estimates yield a loss of 274 adults per year due to entrainment. Cunner are also impinged, so impingement can account for the loss of 1,036 cunner per year. Thus, 1,310 adults a year could be potentially lost. Considering the ubiquitous nature of this species in Cape Cod Bay, losses of this magnitude should not adversely affect the balanced indigenous population.

The effects of the thermal plume may result in the exclusion of smelt from the area immediately adjacent to the discharge during summer periods. The effects of entrainment and impingement were simulated on the locally spawning smelt population. the population level is predicted to be depressed 0.5 percent over the non-impacted population. This effect is expected to be of a negligible nature to the population and therefore should not adversely affect the balanced indigenous smelt population.

Silversides are expected to be excluded from 11 acres in the area of the discharge during summer. Entrainment is conservatively predicted to result in the loss of 187,267 fish from the population while impingement could result in the loss of 8,070 fish. The combined losses are believed to constitute a small fraction of the population, probably less than the year-to-year variation in population size.

The effects of the thermal plume on the alewife is expected to be the exclusion of adults from 3 acres in the immediate area of the discharge during summer months. The effects of entrainment and impingement are conservatively predicted to result in the loss of 29,410 adults from the population. Based on the abundance and life history strategy of this species, this loss is expected to have a minor effect on the population.

7.3 CONCLUSIONS

The effect of the operation of Pilgrim Station on the marine ecosystem has been addressed through predicted impacts to selected species populations and the general characteristics of the ecosystem. The effects on populations which were studied appear to represent a small fraction of the species population. It is believed that these losses would be less than the observed year-to-year variation in the total standing crop.

The general nature of the marine ecosystem in the Cape Cod Bay area can be inferred from the studies at the site. The trophic structure is characterized by diversity at all levels with many interactions between species. There also appears to be a high degree of redundancy in functional groups. Characteristics like the ones mentioned suggest the ecosystem should be able to withstand impacts such as those predicted from Pilgrim station with a minimal change in structure and function. It would also suggest that the risk of irreversible damage to the ecosystem should be minimal.

This assessment of environmental impact, based on an analysis of impact on 13 representative species indicates that Pilgrim Station Units 1 and 2 with the proposed cooling system will not adversely affect the "balanced indigenous population of fish, shellfish and wildlife."

J.O.No. 12577

Include references in Bibliography

Note errors 973-2937

APPENDIX A
HYDROTHERMAL DATA
PILGRIM NUCLEAR POWER STATION - UNITS 1 AND 2
BOSTON EDISON COMPANY

Kathy Cohain 973-2940

TEMPERATURE DATA SHEET

Species: CHONDRUS CRISPUS - IRISH MOSS

I. Mortality

Lethal Temperature (F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
95	Carpospore	6 min	70°F	Prince (1971)
80	Tetraspore		53°F	
81.5 100%		4-10 days		

II. Growth

Optimum Temperature(F)	Range	Life Stage	Data Source
68	28-68		Mathieson & Prince (1973)

III. Reproduction:

	Optimum	Range	Month(s)	Data Source
Migration				
Spawning				
Incubation/ Hatch	70	40-70		Prince (1971)

TEMPERATURE DATA SHEET

Species: ASCOPHYLLUM NODOSUM - ROCKWEED

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
97	Thallus			Fritsch (1945)

TEMPERATURE DATA SHEET

Species: ACANTHOHAUSTORIUS MILLSI - AMPHIPOD

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
97		48 hr	77	Sameoto(1969)

TEMPERATURE DATA SHEET

Species: HOMARUS AMERICANUS - AMERICAN LOBSTER

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
77	adult		41	McLeese (1956)
83	adult		59	McLeese (1956)
87	adult		77	McLeese (1956)
84.5	larvae	24 hrs.		Battelle Memorial Inst. (1974)

II. Growth

Optimum Temperature	Range	Life Stage	Data Source
	68-71	larvae	Shasty pers. comm.
68		adult	Shasty pers. comm.
	28-74	juvenile	Shasty pers. comm.
	71-75		Hughes et.al.(1972)

III. Reproduction:	Optimum	Range	Month(s)	Data Source
Incubation/Hatch		54-59	June-August	Sherman & Lewis (1967)
	68	59-69		Hughes & Mathieson(1962)

IV. Preferred	Life Stage	Acclimation Temperature	Data Source
28-75			McLeese & Wilder (1964)

TEMPERATURE DATA SHEET

Species: MYTILUS EDULIS - BLUE MUSSEL

I. Mortality

Lethal Temperature(°F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
80-105				Kennedy & Minusky (1971)
105.4	adult		59 ?	Henderson (1929)
86	larvae	16-17 days		Brenko & Calabrese (1969)

II. Growth

	Optimum Temperature	Range	Life Stage	Data Source
		41-68		Allen (1955)

III. Reproduction:	Optimum	Range	Month(s)	Data Source
Migration	80			Hutchinson(1947)
Spawning	67			Engle & Loosanoff(1944)
Incubation/Hatch		54.5-71.6		Engle & Loosanoff(1944)
Settling		54.5-66.2	June-July	Engle & Loosanoff(1944)

TEMPERATURE DATA SHEET

Species: LITTORINA LITTOREA - COMMON PERIWINKLE

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
87 TLm	adult	24 hr	52	Newell et al(1970)
84 TLm		96 hr	52	Newell et al(1970)
90 TLm		24 hr	61	Newell et al(1970)
87 TLm		96 hr	61	Newell et al(1970)
104 TLm				Fraenkel (1960)

TEMPERATURE DATA SHEET

Species: BREVOORTIA TYRRANUS - MENHADEN

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
85 CTM	adult	24 hr	59	Hettler(1971)
38.2	larvae		44.6	Kinne(1970) ✓
39.4	larvae		50	Kinne(1970) ✓
40.0	larvae		54.5	Kinne(1970) ✓
41.4	larvae		59.0	Kinne(1970) ✓
84.0	larvae		50.0	Kinne(1970) ✓
93.2-95.0	juvenile		80.6	Clark(1969)
84	larvae		50	Hoss et al(1973)
85	juvenile		59	Hoss et al(1973)
93.2	juvenile	132 hr	69.8	Lewis & Hettler
95	juvenile		75.2	Lewis & Hettler
96	juvenile		84.2	Lewis & Hettler
95	juvenile		84.2	Lewis & Hettler
32	larvae		44.6	Lewis & Hettler
91.8				Gift(1971)
86	adult	24 hr		Battelle-BECO

Lewis (196[illegible])

IV.	Preferred	Life Stage	Acclimation Temperature	Data Source
	51-69	adult		Briggs(1973) ✓?
	70	adult	79	Meldrin & Gift(1971)

TEMPERATURE DATA SHEET

Species: PSEUDOPLEURONOCTES AMERICANUS - WINTER FLOUNDER

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
90.3	adult		77	Hoff & Westman(1966)
84.7	adult		82	Hoff & Westman(1966)
89.4	adult		72	Hoff & Westman(1966)
89.6	adult		44.8	Hoff & Westman(1966)
33	adult		44.8	Hoff & Westman(1966)
34	adult		70.2	Hoff & Westman(1966)
41	adult		82.0	Hoff & Westman(1966)
84	larvae		50-59	Hoff & Westman(1966)
Upper Threshold				
68-71.6	larvae	5-13 min	44.6	Coutant(1974)
71-74.7		5-13 min	57.2	Coutant(1974)
77-80.6		5-13 min	69.8	Coutant(1974)
85	adult		82.4	Huntsman & Sparks(~~1966~~) 1924
87-91	adult		69	Gift & Westman(1971

Not right

II. Growth

Optimum Temperature(F)	Range	Life Stage	Data Source
	52-60	adult	Frame(1973)

III. Reproduction:	Optimum	Range	Month(s)	Data Source
Migration		28-70		Bigelow & Schroeder(1953)
Spawning	38-43.7	32-44	Jan-May	Conn Fishes
Incubation/Hatch	38	32-53.6	15-18 days	Conn Fishes

Thompson et al.

IV. Preferred	Life Stage	Acclimation Temperature	Data Source
51-80	adult		Briggs(1973)
67	adult	57	Meldrin & Gift(1971)

TEMPERATURE DATA SHEET

Species: POLLACHIUS VIRENS - POLLOCK

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
82.4				deSylva(1969)

III. Reproduction:	Optimum	Range	Month(s)	Data Source
Migration				
Spawning	38	36-44		Bigelow & Schroeder(1953)
Incubation/Hatch		43-49	Dec-March	Bigelow & Schroeder(1953)

IV. Preferred	Life Stage	Acclimation Temperature	Data Source
51-56	adult		Briggs(1973)

TEMPERATURE DATA SHEET

Species: TAUTOGOLABRUS ADSPERSUS - CUNNER

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
84.2-86	adult		64.4-71.6	Kinne(1970) ✓
77-78.8	adult		33.8-37.4	Kinne(1970) ✓
41	adult		64.4-71.6	Kinne(1970) ✓
<31	adult		33.8-37.4	Kinne(1970) ✓
84.2	adult			deSylva(1969)

Haugaard & Irving (1943)

III. Reproduction:	Optimum	Range	Month(s)	Data Source
Migration				
Spawning		55-72	May-July	Bigelow & Schroeder(1953)
Incubation/Hatch		55-65		

IV. Preferred	Life Stage	Data Source
56-79	adult	Briggs(1973)

TEMPERATURE DATA SHEET

Species: OSMERUS MORDAX - RAINBOW SMELT

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
70.7-83.3	adult		50-59	deSylva(1969)

TEMPERATURE DATA SHEET

Species: MENIDIA MENIDIA - SILVERSIDE

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
73.4-77	larvae	5-13 min	57.2	Coutant(1974)
83.1-86.7	larvae	5-13 min	69.8	Coutant(1974)
90.5	adult		82.4	Hoff & Westman(1966)
86.8	adult		69.8	Hoff & Westman(1966)
77	adult		57.2	Hoff & Westman(1966)
71.6	adult		44.6	Hoff & Westman(1966)
47.6	adult		82.4	Hoff & Westman(1966)
39.8	adult		69.8	Hoff & Westman(1966)
35.6	adult		57.2	Hoff & Westman(1966)
34.7	adult		44.6	Hoff & Westman(1966)
98.4	adult		72.5	Gift & Westman(1971)
98.9	adult		77.0	Gift & Westman(1971)
88	adult	3 hr		Battelle-BECO

✓ ✓ Not Bibliography

IV.

Preferred	Life Stage	Acclimation Temperature	Data Source
51-80	adult		Briggs(1973)
59	adult	43	Meldrim & Gift(1971)
75	adult	70	Meldrim & Gift(1971)

✓ can't find

TEMPERATURE DATA SHEET

Species: ALOSA PSEUDOHARENGUS - ALEWIFE

I. Mortality

Lethal Temperature(F)	Life Stage	Exposure Time	Acclimation Temperature	Data Source
73.4	adult	90 hr	59	deSylva(1969)
<44.6	adult	72 hr	62.6	Stanley & Colby
88.6	adult			Huntsman(1946)

III. Reproduction:	Optimum Temperature	Range	Month(s)	Data Source
Migration				
Spawning				
Incubation/Hatch	60			Edsall(1970)

IV. Preferred	Life Stage	Acclimation Temperature	Data Source
71	adult	70	Meldrim & Gift(1971)
68	adult	64	

APPENDIX B

LIST OF MARINE ECOLOGICAL AND HYDRAULIC STUDIES ASSOCIATED WITH PILGRIM STATION

APPENDIX B

LIST OF MARINE ECOLOGICAL AND HYDRAULIC STUDIES ASSOCIATED WITH PILGRIM STATION

Project[1]	Contractor-Consultant-Agency	Study Period[2]
I Marine Ecology		
1. Marine Ecology Surveys (fin fish, lobster, ~~plankton &~~ Irish moss) sportfishing, [illegible]	Mass. Division of Marine Fisheries.	1968-1977
2. Benthic Studies	a. Raytheon Marine Lab.	1969-1970
	b. Clapp Laboratory, Batelle Memorial Inst.	1971-1974
	c. Dr. A. Michael (MBL & Yale U.), Dr. R. Wilce (U. Mass.).	1974-1977
3. Ichthyoplankton Survey of Cape Cod Bay	Marine Research, Inc.	1974-1976
4. Biological Entrainment Studies	M.R.I.	1973-~~1975~~ 1977
Winter Flounder Larvae Studies	MRI	1976-1977
Lobster Larvae Studies		
5. Water Quality Measurements	Dr. D. Carritt (U. Mass.).	1973
6. Temperature and Chlorine Tolerance Measurements	CLAPP Laboratory, Batelle Memorial Institute.	1972-1974
7. Life History Study of <u>Chondrus</u> <u>crispus</u>	Cornell Univ. (J. Prince)	1969-1971
8. Menhaden Gas-Bubble Tolerance Studies	New England Aquarium	1974-1976
9. Irish Moss Quality Surveys	Woods Hole Oceanographic Inst. (Dr. J.H. Ryther).	1974-~~1975~~ 1976
10. Pilgrim Unit 1 Intake Monitoring	Mass. ~~DMF/BECO~~ [illegible]	1973-~~1975~~ 1977
11. Study of Alternative Solutions to Menhaden Attraction Problem	Yankee Atomic Service Company/EGG	1975-1977
II Thermal Plume and Oceanographic Studies		
1. Model Development and Predictions of Thermal Plume Behavior.	a. MIT (Dr. D.R. Harleman)	1972-1975
	b. Dr. D.W. Pritchard (Johns Hopkins Univ.)	1970-1974
	c. EGG, Environmental Equipment Division	1974-1975
2. Winter Flounder Larvae Model Development	MIT (Dr. B.F. [illegible])	1975-1977

APPENDIX B (CONT'D)

Project	Contractor-Consultant-Agency	Study Period
2. Field Measurements of Unit 1 Thermal Plume		
2a. Boat Surveys	a. MIT	1972-1973
	b. VAST, Inc.	Dec. 1972
	c. EGG	Oct. 1974
2b. Aerial Infrared Surveys	a. Coastal Research Corp.	Dec. 1974
	b. Aero-Marine Surveys, Inc.	Aug. 1973
	c. Environmental Protection Agency.	Sept. 1974
		Oct. 1975
2c. Dye Release Studies	1. Westinghouse-Zone Research	1971
	2. Vast, Inc.	Dec. 1972
	3. EGG	Oct. 1974
3. Oceanographic Measurements (ambient temperature and currents)	a. MDMF	1968-1977
	b. Endico-Mr. R. O'Hagan	1973-1975
	c. EGG	1974-1975
4. Analyses Related to Physical Oceanography and Thermal Plume (in addition to above)	a. Dames & Moore	1967
	b. Dr. D.W. Pritchard (Johns Hopkins Univ.)	1970-1974
	c. Stone & Webster Environmental Engineering Division	1974
	d. Yankee Atomic Service Co.	1975
III Alternate Cooling System Studies	Bechtel Corp.	1971-1975
IV Impact Analysis for Selected Marine Species	Stone & Webster Environmental Engineering Division	1975

(1) Refer to Pilgrim Unit 1 and 2 ER and Pilgrim Station Semi-Annual Marine Ecological Studies for scope description and Individual study results.

(2) Inclusive periods including extensions into the future wherever contractual arrangements have been made.

SUMMARY OF CALCULATED MAXIMUM EFFECTS PER YEAR OF
PILGRIM NUCLEAR POWER STATION
ON SELECTED SPECIES
BASED ON 316 DEMONSTATION

(See Referenced Section for Detailed Discussion)

Species	Reference Section	Entrainment: Spores/Eggs	Entrainment: Larvae	Entrainment: Projected Adult Loss	Entrapment	Thermal Plume	Total Projected Adult Loss
Irish moss	6.2	*	0	0	0	2.1 acres	2.1 acres
Rockweed	6.3	*	0	0	0	*	*
Amphipod	6.4	0	0	0	0	*	*
American lobster	6.5	0	2.04×10^5	4,080	0	2.1 acres	0.6%
Blue mussel	6.6	0	6.17×10^{11}	2.31×10^9 (24 acres)*	0	2.1 acres	26 acres
Common periwinkle	6.7	2.72×10^{11}	1.56×10^{11}	1.83×10^8 (23 acres)*	0	2.1 acres	25 acres
Atlantic menhaden	6.8	0	1.53×10^8	18,567 (2.75×10^{-3}%)	25,759 (7.3×10^{-3}%)	104,073 (1.56×10^{-3}%)	4.85×10^{-3}%
Winter flounder	6.9	0	*	0.65%*	5.81%*	*	5.89%
Pollock	6.10	*	3.6×10^6	.316	189	Less than 1 acre	505 (2.2×10^{-4}%)
Cunner	6.11	3.46×10^6	2.01×10^4	274	1,036	*	1,310
Rainbow smelt	6.12	0	8.51×10^7	*	4,560	*	0.5%
Atlantic silverside	6.13	0	2.81×10^6	187,267	8,070	*	195,337
Alewife	6.14	0	4.76×10^7	1,387	28,023	*	Less than 29,410

*See reference section for discussion of impact.