**Evaluation of Millstone Nuclear
Power Plant, Environmental
Impact Prediction, Based on
Monitoring Programs**

by
K. L. Gore
J. M. Thomas
L. D. Kannberg
D. G. Watson

February 1977

Prepared for the U.S. Nuclear
Regulatory Commission

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**Battelle
Pacific Northwest Laboratories
Richland, Washington 99352**

PREFACE

In order to evaluate environmental programs conducted in conjunction with constructing and operating nuclear power plants, three plants were selected, in which we assisted the Nuclear Regulatory Commission in preparing the Environmental Impact Statements. The three plants selected, Monticello, Haddam Neck, and Millstone, represent those which we believe had the best environmental programs. Our choice was based, in large part, on monitoring programs covering the longest time span. Thus, while the state-of-the-art of power plant monitoring has improved since the 1960s to a point where these environmental programs may not appear to be "up-to-date," they were among the best of their period. We urge the reader to keep this in mind when reviewing this document.

ACKNOWLEDGMENTS

We wish to acknowledge the many people who gave of their time and effort and enabled us to produce this report.

Special thanks go to Dr. Robert Hillman of Clapp Laboratories who gathered much of the raw data that was not available on computer. In addition, special thanks are acknowledged to Ms. Theodora Bugsch of Clapp Laboratories and Ms. Claire Mathews of Battelle-Columbus who provided us with the computer coding for the available data.

With the help of several people at Northeast Utilities, especially Dr. William Renfro and Mr. Paul Jacobson, the time necessary for us to assess the data and write this report was shortened.

Our thanks go to Ms. Judy Helbling of PNL, who assisted with the editing and publishing of this report.

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I. INTRODUCTION

EVALUATION OF MILLSTONE NUCLEAR POWER PLANT,
ENVIRONMENTAL IMPACT PREDICTION, BASED ON MONITORING PROGRAMS

I. INTRODUCTION

This is the third report of a series that quantitatively evaluates the nonradiological monitoring programs at three nuclear power plants. The results from our evaluation of Monticello and Haddam Neck Nuclear Power Plants were previously reported (Gore et. al., 1976a and 1976b). This report represents our analysis of Millstone Nuclear Power Plant.

The objectives of this study are: 1) to evaluate quantitatively the hydrological and ecological monitoring programs as to their effectiveness in determining if predicted Environmental Statement (ES) or unexpected impacts occurred due to power plant operations; 2) to determine if the Environmental Technical Specifications (Tech Specs) adequately address the potential impacts predicted in the FES or any other potential impact the Tech Specs require; and 3) to determine if the sampling design of the monitoring program was sufficiently sensitive to differentiate between natural variation and power plant-induced effects.

To accomplish these goals, both operational as well as preoperational monitoring programs were analyzed to produce long-term (5 yr or longer) data sets, where possible. In order to determine the effectiveness of these monitoring programs, the appropriate data sets have to be analyzed by the appropriate statistical analysis. Thus, both open literature and current statistical analysis being developed at Pacific Northwest Laboratories (PNL) were employed in data analysis.

A final Summary Report is being prepared which summarizes the results from the first three reports (Monticello, Haddam Neck and Millstone), presents our conclusions as to their effectiveness in measuring environmental impacts, and presents our recommendations for possible improvement of nuclear power plant monitoring (hydrological and ecological).

II. PLANT SITE AND HISTORY

II. PLANT SITE AND HISTORY

Millstone Nuclear Power Plant is located in Waterford, Connecticut, on Millstone Point, a peninsula jetting southward into Long Island Sound. Niantic Bay is located west of the plant site. New London is about 5.2 km to the east with Hartford about 64 km northwest and Brookhaven 29 km southwest (Figure 1). The plant occupies about 200 hectares of land. Metropolitan areas of Connecticut, Rhode Island and New York are within 80 km. The surrounding area consists of residential areas, institutional and governmental property, state parks and agricultural areas.

The mean tidal range of the Connecticut River at the plant site is about 0.8 m with a corresponding flow of $3468 \text{ m}^3/\text{sec}$. Salinities vary seasonally and range from 26 to 32 ppt. The salt water intrusion comes from the Atlantic Ocean via Block Island Sound and most of the fresh water enters from Niantic River and Bay. Diatoms are the principal phytoplankton group. Zooplankton are typical of Atlantic Coast estuaries with Acartia spp. and ctenophores the seasonally abundant forms. Benthic communities are composed of barnacles, snails and mussels. The American lobster is of commercial and sport importance with scallops, clams and crabs also supporting local fisheries. Striped bass, bluefish, winter flounder, weakfish, sculp, and sea bass are important sport fish. The commercially important Atlantic menhaden is common to the plant area in late summer and fall.

On 10 November 1965, application was made to the former Atomic Energy Commission (now Nuclear Regulatory Commission) for all necessary permits and licenses to construct and operate a single unit nuclear generating facility by the Millstone Point Company. A construction permit was issued on 19 May 1966. In March 1970, a notice of intent to issue a provisional operating license for Unit 1 was announced by the AEC. This permit was actually issued on 7 October 1970. However, on 10 June 1970, the applicant submitted an environmental report for the construction of Unit 2. By 22 November 1971, the applicant was still operating under a provisional permit and not until 1 August 1975 did Unit 1 receive its full operating license. Since December 1970, the plant has been averaging about 70% of full power loads except for refueling shutdowns (Figure 2).

FIGURE 1. Millstone General Site Area to Within 80 km

FIGURE 2. Gross Monthly Power Output (1971-1974) at Millstone Nuclear Power Station

III. PLANT DESIGN AND CHARACTERISTICS

III. PLANT DESIGN AND CHARACTERISTICS

Millstone Unit 1 is a single-cycle, forced circulation, boiling water reactor operated by the Millstone Point Company, a subsidiary of Northeast Utilities. The reactor is capable of producing 2011 MW_t and 652 MW_e power. The plant withdraws about 27 m³/sec (935 cfs) of water from Niantic Bay and discharges about the same volume of water into Long Island Sound via a quarry. The intake structure is shielded by a curtain wall to prevent warm surface water and their organisms from entering the intake. Bar screens and vertical traveling screens (9.5 mm mesh) prevent debris and larger organisms from entering the cooling system. Approach velocities to the traveling screens vary between 15 to 28 cm/sec depending on tidal stage. Designed cooling water temperatures rise (AT) across the condensers is 12.8°C. After water passes through the condensers, it is discharged into Millstone quarry (volume = 1.0 x 10⁶ m³). From the quarry, the water travels into a 18 m by 76 m discharge canal before entering Long Island Sound by Twotree Island Channel. The discharge velocity varies between 0.14 - 0.18 m/sec depending on tidal stage. A barrier has been installed in the discharge canal to prevent fish from entering the quarry.

IV. SUMMARY OF THERMAL MONITORING PROGRAMS

IV. SUMMARY OF THERMAL MONITORING PROGRAMS

NONECOLOGICAL

This discussion of methods and program design is incorporated into the Results section on Nonecological Thermal Monitoring.

ECOLOGICAL

Most of the ecological sampling programs at Millstone measured salinity, dissolved oxygen and temperature data along with the biological collection of organisms (see Tables 1-3). These programs during the course of the study period either terminated, changed direction or remained the same with the majority following the former two criteria. Thus, no program produced comparable preoperational and operational data sets and few actual temperatures were reported in the reports we were able to obtain for analyses.

Few of the ecological programs did report on temperatures taken with the collection of organisms. These programs are discussed in more detail in the results section of this report.

V. SUMMARY OF ECOLOGICAL MONITORING PROGRAMS

V. SUMMARY OF ECOLOGICAL MONITORING PROGRAMS

Millstone's ecological monitoring programs consist of about 2-1/2 yr of preoperational data and 4-1/2 yr of operational data. Approximately twenty individual studies have been conducted on different species, communities, populations and/or physical-chemical parameters in association with the ecological programs. We were able to obtain data through 1974, thus our analyses are limited for the data between 1968-1974.

Monitoring of the aquatic environment began in 1968 and, for the most part, is still continuing. Between 1970 and 1973, six ecological studies out of more than twenty were terminated. These programs (Table 1) had collected data for 2 to 5 yr and were terminated for one of the following reasons: 1) produced only qualitative data, 2) lacked consistency in the results they produced, and 3) results were difficult to interpret due to the qualitative nature of the program. However, most of these studies were replaced by improved, quantifiable monitoring programs.

There are approximately fifteen marine ecology programs presently being conducted at Millstone. Table 2 summarizes these studies in terms of sampling locations, frequency, dates, methods and analyses performed. These include studies on boring and fouling organisms, benthic macroinvertebrates and fish studies. Some of these studies have been in existence on a long-term basis. For example, the boring and fouling organisms program began in June 1968 and continued beyond 1974. Other studies, such as the lobster population study, have only been in existence since July 1973.

Table 3 summarizes the entrainment, impingement and other related studies in the same manner as the previous two tables. The entrainment program investigated phytoplankton, zooplankton, ichthyoplankton and lobster larvae effects. Some of the individual studies were short, but intense, while others were long-term. For example, special studies were conducted to determine the effect of chlorine on phytoplankton productivity (6 month duration) whereas study of the effect of ichthyoplankton passage has been

TABLE 1. Summary of Terminated Ecological Monitoring Program at Millstone Nuclear Power Station

PROGRAM	COLLECTION DATES	COLLECTION METHOD	SAMPLING FREQUENCY	STATION LOCATION AND NUMBER	ANALYSIS PERFORMED	REMARKS
PLANKTON	MAY 1969 - SEP 1972	ZOOPLANKTON CLARK-BUMPUS (NO. 20 AND NO. 6 MESH NETS) PHYTOPLANKTON SURFACE AND 15 m DEPTH WITH VAN DORN BOTTLE	FEB, MAY, AUG, NOV	ONE STATION-IN LONG ISLAND SOUND JUST OUTSIDE OF QUARRY. 3 HOUR OR 4.8 km CLARK-BUMPUS TOW. VAN DORN BOTTLE COLLECTION AT APPROXIMATE SAME LOCATION	PACK-CELL VOLUME DETERMINATION (MAY 1969 - MAY 1970) JUN 1970 - SEP 1972. (SPECIES ENUMERATION). CHLOROPHYLL A FOR VAN DORN SAMPLE. SALINITY AND D. O. WITH EACH TOW	TERMINATED BECAUSE IN-ADEQUATE TO COMPLEMENT ENTRAINMENT STUDIES
LOBSTER SURVEY	JUL 1968 - MAR 1973	VISUAL OBSERVATION BY SCUBA DIVERS FOR ONE 61m TRANSECT	MAY, JUL, SEP AND ONCE DURING WINTER	TWO STATIONS, ONE JUST OFF QUARRY AT 9.1m DEPTH AND SECOND OFF SEASIDE POINT (ESTABLISHED IN JUL 1970)	COUNTS OF ALL PLANTS AND ANIMALS, ESPECIALLY LOBSTERS AND SOME FISH	REPLACED BY A MORE QUANTITATIVE BENTHIC AND LOBSTER TAGGING PROGRAM
LOBSTER POT SURVEY	FEB 1969 - MAY 1973	COMMERCIAL CATCH RECORDS AND OWN POT DATA	FEB, MAY, JUL. SEP. POTS SET FOR 1 WEEK DURING EACH QUARTER	TWO STATIONS - FOX ISLAND AND SEASIDE POINT. 6 POTS / STATION	TOTAL NUMBER AND TOTAL LENGTH	PROGRAM REPLACED BY A MORE INTENSIVE LOBSTER TAGGING STUDY
OYSTER SEED GROWTH	AUG 1968 - FEB 1970	OYSTER TRAY	MAY, JUL, SEP AND ONCE DURING WINTER	FOUR STATIONS - WHITE POINT, FOX ISLAND, BLACK POINT (MOVED TO GIANTS NECK IN MAY 1969) AND JUST OUTSIDE OF QUARRY (MOVED TO INSIDE QUARRY IN DEC 1969)	MAXIMUM LENGTH AND CONDITION INDEX (DRY WEIGHT MEAT DIVIDED BY WEIGHT WET)	TERMINATED DUE TO TOO MANY UNCONTROLLABLE VARIABLES
BARNACLES	MAY 1969 - FEB 1973	30m TRANSECTS WITH 50 x 50cm QUADRANTS ALONG ROCKY SHORE-LINE AT 1 m ABOVE MEAN LOW WATER	FEB, MAY, JUL, SEP AND DEC	FIVE STATIONS - WHITE POINT, FOX ISLAND (SOUTH AND NORTH) BAY POINT, AND GIANTS NECK (CONTROL)	BASE DIAMETER MEASUREMENT OF 1 ADULT AND 1 JUVENILE WITHIN EACH 5 x 5 cm GRID	TERMINATED DUE TO LACK OF CONSISTENT DATA AND REPLACED BY A MORE QUANTITATIVE INTERTIDAL STUDY
INTERTIDAL SAND INFAUNA	MAY 1969 - MAY 1973	CORES 12.7 cm DIAMETER x 5 cm DEEP FOR MACROFAUNA. 3.5 cm DIAMETER x 1 cm DEEP FOR MEIOFAUNA	FEB, MAY, JUL, SEP AND DEC	TWO STATIONS - JORDAN COVE AND EASTERN SHORE OF GIANTS NECK (CONTROL)	ENUMERATION, IDENTIFICATION AND SOME BIOMASS ESTIMATES. SAND GRAIN SIZE DISTRIBUTION	REPLACED BY A MORE EXTENSIVE AND QUANTITATIVE BENTHIC PROGRAM

TABLE 2. Summary of Continuing Ecological Monitoring Programs at Millstone Nuclear Power Station

Program	Collection Dates	Collection Method	Sampling Frequency	Station Location and Number	Analyses Performed	Remarks
Boring and fouling organisms	June 1968-Dec 1974	Rack of 13 exposure panels made of White Pin with transite backing	Monthly; each month 2 panels removed, 1 exposed for 1 month, the other for 12 months	Six stations-White Point; Fox Island; Millstone Haroor; Black Point (Oct-Dec 1968), moved to Giants Neck. (Jan 1969); Unit #1 Intake (Apr 1969) ; and Quarry (Jul 1973)	Enumeration, identification, Chi-Square contingency test and diversity index	Station at Giants Neck was the only control
Benthic studies Rocky Shores	May 1968-Dec 1974	Visual observation of a study area within 1 hr of low tide	Feb, May, Jul , Sep and Dec	Seven stations-White Point, Fox Island South, Fox Island North, Giants Neck and both sides of Seaside Point Jetty (Feb 1973-Dec 1974)	Identification of dominant organisms; relative abundance estimated + 10%	Three control stations-Giants Neck and both sides of Seaside Point Jetty
Rock substrates (subtidal)	Mar 1973-Dec 1974	Scuba divers scraped 25 x 25 cm area at five 0.6m intervals. Each consecutive, 6m interval was rotated 72° until a full circle was sampled	Mar, June, Sep, Dec	Originally 3 stations; reduced to two in March 1974, one near Quarry, the other at Giants Neck (control)	Enumeration, identification and dry weight	Highly quantitative for both plants and animals
(Intertidal)	June 1973-Dec 1974	Same as above except Scuba gear not needed	Same as above	Three stations-White Point; Fox Island; Giants Neck (control)	Same as above	
Sand substrates (subtidal)	Mar 1973-Dec 1974	Mar 1973-Mar 1974, five 25 x 25 x 5 cm deep (3125cm³) samples/station. Jun-Dec 1974, two 10 cm diameter x 5 cm deep cores (393 cm³). Collected by Scuba divers	Same as above	Five stations-Jordan Cove, south of Quarry Cut, Two Tree Island, Little Rock and Bay Point. Added Giants Neck in Mar 1974, and near the Intake in June 1974	Enumeration , identification; largest and smallest organism measured (mm) and dry weight determined; sand grain size measurement	
(Intertidal)	June 1973-Jun 1974	Same as above except Scuba not needed	Same as above	Same as rock substrate (intertidal)	Same as above	
Lobster population studies	Oct 1973-Dec 1974	Observation of both natural and artificial habitats by Scuba divers tagged 650 lobsters	Monthly observations of artificial and natural habitats; continuous for tag returns	Seven artificial and four natural substrates; located between Giants Neck and Seaside Point	Population estimates to be made	Most of the lobsters were tagged after Apr 1974
Oyster growth studies	May 1970-Dec 1974	Sixty tagged 2-3 yr old oysters were suspended on plastic-coated wire trays	Feb, May, Jul , Sep and Dec	Four stations-White Point, Fox Island, Giants Neck (control) and in the Quarry	Length and weight measurements: Mortalities	Measurements made underwater by Scuba divers

TABLE 2. Summary of Continuing Ecological Monitoring Programs at Millstone Nuclear Power Station (continued)

Program	Collection Dates	Collection Method	Sampling Frequency	Station Location and Number	Analyses Performed	Remarks
Trace metal analysis water	Sep 1971-Dec 1974	Grab sample of surface sea water	Same as above	Four stations-Quarry. Two-Tree Channel, Intake and Giants Neck (control)	Atomic absorption spectrophotometry-lead, iron chromium, zinc, copper	
Oyster and mussel tissue	Same as above	Oysters from trays and mussels from natural beds	May and Wep (Sep 1971-Sep 1973). Feb, May, Jul, Sep and Dec (May 1973-Dec 1974)	Three stations-Two in Plume Path (Quarry and Fox Island) and Giants Neck (control)	Atomic absorption spectrophotometry-lead, iron, chromium, zinc, copper	
Fish studies Shore zone fish	May 1969-Dec 1974	Three adjacent 30m haul/station with 9.1m x 1.2m bag seine (6mm mesh)	Feb, May, Jul, Sep, Dec (May 1969-Dec 1973) Feb, May, June, Jul, Aug, Sep, Oct. Dec (Feb-Dec 1974)	May 1969-Dec 1972, Four stations- (White Point, Jordan Cove, Bay Point, and Giants Neck). From Feb 1973, Seaside Point and Black Point added	Enumeration, identification, species diversity and ranking by relative abundance	Aliquots measured from large samples
Gill netted fish	Dec 1971-Dec 1974	Gill nets set overnight, net made of 6-25' panels of 2", 1 1/4", 1", 3/4", 1 1/2" and 2 1/2" mesh	Dec 1971-May 1973, quarterly. June 1973-Dec 1974, bimonthly. Jan 1974-Dec 1974, monthly	Dec 1971-May 1973, two stations (near Two-Tree Island and Bay Point). June 1973-Dec 1974, two stations added (Black Point and Jordan Cove)	Enumeration-identification, standard length and relative abundance	Sampling frequency increase to take measure of spring and fall migrations
Trawl netted fish	Apr 1973-Dec 1974	9.1m otter trawl with 6mm cod end liner, towed for 15 min	Biweekly	Eight stations with two controls (Niantic Bay and Long Island Sound)	Enumeration-identification, wet weight and total length	Invertebrates collected were also counted
Fish tagging	Mar 1983-Dec 1974	Gill nets, otter trawls and trap nets, tagged 3 species (winter flounder, windowpane flounder and tautog)	Continuous	No particular stations	Used Jolley's method for population estimates based on mark-recapture data	Tag returns from otter trawling and from sport and commercial catch
Fish stomach content analysis	Jun 1973-Nov 1974	Same as trawl netted fish	Monthly	Same as trawl netted	Stomachs first ranked according to fullness, then contents were identified and counted	Stomachs came from otter trawl netted fish
Ichthyoplankton and zooplankton	May 1973-Dec 1974	Bongo nets- ~ 1/2 and 1/3mm mesh, 0.6m mouth diameter. 15 min. Oblique tow filtering ~ 200 m ³	Very complex, but generally: All station weekly, every 4th week night tows and stratified surface and bottom tows at 1/2 of all stations every other week. Frequency varied seasonally	Fourteen stations throughout surrounding area	Enumeration and identification	Ichthyo and zooplankton samples were collected side by side also measured temperature, salinity, pH and D.O. at surface and bottom

**TABLE 3. Summary of Special Ecological Studies
(Entrainment, Impingement, etc.) at
Millstone Nuclear Power Station**

PROGRAM	COLLECTION DATES	COLLECTION METHOD	FREQUENCY	STATION LOCATION AND NUMBER	ANALYSES PERFORMED	REMARKS
ENTRAINMENT STUDIES ZOOPLANKTON	NOV 1970 - NOV 1971	0.5 m NET WITH 0.33 MESH FOR 20 min. AT 3 m DEPTH. DUPLICATE TOWS MADE	BIWEEKLY	THREE STATIONS - INTAKE, DISCHARGE TO QUARRY AND QUARRY CUT	SEASONALITY; MORTALITY RATES BY VITAL STAINING UNDER FOLLOWING CONDITIONS: HEAT ALONE, HEAT AND CHLORINE, NO HEAT AND NO CHLORINE AND CHLORINE ALONE; SINKING RATES; AND DELAYED MORTALITIES BY PLACING ENTRAINED COPEPODS IN PLASTIC BAGS AND HOLDING THEM IN M E QUARRY AND AT JORDAN COVE (CONTROL)	BOTH DAY AND NIGHT REPLICATES WERE COLLECTED FOR DIURNAL DIFFERENTIATION. PLANT HAD TO BE OPERATING AT DESIRED MODE FOR A MINIMUM OF 48 hr. BEFORE SAMPLING
ZOOPLANKTON	NOV 1971 - OCT 1972 MAR 1974 - FEB 1975	0.5 m NET WITH 0.33 MESH FOR 20 mm AT 3 m DEPTH	SAME AS ABOVE	ONE STATION AT INTAKE ONLY	ENUMERATION AND IDENTIFICATION	A TWO CYCLE (2 YEARS APART) STUDY TO DETERMINE COPEPOD SEASONALITY
PHYTOPLANKTON CHLORINE AND PRODUCTIVITY	JUL 1971 - DEC 1971	1 L OF SEAWATER BY VAN DORN BOTTLE AT 3 m (INTAKE) AND 1 m DEPTHS	INTERMITTENT DEPENDING ON CHLORINE INJECTION	THREE STATIONS - INTAKE, QUARRY AND QUARRY OUTLET	PRODUCTIVITY BY TH ¹⁴ C LIGHT-DARK BOTTLE METHOD	CHLORINE LEVEL VARIED BETWEEN 0 - 1.2 ppm
TEMP. AND PRODUCTIVITY	MAR 1971 - R B 1972	SAME AS ABOM	SAME AS ABOM	SAME AS ABOM	SAME AS ABOVE	
TEMP. AND STANDING CROP	MAR 1971 - JUN 1971	SAME AS ABOM	SEVEN DATES, DUPLICATE SAMPLES	INTAKE AND QUARRY OUTLET	ENUMERATION AND IDENTIFICATION	
LOBSTER LARVAE	APR 1974 - DEC 1974	1 m NET WITH 0.33 mm MESH FOR 20 min. BOTH DAY AND NIGHT	WEEKLY	ONE STATION AT THE DISCHARGE TO THE QUARRY	ENUMERATION	NET POSITIONED IN FAST MOVING WATER TO PREVENT NET AVOIDANCE
ICHTHYOPLANKTON	NOV 1970 - SEP 1974	SAME AS ZOOPLANKTON	BIWEEKLY	SAME AS ZOOPLANKTON	ENUMERATION, IDENTIFICATION AND SURVIVAL (HELD LIVE FISH FOR 24 hr. TO MEASURE DELAYED MORTALITY)	TAKEN CONCURRENTLY WITH ZOOPLANKTON
TEMP. AND FISH LARVAE	UNKNOWN	UNKNOWN	UNKNOWN	COLLECTED FISH LARVAE FROM NANTIC BAY AND JORDAN COVE	LABORATORY TESTS TO DETERMINE CRITICAL TEMPERATURE MAXIMUM FOR 3 SPECIES: ATLANTIC SILVERSIDES, WINTER ROUNDER AND KILLIFISH	WATER TEMPERATURE RAISED ~1°C/min.
IMPINGEMENT	JAN 1972 - DEC 1974	SCREEN WASHING INTO TRASH BASKET	DAILY (1972 - JUN 1973) TWICE/DAY (JUL 1973 - JUN 1974) ON FOUR DAY/WEEK	INTAKE SCRWS	ENUMERATION AND IDENTIFICATION; FROM JAN 1973 ALL ORGANISMS SORTED INTO 0 - 3, 3 - 6 AND 6" AND OVER SIZE CATEGORIES	
WINTER FLOUNDER ENTRAINMENT MODEL	IN M I S MODEL PLANT INDUCED MORTALITY IS CONSIDERED SEPARATELY FROM NATURAL MORTALITY; THUS THE COMPENSATION OF NATURAL MORTALITY FOR ENTRAINMENT MORTALITY IS IGNORED. THEREFORE IF NATURAL MORTALITY IS DENSITY DEPENDENT, ENTRAINMENT MORTALITY WILL BE OVERESTIMATED. OTHERWISE M E RESULTS WOULD BE M E SAME AS IF THE TWO WERE CONSIDERED TOGETHER					
WATER QUALITY	AN INTENSE, BUT ONLY ONE MAR (1974) WATER QUALITY SURVEY WAS CONDUCTED ON A MONTHLY AND QUARTERLY SCHEDULE WITH 45 PARAMETERS MEASURED. MONTHLY PARAMETERS INCLUDED THE FOLLOWING: NH ₃ -N, NO ₂ -N, NO ₃ -N, ORGANIC-N, ORTHO-PO ₄ , CONDENSED PO ₄ , TOTAL PO ₄ , DISSOLVED NITROGEN, DISSOLVED OXYGEN, BIO-CHEMICAL OXYGEN DEMAND, TOTAL ORGANIC CARBON, TEMPERATURE °C, SALINITY, pH, SULFATE, MBAS, FREE CHLORINE, TOTAL CHLORINE, BORON, OIL AND GREASE, SUSPENDED SOLIDS, TOTAL CHROMIUM, COPPER, LEAD, NICKEL, IRON, MANGANESE, ZINC AND ALUMINUM. QUARTERLY PARAMETERS INCLUDED: TOTAL ALKALINITY, CHLORIDE, POTASSIUM, CALCIUM, MAGNESIUM, ARSENIC, MOLYBDENUM, TITANIUM, VANADIUM, CADMIUM, BERYLLIUM, MERCURY, TOTAL SOLIDS, TOTAL VOLATILE SOLIDS, TIN AND PHENOL.					

continuous from November 1970 through September 1974. Thus, the individual effects of temperature, chlorine and mechanical stress were determined as well as the synergistic effects over varying periods of time.

In addition to entrainment and impingement studies, a winter flounder entrainment model was developed. This model was based on a tidal circulation model of Niantic Bay and its surrounding area. Plant-induced mortality was considered separately from natural mortality and, thus, tends to overestimate entrainment mortality. Because density-dependent natural mortality was ignored, it does not compensate for plant mortalities.

A 1 yr water quality monitoring program was conducted in 1974 on a monthly and quarterly schedule at nine locations. The following parameters were monitored monthly: $\text{NH}_3\text{-N}$, $\text{NO}_2\text{-N}$, $\text{NO}_3\text{-N}$, organic-N, ortho PO_4 , condensed PO_4 , total PO_4 , dissolved N, dissolved O, BOD, TOC, temperature ($^{\circ}\text{C}$), salinity, pH, SO_4 , MBAS, free-Cl, total-Cl, B, oil and grease, SS, Cr, Cu, Pb, Ni, Fe, Mn, Zn and Al. Quarterly samples included: total alkalinity, chloride, K, Ca, Mg, As, Mo, Ti, V, Cd, Be, Hg, Zn, total solids, total volatile solids, and phenol. In addition to the above parameters, sediment samples were collected on a quarterly basis and analyzed for the following: total-N, total- PO_4 , TOC, TVS, B, Al, Fe, Cu, Ni, Pb, Hg, Zn, Be, Cd, V, Ti, Mo, Mn, As, Cr, oil and grease, and phenols. Monthly samples were collected on both ebb and flood tides with a Van Dorn water sampler while a core sampler was used for obtaining sediment samples. The stations were sampled at the maximum of each tide. For example, Stations 4 and 8 were influenced by the thermal plume on the flood tide, and thus, were sampled at the maximum of the flood tide.

Figure 3 is a composite of the ecological monitoring program sampling locations. Sites for specific programs are designated in the legend.

FIGURE 3. Composite of the Ecological Sampling Stations at Millstone Nuclear Power Station

VI. PREDICTED IMPACTS AND TECHNICAL SPECIFICATIONS

VI. PREDICTED IMPACTS AND TECHNICAL SPECIFICATIONS

The final, Environmental Technical Specifications for Millstone, Unit 1 were published by NRC on 19 December 1975. This nuclear power plant began commercial operation in November 1970 with aquatic ecology studies beginning in 1968 and continuing to date. Thus, about 2-1/2 yr of preoperational and 5 yr of operational data have been collected before final Tech Specs were approved. However, this situation probably existed because the plant was back-fitted with an environmental impact statement to satisfy the intent of NEPA.

The final Tech Specs (NRC, 1975) points out that the ecological programs conducted at Millstone have produced a large body of information prior to plant operation with additional data on the impact of Unit 1. This document also points out that the present ecological program provides "reasonable assurance that both the short and long-range changes which might result from the operation of multiple units can be detected and evaluated." The final Tech Specs, therefore, call for a continuation of the present ecological monitoring program. This includes about ten separate programs with additional special surveillance studies. For an overall summary of these programs, refer to Tables 2 and 3 of this report.

Predicted ES impacts for Millstone include: 1) loss of planktonic organisms through entrainment, 2) loss of organisms through impingement, 3) potential for fish kills in the discharge quarry, and 4) creation of a thermal plume covering up to 44.5 hectares. The final Tech Specs address these predicted impacts and include many additional studies. The Tech Specs, thus, call for a more demanding monitoring program than the FES predicted, in terms of potential impacts. The reason for such a rigorous monitoring program is that multiple units are planned for Millstone. It appears that the monitoring programs, which began in 1968 and since have been modified (1972 and 1973), meet the objective of this study. These objectives are to evaluate the potential impacts of Unit 1 and provide a sufficient data base for the construction and operation of additional units.

Since the Tech Specs call for broad coverage of the aquatic ecosystem, actually more than the ES predicted, certain questions arise. How quantitative are these present and past monitoring programs? How much useful data was and will be collected and evaluated with the present state-of-the-art knowledge about environmental impacts?

Instead of attempting to sample the entire aquatic ecosystem for potential changes, which may or may not be detrimental, monitoring programs perhaps should be implemented focussing on important species or communities. With this in mind, more consideration should be given to a sampling design, that is statistically oriented in order to try to differentiate between natural variation at a station, between stations, between years and plant-induced effects.

VII. RATIONALE FOR DATA SYNTHESIS

VII. RATIONALE FOR DATA SYNTHESIS

More than twenty separate ecological monitoring programs have been conducted for 8 yr at the Millstone site. Some populations have been extensively monitored (1968-1974), while others have been short-term (1 yr or less). Thus, data recording and synthesis for statistical analyses were a very important and sometimes cumbersome aspect of this study. However, due to certain inconsistencies (e. g. , adding and/or deleting sampling stations from year to year, changing sampling programs, changing sampling methodologies and reporting formats) not all of the data collected could be quantitatively evaluated. Therefore, we present here the rationale for our choices whereby selected data sets were used for subsequent statistical analysis and the reasons why others were not evaluated.

STUDIES EVALUATED

We statistically evaluated studies when several or all of the following criteria were met:

- Both preoperational and operational data sets were collected.
- At least one control station was sampled.
- Several samples were collected each year at each station.
- Sampling stations and methodologies were consistent from year-to-year.
- Data collections were quantitative in nature.

The following studies met the above criteria and were analyzed in detail: boring and fouling organisms (exposure panel), oyster growth, trace metals in seawater and their concentration levels in oyster and mussel tissue and shore-zone fish. In addition to the above, two programs that were terminated in 1973 (barnacle populations and intertidal sand infauna) also met the aforementioned criteria, and thus were evaluated.

Several other studies were evaluated because of their uniqueness, commonality, and/or mention of a statistical analysis performed by the applicant. For example, the Rocky Shore Community Study was highly qualitative

because all organisms were classified by their relative abundance (visual observation). However, this study was conducted from May 1968 through December 1974. It was one of the longest, in terms of years of data collected, and best from the standpoint of consistent data collection methodology. Although the impingement study can only be conducted during operation, we evaluated the study because of its potential for environmental impacts and the interest shown by all parties concerned (commonality). Entrainment studies were evaluated for similar reasons, however, not all of the entrainment studies received detailed analyses. There were eight separate studies but we analyzed two--zooplankton and ichthyoplankton. Zooplankton were evaluated for seasonality, mortality (heat, chlorine and mechanical stresses - individual and combined effects) and delayed mortality. Ichthyoplankton were assessed for immediate and delayed mortality.

STUDIES NOT EVALUATED

Four monitoring programs were terminated between 1970 and 1973 either because the results were not quantifiable or they lacked consistency. However, these programs were replaced by more quantitative studies in 1973. The terminated programs included: plankton survey (May 1969 to September 1972), lobster survey (July 1968 to March 1973), lobster pot survey (February 1969 to May 1973) and the oyster seed growth study (August 1968 to February 1970).

Other programs not evaluated were either replacement studies for the terminated studies, or change-of-direction studies to examine a new dimension in the surrounding aquatic ecosystem. Replacement studies include: lobster population measurements, ichthyoplankton and zooplankton surveys of the surrounding area, and benthic surveys (intertidal, subtidal rock and sand substrates). Otter trawling for demersal fish, gill netting and subsequent fish stomach content studies are examples of change-of-direction studies. The above studies were not evaluated either because of paucity of available data or lack of preoperational data sets to compare to operational and/or lack of consistency in station locations. For example, during both the benthic and gill-netting studies the number of stations increased or decreased between March 1973 and December 1974. Attempts to accumulate data sets for analyses were quite arduous.

As mentioned above, only two out of several entrainment studies were analyzed in detail. Those studies not evaluated include: phytoplankton; the effects of chlorine, heat and mechanical stress (individual and combined) on standing crop and productivity; lobster larvae; one zooplankton study; and a two-cycle study for which the final data are unavailable. The phytoplankton studies were not evaluated because the results were similar to those of zooplankton, which were evaluated (i.e., samples were simultaneous). Lobster larvae entrainment was not evaluated because no larvae were entrained. The second two-cycle zooplankton study is still awaiting completion, and, therefore, cannot be evaluated.

An intense, 1 yr water quality study was conducted in 1974 on a monthly and quarterly schedule. Approximately 45 parameters were measured including water column and sediment characteristics for some parameters. However, without preoperational baseline conditions, we could only compare these measurements to themselves and so this study was not evaluated.

VIII. ANALYSIS OF THERMAL MONITORING PROGRAMS

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NONECOLOGICAL THERMAL MONITORING

Monitoring associated with temperature, tidal levels and currents has been conducted since 1966. Much of the data gathered in these monitoring efforts have, however, been gathered only in the last few years, after Unit 1 became operational. The monitoring has been conducted in several programs by several different monitoring groups. A summary of the nonecological hydrological monitoring programs is presented in Table 4. Included in this table are the parameters measured, the duration of the monitoring, the dates of program initiation and other pertinent information that could be gathered from the available information.

When considering the hydrologic monitoring for this plant, it should be remembered that much of the monitoring was performed after the plant began operation. The emphasis of the monitoring was to provide calibration and verification for models used prior to operation and those planned for use before Units 2 and 3 begin operation. It is fortuitous that one of the three nuclear generating stations examined in this monitoring review geared its monitoring to hydrodynamic and ecological models. This gives a unique opportunity to evaluate the success or failure of this type of monitoring program direction.

An examination of the material displayed in Table 4 shows that the temperature monitoring was almost exclusively of the survey type. Only one program provided temperature information at several locations in the plant vicinity with any regularity, that being data obtained by Northeast Utilities Services Company (NUSCo). The information gathered by NUSCo is for eight shoreline stations extending from Niantic Bay Yacht Club on the west shore of Niantic Bay to the east side of Jordan Cove, at White Point. Five of the eight stations were located within 500 yd of the Unit 1 outfall. Only one of these five, Millstone Cove Point, provided preoperational data. It is unlikely that the temperatures reported for Niantic Bay Yacht Club,

TABLE 4. Summary of Nonecological Hydrology Monitoring Programs

DATES	PARAMETERS	SAMPLING STATIONS	FREQUENCY	REPORTING FORMAT	PERFORMER	COMMENTS
1966 - PRESENT	TEMPERATURE	8 - SHORELINE STATIONS	UNKNOWN	GRAPH OF WEEKLY MEAN BOUNDED BY RANGE	NUSCo	ONLY ONE MONITORING STATION IN REGION OF DISCHARGE HAS RESULTS BEFORE PLANT OPERATION BEGINS
MAY 8 - 20, 1966	DYE CONCENTRATION	SURVEY - TRANSECTS UNKNOWN. VERTICAL SAMPLING BUT NO RESULTS OR DATA GIVEN	UNKNOWN	TEST DISCUSSION OF RESULTS AND SCHEMATIC OF PLUME AT END OF FLOOD AND EBB TIDES	PRITCHARD-CARPENTER CONSULTANTS	DYE WAS INTRODUCED OUTSIDE OF QUARRY WITH NO CIRCULATING WATER DISCHARGE. DURATION OF SURVEY UNKNOWN
FEB. 1970	DYE CONCENTRATION	SURVEY-TRANSECTS UNKNOWN. VERTICAL SAMPLING BUT NO DATA OR RESULTS GIVEN	UNKNOWN	TEST DISCUSSION OF DYE DISTRIBUTION AND SCHEMATIC OF PLUME AT END OF FLOOD TIDE ON A WINDY DAY	PRITCHARD-CARPENTER CONSULTANTS	DYE IN DISCHARGE TO QUARRY WITH NON- BUOYANT CIRCULATING WATER. I.E. NOT HEATED. DURATION OF SURVEY UNKNOWN
AUG 29, 1968	TEMPERATURE SALINITY	3 - STATIONS IN EXPECTED REGION OF THE PLUME, EXACT LOCATION UNKNOWN. VERTICAL PROFILES TAKEN	— HOURLY	PLOTS OF TEMPERATURE AND SALINITY WITH DEPTH AT EACH STATION. TABULATED DATA	RAYTHEON CORPORATION	MAXIMUM TEMPERATURE AND SALINITY DIFFERENCES BETWEEN SURFACE AND 76 m DEPTH WERE 0.7°C AND 0.2 ppt., RESPECTIVELY
MAR 20, 1969	TEMPERATURE SALINITY	3 - STATIONS IN EXPECTED REGION OF ME PLUME- VERTICAL PROFILES TAKEN	~ HOURLY	PLOTS OF TEMPERATURE AND SALINITY WITH DEPTH AT EACH STATION. TABULATED DATA	RATHEON CORPORATION	MAXIMUM TEMPERATURE AND SALINITY DIFFERENCES BETWEEN SURFACE AND 76 m DEPTH WERE 1.7°C AND 1.1 ppt., RESPECTIVELY

* NUSCo - NORTHEAST UTILITIES SERVICES COMPANY

** FIRST NUMBER IS ME REFERENCE NUMBER AS GIVEN IN ME BIBLIOGRAPHY, ADDITIONAL INFORMATION IS GIVEN ON THE SECTION AND SUBSECTION

TABLE 4. Summary of Nonecological Hydrology Monitoring Programs (Continued)

DAES	PARAMETERS	SAMPLING STATIONS	FREQUENCY	REPORTING FORMAT	PERFORMER	COMMENTS
JUNE 14 - 20, 1971	TEMPERATURE	SURVEY - TRANSECTS IN HORIZONTAL, VERTICAL PROFILES	ONE FOR EACH TIDAL CONDITION	PLOTS OF VERTICAL EMPERANRE PROFILES AT EACH STATION, PLOTS OF M E HORIZONTAL SURFACE TEMPERATURES FOR EACH TIDAL CONDITION	VAST INC	SURVEY DESIGN, TECHNIQUES AND EQUIPMENT WERE DISCUSSED AND DETAILED. DATA WERE OFFERED I N DETAIL. DISCUSSION OF M E RESULTS WAS INFORMATIVE. DURATION OF SURVEYS UNKNOWN , PROBABLY ABOUT 3 hrs
SEP 22 AND 3 WEEKS I N NOV, 1971	CURRENT (2 STATIONS), pH, SALINITY, TEMPERATURE, DYE CONCENTRATION AND TURBIDITY	SURVEYS ISEE FIGURE C, D AND E I N HORIZONTAL AND VERTICAL	SAMPLING TIMES REPORTED. NOT AT REGULAR INTERVALS	TABULATION OF ALL TEMPERATURE AND DYE CONCENTRATION, CURRENTS, WIND AND TIDAL HEIGHTS	VAST INC.	PROJECT PERFORMED I N TWO PARTS: DYE WAS INTRODUCED INTO DISCHARGE TO QUARRY I N PART ONE AND MONITORED I N THE OCEAN WATERS: THE SECONDEMPLOYED 5 RAFTS I N TWO -TREE CHANNEL WITH DYE DISCHARGE FROM EACH. SURVEY DESIGN, TECHNIQUES AND EQUIPMENT WERE DISCUSSED. EACH SURVEY TOO. FROM 2 TO 3 1/2 hrs
AUG 8 - SEP 10. 1973	CURRENT TIDE LEVEL	5 TIDE LEVEL 12 CURRENT METERS (2/LOCATION)	EVERY 20 min. EVERY 10 min.	A PLOT REPRESENTATIVE OF DATA	BRAINCON	DATA GATHERED WERE NOT PRESENTED I N ANY FORM. DISCUSSION INCLUDES EQUIPMENT SPECIFICATIONS AND CHRONOLOGICAL DESCRIPTION OF INSTALLATION
FEB 6 - 20, 1974	CURRENT TIDE LEVEL	7 TIDE LEVEL 18 CURRENT METERS (2/LOCATION)	EVERY 20 min.	A PLOT REPRESENTATIVE OF DATA	BRAINCON	DATA GATHERED WERE NOT PRESENTED I N ANY FORM. DISCUSSION INCLUDES EQUIPMENT SPECIFICATIONS AND CHRONOLOGICAL DESCRIPTION OF INSTALLATION
FEB, MAY, JULY. SEPT, AND DEC SINCE 1969	TEMPERATURE	VARIOUS LOCATIONS	UNKNOWN	NONE PRESENKD. REASONS CITED I N REFERENCE 1, SEC 3.4	WILLIAM CLAPP LABS	LITTLE DISCUSSION
1974	TEMPERATURE	NEAR MILLSTONE POINT	MONTHLY	NONE PRESENTED, REASONS CITED I N REFERENCE 1, SEC 3.4	RESEARCH CORPORATION OF NEW ENGLAND (TRC)	LITTLE DISCUSSION

Mijoy Dock, and White Point would display any observable temperature increases due to plant operation, because of the variability of shoreline temperatures from solar insolation. The effect of solar insolation on observed temperatures in Niantic Bay and Jordan Cove are cited in the Results section of the first VAST Inc. Survey (June 14-20, 1971) presented in Millstone Point Company (1972). The only monitoring station that provides both preoperational and operational temperature data on a regular basis is at Millstone Point Cove. The temperatures for this station are given in bar graph form as weekly values. In this format the temperatures are not suitably amenable to analysis. Therefore, the data were not considered in this review.

Other temperature information is available from several survey monitoring programs. However, these programs had the following shortcomings:

- Sampling stations for the several programs were not at common locations.
- Sampling occurred for short durations at irregular intervals.
- Data from several of the stations were not available for an entire tidal cycle.
- No preoperational data existed for any of the stations.
- Only a relatively few sampling periods are represented.

For the above reasons, none of the sampling programs could be used for statistical examination of the thermal alteration of preoperational conditions.

The only valid uses of data gathered in the hydrological monitoring programs are for computer model input and verification. Nearly all models employed for hydrothermal prediction are deterministic and allow comparison only with deterministic monitoring data. However, all processes, particularly those for tidal-affected waterbodies, are influenced to a considerable degree by pseudo-random parameters. The thermal plume entering tidal-affected waters may exhibit a wide variety of shapes and motions, depending

on constantly varying ambient and discharge conditions. The possible variation in plume characteristics is pointed out in Gore, et. al. (1976b) and Dunn and Policastro (1975). In those references, the plume extent and surface areas have been noted to vary by factors of 2 and 5, respectively, for electric generating stations on the Great Lakes and for a generating station on the tidal affected portion of the Connecticut River.

Aquatic biota in the region of the plant may experience a constantly varying level of thermal exposure. The exposure level, duration and time percentage were not accurately estimable from only a few thermal surveys (provided for plume model verification) since they represent only a few of the possible plume distributions.

In addition to the considerations above, the thermal sampling was not designed to augment the aquatic ecological monitoring performed at Millstone Nuclear Power Plant.

For these reasons, the thermal and dye surveys do not support any analyses attempting to quantify the thermal impact of the discharge on aquatic biota.

MODELS

The modeling of the Millstone discharge, intake and surrounding waters took two forms. The first attempted to determine the extent and shape of the thermal plume. The second attempted to generate a typical flow-field tidal sequence near the plant to be used in a model of the long-term effects of plant operation on winter flounder.

The models employed for prediction of the thermal plume had the following characteristics [c.f. Northeast Utilities Company (1975)]:

- Steady state conditions.
- Uniform ambient current.
- No wind effects.
- No ambient stratification.
- No vertical or longitudinal diffusion for the far field model.
- Lateral eddy diffusion coefficient proportional to the 4/3 order of the plume width.

These characteristics are adopted by the near-field Stolzenback and Harleman (1971) model for surface discharges and are employed for calculations of the far-field dilution according to Harleman (1972). A recent review, Dunn and Policastro (1975), of state-of-the-art surface discharge models does not recommend the use of the Stolzenback and Harleman surface discharge model based on a comparison of predictions (for numerous models) and field data. A valid analysis of this model's success in predicting the plume characteristics for the Millstone discharge is not possible. The only thermal monitoring survey (there were only two) which was able to isolate the thermal plume from the background thermal structure (VAST, Inc., March-April 1972) was used to both calibrate and verify the plume predictions. The results of this calibration-verification are shown in Figure 4. Model computational parameters (probably entrainment or eddy diffusion coefficients) were adjusted until reasonable agreement was obtained between prediction and field data.

FIGURE 4. Predicted vs Measured Thermal Patterns (from March 1972 Survey-Unit 1)

The second modeling effort utilized the two-dimensional long wave model developed by Leenderste (1967). This model calculated the flow field in the tidally influenced region as a function of time. It was one of the more sophisticated tools available for flow field prediction when the winter flounder study began. The code has demonstrated its potential for accurate prediction of tidal flow fields, provided that accurate knowledge of flow conditions at boundaries are available. It also requires reasonable verification data in order that bottom friction can be estimated. Additional required input includes: boundary geometry, bathymetry, latitude of the area, river and power plant discharge and intake flow rates, and wind and atmospheric pressure data. In addition to the two-dimensional assumptions on flow field characteristics, the model also assumes that the water body is homogeneous horizontally and that lateral eddy viscosity is negligible compared to the vertical momentum flux. The latter can be treated as a bottom shear stress in the two-dimensional momentum equations. The equations employed in the model include accelerative terms as well as Coriolis forces.

The region around Millstone Nuclear Power Station that was segmented is shown in Figure 5 with the model boundaries indicated. The open boundary (the dashed line) must input the tidal height as a function of time at every node. Since Long Island Sound acts as a tidal resonator, the tidal heights and phases change as one proceeds from the Atlantic to New York Harbor (tidal height changes from about 0.7 m at Mystic River, Connecticut to 2.2 m at Port Chester, New York). For the model area, the change in tidal height was determined to be 0.05 m with a standard deviation of 0.04 m (from tide-level monitoring performed in 1973 and 1974). The phase lag in tides for the western end of the model was estimated to be 11.1 min with a standard deviation of 18.2 min (Northeast Utilities, 1975). The inclusion of even these slight changes in boundary conditions improved the predictions dramatically.

The model used tide level information obtained from hydrological monitoring to obtain a flow field prediction, and then velocity data from current meter monitoring for comparison and calibration. The bottom roughness (or Manning's coefficient) equalled one of three values (0.02, 0.03, or 0.045)

FIGURE 5. Tidal Circulation Model

depending on the bathymetric conditions and the velocity profiles obtained. The tidal wave amplitudes used in the model region varied from 0.41 m on the east boundary to 0.44 m in the southwest corner. A phase lag of 10.5 min was used across the model region (east to west). With these inputs and refinements, the code predicted the flow field and tidal heights within the model region. A comparison of the predicted flow field velocities at points where current meter measurements were available is shown in Figure 6. Reasonably good agreement between current direction and magnitude existed between predicted and observed data. It is interesting to note that this model was applied by two different groups at the same time (as directed by the utility) with essentially the same results.

FIGURE 6. Comparison of Field and Tidal Model Current Data

The data from the February, 1974, current and tidal level monitoring program were the only data used for calibration/verification of the model. The data from the August-September, 1973, current and tidal level monitoring study were found to be unacceptable for use in model calibration/verification for the following reasons [c.f. Northeast Utilities Company (1975)]:

- Data were not of high statistical quality.
- There was no log of the current meter starting times.
- The field data collected were not at the end points of the open boundaries of the tidal circulation model.
- The 10 min sampling rate was not fast enough to reduce the error in tidal lag measurements to an acceptable level.

These problems were evidently corrected for the 1974 measurements.

One other aspect of the model application is that it was necessary to use field tide level information on the model boundaries rather than the common sinusoidal tide level relation, in order to obtain acceptable agreement between field data and model predictions.

All of the above factors point to the necessity for consideration of the type of models used for hydrodynamic and hydrothermal prediction when the monitoring programs are being designed, particularly the operational and preoperational programs.

It is unfortunate that the predictions of the tidal current model obtained during examination of winter flounder was not tapped as input to a transport model for thermal advection and diffusion. Considering the number of dye diffusion studies that were carried out at the site (providing an excellent estimate of the eddy diffusion), an improved prediction of far field transport of the thermal effluents might have been possible.

The only other model employed for examination of the site was a physical model of the region performed by Alden Labs. However, little use was made of the quantitative information resulting from this model study. No monitoring data were compared to simulations from this model.

ECOLOGICAL

Introduction

Few of the ecological monitoring programs provided temperature data which could be used to detect thermal impacts on the biota near the plant. For example, the benthic sampling stations were located in areas most likely to experience a thermal influence, but very little preoperational and operational data were presented. The reported temperatures were collected by divers quarterly.

Trawl and Ichthyoplankton

The trawl studies recorded semi-monthly water temperatures during each trawl. Although a trawl was made in the vicinity of the plant intake, no trawls occurred near the thermal discharge, nor in the areas affected by

the thermal plume on the ebb tide. The data are not useful for determining the effect of thermal increases because it is not known where or how the data were taken during each trawl.

The ichthyoplankton study produced temperature data more suited for analysis of thermal impacts. Even so, data are only available from May 1973 to April 1974. Weekly temperature observations exist at the surface, mid-depth and bottom at the stations shown in Figure 7. No preoperational temperatures were available for these stations. Data from Stations 5, 6, 8, 10, 11 and 13 were selected for analysis because these stations were nearest to the plant's discharge.

FIGURE 7. Ichthyoplankton Sampling Stations

No ichthyoplankton temperature data were presented in the reports we were able to obtain. Data were obtained from printouts of ichthyoplankton computer data cards. Values were selected from similar times of day at each station. Stations 5, 6, 8 and 10 had weekly temperatures from 1 June 1973 to mid-August 1974. Stations 11 and 13 recorded temperatures from early February 1974 to April 1974.

Figure 8 presents surface temperatures from Stations 5, 6 and 8 near Millstone Point. Temperatures show a seasonal increase and decline, and from September through November, 1973, temperatures at Stations 6 and 8 appeared slightly higher than temperatures at Station 5. In addition, it appears that temperatures were slightly elevated at Station 6 compared to Station 8. These comparisons indicate that the higher temperatures observed at Station 6 were not due to chance variations in normal water temperature.

FIGURE 8. Ichthyoplankton, Temperature (°C) at Stations 5, 6 and 8

Figure 9 presents temperatures from Station 10, one-half mile south of Bartlett Reef Horn. A comparison with the data for Station 8 in Figure 8 indicates no numerical difference. Station 10 is well out of any thermal influence from the plant and is assumed to represent thermally unaffected temperatures. Since no difference existed between Stations 8 and 10, then we could surmise that Station 8 also received no thermal influence from the plant.

FIGURE 9. Temperatures (°C) at Ichthyoplankton Station 10

Ichthyoplankton - Thermal Plume

Surface regions affected by the plant's thermal discharge are depicted in Figure 4. Comparison of this figure with ichthyoplankton Stations 5, 6 and 8 in Figure 7 indicates that the plume would most likely affect Station 6. Station 6 and 8 show significant temperature differences, although only at the $\alpha = 0.05$ level.

Some thermal impact, however small, does exist at Station 6. No adverse effects on ichthyoplankton at Station 6 are cited in the Environmental or Summary Reports. Data from the other stations disclosed no significant thermal impact. The water temperatures at these stations represented ambient conditions. Thus, although the ichthyoplankton study provided no preoperational temperature data, it provided more comprehensive temperature data in the general vicinity of the thermal plume than any of the other ecological monitoring programs.

Water Quality

Temperatures were collected during a 1 yr water quality study performed by the Travellers Research Company (TRC). Samples were collected monthly at all stations on ebb and flood tides. Stations located within the influence of the thermal plume were sampled at the surface, mid-depth and 0.3 m above the bottom. No direct temperature data were reported in the data available to us.

SUMMARY

The nonecological monitoring programs did not provide either qualitative or quantitative analysis of thermal impact on aquatic biota. Monitoring programs were designed primarily to provide input, calibration and verification of hydrodynamic and hydrothermal models. The only monitoring results, which provided for application of the thermal plume model, were used for both calibration and verification, therefore no assessment of the model predictive capability is possible for this site.

Use of the Leendertse two-dimensional long wave model to simulate the currents in the vicinity of Millstone Power Plant was calibrated and verified with tidal gage and current meter measurements for 2 weeks in February 1974. Although reasonable quantitative agreement was obtained for tidal flows in the site vicinity, no use was made of this code relative to transport of thermal or chemical effluents.

From the examination of the limited amount of suitable data obtained from the hydrological monitoring programs for this plant, it appears that

monitoring programs designed for the verification of model predictions do not provide good data for support of operational assessment of thermal impact on aquatic biota.

None of the ecological monitoring programs collected adequate hydrological temperature data. No program produced comparable preoperational and operational temperatures. Few actual temperatures were reported in the reports available to us. Although temperature data from the ichthyoplankton studies indicate that Station 6 experienced a small temperature increase, the data were not comparable with other ecological and nonecological temperature monitoring programs. No analyses of thermal impacts on the aquatic biota surrounding Millstone Point was possible from the collected temperature data because the data were collected for thermal model verifications.

IX. ANALYSIS OF ECOLOGICAL MONITORING PROGRAMS

IX. ANALYSIS OF ECOLOGICAL MONITORING PROGRAMS

ROCKY SHORE COMMUNITIES

We were unable to use percent coverage estimates from the six individual quadrats, made along each of the 30 m station transects, because data were reported for only 2 preoperational yr. In addition, we found no relationship between mean or individual quadrat percent coverage values and those reported for the entire respective station transect. The latter values were reported for 2 preoperational yr up to the present time but we only used data through 1973 in our analysis. However, in several reporting periods at different stations no value for percent coverage was reported. We have assumed that the measurements were not collected because we could not accept as factual the disappearance of an entire community in one sampling period and its subsequent reappearance in the next sampling period. Examples for the barnacle Balanus balanoides at Giants Neck in 1971 and at Fox Island South in 1972 are illustrated in Table 5 where all the available data through 1973 for three algae species and two species of barnacles (a different species was found at the Bay Point station) are listed. Because of these presumed missing values, we only made comparisons where percent coverage values were obtained at both Giants Neck (control), and one of the three stations subject to heated effluent (Bay Point and Fox Island stations). Data was not used from White Point because of the potential effects from two reported oil slicks during the preoperational period (February 1969 and May 1970). In addition, the one-to-one comparison with three heated stations and one control already emphasized any bias for the control station. We were unable to obtain information to indicate that an effort was made to "ecologically match" the control station to any of the heated locations. Apparently, the Bay Point station was subject to the heaviest surf and winds, Fox Island South was the most sheltered, while the others were intermediate. Strong surf may explain the different barnacle species observed at Bay Point. We selected four of the five species shown in Table 5 for further evaluation because they were most abundant during a majority of observation times.

TABLE 5. Estimated Coverage (% of Total Transect, Area Covered)¹
for Selected Flora and Fauna in the Millstone Point Area

	GIANTS NECK				FOX ISLAND NORM				FOX ISLAND SOUTH				BAY POINT				
DATE	PERCENTAGE ESTIMATED	<u>Ascophyllum nodosum</u>	<u>Fucus spp</u>	<u>Chondrus crispus</u>	<u>Balanus balanoides</u>	<u>Ascophyllum nodosum</u>	<u>Fucus p</u>	<u>Chondrus crispus</u>	<u>Balanus balanoides</u>	<u>Ascophyllum nodosum</u>	<u>Fucus spp</u>	<u>Chondrus crispus</u>	<u>Balanus balanoides</u>	<u>Ascophyllum nodosum</u>	<u>Fucus spp</u>	<u>Chondrus crispus</u>	<u>Balanus² crenatus</u>
PREOPERATIONAL PERIOD																	
<u>1969</u>																	
MAY		30	70		85	10	90	5	95	50	50				35		75
JUL		30	70		85		100	5	90	50	50		45		20		70
SEP		50	50		75		90		85	40	60		60		5		30
DEC		60	40	55	65		65	15	65	60	40		40		25		75
<u>1970</u>																	
FEB		50	M				50	30	70	60	40		70		10		75
MAY		40	50	5	50		60	10	90	40	75		70		10		90
JUL		30	95		80	5	90	10	85	40	60		70				85
SEP		60	60	20	90	20	85	5	70	40	60	10	65		5		60
OEC		50	40	10		10	50	10	-	40	60	35		5	10	17	
OPERATIONAL PERIOD																	
<u>1971</u>																	
FEB		40	30	15	75	ICE COVERED				40	30	15	67	ICE AND SNOW			
MAY		M	20	10	90	40	40	10		10	60	5	85	5	5	5	90
JUL		30	50			10	60	5		40	40	10	75	5	5	10	80
SEP		M	60	10	70	10	60	5	50	50	10	5				50	40
DEC		40	40	5		M	40	5	40	30	25	5		2	2	5	40
<u>1972</u>																	
FEB		40	30	5	75	10	50	1	-	30	20	10	50	1		10	
MAY		30	70	5		20	50		85	M	5	5				5	85
JUL		40	40	5		30	20	5	75	10	50		80			5	70
SEP		40	60	5		10	60	5		30	30	5				3	35
OEC		30	50			20	40	5		30	30		70			5	50
<u>1973</u>																	
FEB		35	40	5	50	20	50	1	50	30	25	5	40			10	
MAY		45	35	3	80	5	50	1	70	30	25	1	80	1		5	85
JUL		60	40	1	75	5	50	1	40	30	20	1	75	1		5	70
SEP		50	40	3	75	1	70	1	40	40	20		60			3	35
OEC		50	40	5	70	10	55	1	50	M	25	5	65			5	50

¹ ACCURACY ESTIMATED AS $\pm 10\%$

² SPECIES IS *Balanus crenatus* RATHER THAN *Balanus balanoides* AT OTHER STATIONS

ALGAE

Ascophyllum nodosum

Fucus spp

Chondrus crispus

BARNACLE

Balanus balanoides

However, in examining only these data and only percent coverage information we may have failed to detect changes for the less abundant organisms. Finally, both in a Battelle Report (1975) and others, the reported coverage estimates for each organism are to be accurate to $\pm 10\%$. No indication as to how this was determined or what it means (i.e. standard deviation, range or etc.) was given. We presume the authors meant precision vis-a-vis accuracy. Our experience indicates that ecological measurements often have coefficients of variation of 50% and sometimes higher (up to and over 100%). We choose to interpret the 10% accuracy value to mean the reported coverage could range to $\pm 10\%$ (i.e. $50\% \pm 10\%$) except for coverages of 10% or less and 90% or greater.

The differences between percent coverage for the control and the three heated stations for each sampling period are in Tables 6-9. Ascophyllum nodosum coverage at Bay Point was minimal during the operational period (Table 5) and only one value was reported during preoperation, so no comparisons were justified. In contrast, complete preoperational data were available for Fox Island South but the yearly average of station differences (evaluated in conjunction with their standard deviations, Table 6) show no conclusive change, even though it appears the Ascophyllum coverage declined relative to Giants Neck in 1973. Apparently coverage at Fox Island North increased relative to Giants Neck during the 1971 and 1972 operational years but returned to the 1970 average preoperational difference values during 1973 (if the average of three sampling periods during 1970 accurately estimates the true preoperational status). However, the 1970 average estimate itself is questionable because two sampling periods were not represented.

Differences between control and heated station coverage for barnacles are in Table 7. Because of limited data in 1971 and 1972 we cannot attribute the apparent decrease in mean coverage at Fox Island North relative to Giants Neck in 1973 over that exhibited during the preoperational years to Millstone operations. The two other stations differed by about 20% during one of the 2 preoperational years (1969 and 1970). Thus, changes at least this large in the operational years would be necessary in order to reach any conclusion.

TABLE 6. Differences Between Coverage (% of Total Transect Area Covered) for the Algal *Ascophyllum nodosum* at Control and Heated Stations¹

MONTH PERCENTAGE ESTIMATED	GIANTS NECK (-) FOX ISLAND NORM	GIANTS NECK (-) FOX ISLAND SOUTH	GIANTS NECK (-) BAY POINT
PREOPERATIONAL PERIOD			
<u>1969</u>			
MAY	20	- 20	
JUL	-	- 20	
SEP	-	+ 10	
DEC	-	0	-
MEAN ± SD		-7.5 ± 15.0	-
<u>1970</u>			
FEB		-10	-
MAY	-	0	-
JUL	25	- 10	-
SEP	40	20	-
DEC	40	10	45
MEAN ± SD	35 ± 8.7	2 ± 13	-
OPERATIONAL PERIOD			
<u>1971</u>			
FEB	-	0	-
MAY	- 10	20	25
JUL	20	- 10	25
SEP	23	- 20	-
DEC	10	10	38
MEAN ± SD	10 ± 14.1	0 ± 15.8	29.3 ± 7.5
<u>1972</u>			
FEB	30	10	39
MAY	10	-	-
JUL	10	30	-
SEP	30	10	-
DEC	10	0	-
MEAN ± SD	18 ± 10.9	10 ± 12.3	
<u>1973</u>			
FEB	15	5	
MAY	40	15	44
JUL	55	30	59
SEP	49	10	
DEC	40	20	-
MEAN ± SD	39.8 ± 15.3	15 ± 9.6	51.5

¹ IF THE SPECIES WAS NOT MENTIONED AS SEEN AT ONE OR THE OTHER STATION
NO VALUE IS PRESENTED ABOVE

TABLE 7. Differences Between Coverage (%of Total Transect Area Covered) for the Barnacle Balanus balanoides at Control and Heated Stations

MONTH PERCENTAGE ESTIMATED	GIANTS NECK (-) FOX ISLAND NORM	GIANTS NECK (-) FOX ISLAND SOUM	GIANTS NECK (-) ¹ BAY POINT
PREOPERATIONAL PERIOD			
<u>1969</u>			
MAY	- 10	-	10
JUL	- 5	40	15
SEP	- 10	15	45
DEC	0	25	- 10
MEAN ± SD	-6.3 ± 4.8	26.7 ± 12.6	15.0 ± 22.7
<u>1970</u>			
FEB	-	-	-
MAY	- 40	- 20	- 40
JUL	- 5	10	- 5
SEP	20	25	30
DEC	-	-	-
MEAN ± SD	-8.3 ± 30.1	5.0 ± 22.9	-5.0 ± 35.0
OPERATIONAL PERIOD			
<u>1971</u>			
FEB		8	
MAY		5	0
JUL	-	-	-
SEP	20	-	30
DEC	-	-	-
MEAN ± SD		6.5	15
<u>1972</u>			
FEB	-	25	-
MAY	-	-	-
JUL	-	-	-
SEP	-	-	-
DEC	-	-	-
MEAN ± SD			
<u>1973</u>			
FEB	0	10	-
MAY	10	0	- 5
JUL	35	0	5
SEP	35	15	40
DEC	20	5	20
MEAN ± SD	20 ± 15.4	6 ± 6.5	15 ± 19.6

¹ ACTUALLY Balanus creantus AT BAY POINT

TABLE 8. Differences Between Coverage (% of Total Transect Area Covered) for the Algae *Fucus* spp at Control and Heated Stations

MONTH PERCENTAGE ESTIMATED	GIANTS NECK (-) FOX ISLAND NORM	GIANTS NECK (-) FOX ISLAND SOUTH	GIANTS NECK (-) BAY POINT
PREOPERATIONAL PERIOD			
<u>1969</u>			
MAY	- 20	20	35
JUL	- 30	20	50
SEP	- 40	- 10	45
DEC	- 25	0	15
MEAN ± SD	-28.8 ± 8.3	7.5 ± 15	36.3 ± 15.5
<u>1970</u>			
FEB	0	10	40
MAY	- 10	25	40
JUL	5	35	-
SEP	- 25	0	55
DEC	- 10	- 20	30
MEAN ± SD	-8 ± 11.5	0 ± 24.2	41.3 ± 10.3
OPERATIONAL PERIOD			
<u>1971</u>			
FEB	-	0	-
MAY	- 20	- 40	15
JUL	- 10	10	45
SEP	0	50	-
DEC	0	15	38
MEAN ± SD	-7.5 ± 9.6	7 ± 32.3	32.7 ± 15.7
<u>1972</u>			
FEB	- 20	10	-
MAY	20	65	-
JUL	20	- 10	-
SEP	0	30	-
DEC	10	20	-
MEAN ± SD	6 ± 16.7	23 ± 27.8	-
<u>1973</u>			
FEB	- 10	15	-
MAY	- 15	10	-
JUL	- 10	20	-
SEP	- 30	20	-
DEC	- 15	15	-
MEAN ± SD	+16 ± 8.2	16 ± 4.2	-

TABLE 9. Differences Between Coverage (% of Total Transect Area Covered) for the Algal Chondrus crispus at Control and Heated Stations

<u>MONTH PERCENTAGE ESTIMATED</u>	<u>GIANTS NECK (-) FOX I ISLAND NORTH</u>	<u>GIANTS NECK (-) FOX I ISLAND SOUTH</u>	<u>GIANTS NECK (-) BAY POINT</u>
<u>PREOPERATIONAL PERIOD</u>			
<u>1969</u>			
MAY		-	
JUL		-	
SEP		-	
DEC	40	-	-
MEAN $\pm$ SD	-		-
<u>1970</u>			
FEB	-		-
MAY	- 5		-
JUL	-	-	-
SEP	15	10	-
DEC	0	- 25	- 7
MEAN $\pm$ SD	3.3 $\pm$ 10.4	-7.5	
<u>OPERATIONAL PERIOD</u>			
<u>1971</u>			
FEB	-	0	
MAY	0	5	5
JUL	-	-	-
SEP	5	5	- 40
DEC	0	0	0
MEAN $\pm$ SD	1.7 $\pm$ 29	2.5 $\pm$ 29	-11.7 $\pm$ 24.7
<u>1972</u>			
FEB	4	- 5	- 5
MAY	-	0	0
JUL	0	-	0
SEP	0	0	2
DEC	-	-	-
MEAN $\pm$ SD	13 $\pm$ 23	-1.7 $\pm$ 29	0.8 $\pm$ 3
<u>1973</u>			
FEB	4	0	- 5
MAY	2	2	- 2
JUL	0	0	- 4
SEP	2	-	0
DEC	4	0	0
MEAN $\pm$ SD	24 $\pm$ 17	0.5 $\pm$ 1	-22 $\pm$ 23

The station differences for the algae Fucus species are in Table 8. Fox Island North station coverage remained nearly constant relative to Giants Neck coverage values over the 5 yr period (1972 might be an exception) studied, even though percent coverage apparently declined at both stations (see Table 5 and compare data from 1969 with 1973). A similar diminution is evident for coverage at Fox Island South (Table 5) but, again, the nearly concomitant change at Giants Neck resulted in almost constant station differences. Few data were available from the operational period at Bay Point so comparisons were not made. However, if the unreported coverage values really were nearly zero, and not missing as shown, then a reduction in coverage similar to all the other stations probably occurred. Overall, it appears that coverage by Fucus species declined over the study period irrespective of the status of the Millstone Plant. The availability of data from a second control station would be of substantial aid in validating such an assertion.

The difficulties in quantitatively/qualitatively evaluating coverage for a less abundant algal species Chondrus crispus is evident from Table 9. Few preoperational data were available and mean differences tended toward zero because observed coverages were often between 0 and 10% (Table 5). Thus, quantitative analysis of "estimated coverage" for less abundant flora or fauna may be impossible under the best conditions of measurement and frequency of observation.

Summary

We did not statistically assess the percent coverage data for significant changes for three algal species and barnacles because of the reported measurement error and at times, limited data. However, a qualitative examination of the coverage results indicate that both Ascopyllum nodosum and Balanus balanoides showed changes which were difficult to interpret in terms of the operational/preoperational status of Millstone. Coverage by Fucus species declined at all stations. We questioned the usefulness of coverage measurements for less abundant species in assessing change, but believe the

measurements for more abundant species should be quantitative where possible, rather than estimated, **if** statistically reliable estimates of change are desired (in addition to good experimental or survey design with adequate replication).

BARNACLE STUDY

The data obtained at the five sampling stations are in Table 10 and the average difference in adult barnacle diameters (mm) for the control (Giants Neck) and three heated stations are in Figures 10-12. We did not examine the size difference for barnacles from Giants Neck and Bay Point because the two species were different.

TABLE 10. Average Base Diameters (mm) for Adult Barnacles taken at the Millstone Point Area¹

DATE CAUGHT	STATIONS				
	GIANTS NECK	WHITE POINT	FOX ISLAND NORTH	FOX ISLAND SOUTH	BAY POINT
PREOPERATIONAL PERIOD					
<u>1969</u>					
MAY	6.6	6.3	6.5	5.2	3.5
JUL	7.9	8.0	6.7	6.6	6.4
SEP	7.9	6.9	8.2	7.1	7.6
DEC	7.7	7.6	7.5	7.1	7.6
<u>1970</u>					
FEB	8.2	8.0	7.8	7.3	9.1
MAY	5.9	6.2	5.7	5.6	4.6
JUL	8.1	8.0	7.5	6.8	7.7
SEP	9.2	8.7	8.6	7.6	9.0
DEC	8.4	8.4	8.0	7.5	9.6
OPERATIONAL PERIOD					
<u>1971</u>					
FEB	7.7	7.7	7.6	6.3	8.7
MAY	7.9	7.9	7.9	7.3	8.2
JUL	8.1	8.4	8.8	7.3	11.0
SEP	8.6	9.1	8.7	8.3	9.6
DEC	8.7	9.1	9.0	8.8	10.1
<u>1972</u>					
FEB	8.8	8.0	7.7	7.9	8.8
MAY	7.7	7.9	7.6	7.5	8.6
JUL	8.4	8.8	8.2	8.3	8.7
SEP	9.3	9.2	8.6	8.1	10.3
DEC	8.4	8.9	8.1	7.7	9.9

¹ EACH ENTRY REPRESENTS MEAN OF SIX QUADRATS. THIRTY RANDOMLY CHOSEN BARNACLES WERE MEASURED IN EACH QUADRAT

FIGURE 10. Difference Between Adult Barnacle Diameters (mm) at Giants Neck and Fox Island South

FIGURE 11. Difference Between Adult Barnacle Diameters (mm) at Giants Neck and Fox Island North

FIGURE 12. Difference Between Adult Barnacle Diameters (mm) at Giants Neck and White Point

It appears that average barnacle diameters were larger at Giants Neck (Figures 10-12) than at all three heated stations during the preoperational period (no exceptions at Fox Island South, one at Fox Island North and two at White Point). Confidence limits (see the figure legends for the appropriate value to add or subtract from the means) for the preoperational data support this statement for the two Fox Island stations because zero differences are not in the interval (hopefully by using station barnacle diameter differences in our evaluation some of the serial correlation in the data were removed). Moreover, when the reactor became operational all three average diameter differences were closer to zero, indicating diameters at the heated stations approached those of the control animals at Giants Neck. In fact, average barnacle diameters increased each year at Giants Neck 7.5 ± 1.6 , 8.0 ± 0.6 , 8.2 ± 0.6 , (mean $\pm$ standard deviation) so that more than just proportional diameter increases took place at the other stations.

Summary

No evidence for changes in barnacle diameters due to the operation of Millstone were found. Moreover, the data suggest that stations subjected to the effluent may have barnacles with diameters averages larger than expected during plant operation. However, this observation cannot be statistically supported.

INTERTIDAL SAND INFAUNA

The data collected at two nearly similar stations are in Table 11 where both total organisms counted and numbers of the principal organism (gem clam, Gemma gemma) are listed. It appears from both counts at each station and station count differences that 1969 was not a representative year, especially during December. We have plotted the differences between the control (Giants Neck) and heated station (Jordan Cove) for total organisms in Figure 13 and the gem clam in Figure 14. Even though we have included the very low values from 1969 in the calculation of preoperational average differences (legend of each figure), it appears that the two stations were "more alike" during operational periods since these means were closer to zero. The reason (at least insofar as a comparison to 1970 data is concerned) was decreased total counts at Giants Neck (means and standard deviations were 2165 ± 596 , 878 ± 363 and 1176 ± 789 for 1970, 1971 and 1972, respectively) while total counts were nearly constant at Jordan Cove (1015 ± 484 , 1147 ± 746 , and 920 ± 552). We have no reason to ascribe decreased counts at Giants Neck to other than normal population cycles. Since no concomitant decline in counts (relative to 1970) occurred at Jordan Cove, it is possible that Millstone heated effluents were beneficial. We could not statistically evaluate this possibility.

Summary

Total counts of sand infauna organisms decreased at the control station during the years compared to the preoperational years. However, no such decline was observed at the heated station, so no detrimental effect due to Millstone operation could be determined. However, this could not be tested statistically.

TABLE 11. Total Number of Intertidal Sand Organisms and Number of *Gemma gemma* (Organisms/3197 cm³) taken at the Millstone Point Area¹

DATE CAUGHT	STATION				GIANTS NECK (-) JORDAN COVE	
	GIANTS NECK		JORDAN COVE		GIANTS NECK (-) JORDAN COVE	
	TOTAL	TOTAL <i>Gemma gemma</i>	TOTAL	TOTAL <i>Gemma gemma</i>	TOTAL	TOTAL <i>Gemma gemma</i>
PREOPERATIONAL PERIOD						
<u>1969</u>						
MAY	233	229 (98) ²	41	41 (100)	192	188
JUL	521	428 (82)	180	84 (47)	341	334
SEP	245	236 (96)	134	107 (80)	111	129
DEC	43	29 (67)	27	9 (33)	16	20
<u>1970</u>						
FEB	1594	1137 (71)	370	333 (90)	1224	904
MAY	1475	690 (47)	869	508 (58)	606	182
JUL	2826	1180 (42)	1303	543 (42)	1523	637
SEP	2424	1345 (56)	1648	902 (54)	776	443
DEC	2510	1447 (58)	886	675 (76)	1624	772
OPERATIONAL PERIOD						
<u>1971</u>						
FEB	1018	470 (44)	817	649 (81)	261	- 179
MAY	1144	484 (42)	1399	344 (25)	- 255	140
JUL	870	441 (51)	550	183 (33)	320	258
SEP	255	179 (70)	626	256 (41)	- 371	- 77
DEC	1042	443 (43)	2343	2170 (93)	- 1301	- 1727
<u>1972</u>						
FEB	957	540 (56)	690	604 (88)	267	- 64
MAY	830	627 (76)	176	147 (84)	654	480
JUL	2577	1022 (48)	1652	531 (32)	925	701
SEP	840	593 (71)	887	383 (43)	- 47	210
DEC	675	675 (49)	1197	799 (67)	- 522	- 124
<u>1973</u>						
FEB	2064	1146 (56)	624	581 (93)	1440	565
MAY	1287	517 (40)	744	665 (89)	543	- 148

1 EACH ENTRY REPRESENTS THE SUM OF FIVE SUBSAMPLES (639.39 cm³) / SITE

2 PARENTHETIC VALUES ARE PERCENTAGES OF *Gemma gemma*

FIGURE 13. Difference Between Number of Total Intertidal Sand Organisms (Number/cm³) at Giants Neck and Jordan Cove

FIGURE 14. Differences Between Numbers of *Gemma gemma* (Organisms/3197 cm³) at Giants Neck and Jordan Cove

OYSTER GROWTH STUDY

The data for both average oyster length and weight collected at one control (Giants Neck) and three heated stations are shown in Table 12. The study was designed to test the supposition that heated effluents might effect the food supply for oysters and thereby change growth patterns for these animals. Oysters were not indigenous to the Millstone area so growth may not be as good as could be expected where they occur naturally. It should be noted, also, that the water at the Quarry Cut site was extremely turbulent so that growth could have been impaired simply by this factor alone.

TABLE 12. Average Weight (g) and Length (mm) for Adult Oysters Held in Trays at the Millstone Point Area¹

DATE SAMPLED	GIANTS NECK		WHITE POINT		FOX ISLAND		QUARRY CUT	
	WEIGHT	LENGTH	WEIGHT	LENGTH	WEIGHT	LENGTH	WEIGHT	LENGTH
PREOPERATIONAL PERIOD								
<u>1970 - 1971</u>								
MAY	49	78	44	78	42	76	45	76
JUL	40	84	41	85	37	80	40	82
SEP	47	84	47	85	41	84	43	83
DEC	49	84	49	88	45	85	48	82
OPERATIONAL PERIOD								
FEB	48	84	4	8	8	7	4	6
MAY	48	87	53	90	43	88	50	82
<u>1971 - 1972</u>								
MAY	44	86	4	4	8	4	4	8
JUL	43	93	4	2	9	4	4	2
SEP	47	92	53	100	50	99	55	90
DEC	52	90	58	100	53	101	56	85
FEB			56	99	56	99	60	89
MAY			58	99	55	98	58	91
<u>1972 - 1973</u>								
MAY	42	96	3	8	9	2	4	3
JUL	46	102	41	98	44	97	41	94
SEP	46	98	45	102			43	96
DEC	45	93	49	102			43	95
FEB	41	91	48	101			40	92
<u>1973 - 1974</u>								
R B	36	87	35	87	39	86	37	88
MAY	36	86	40	87	39	87	40	88 (2)
JUL	41	90	43	89	42	88	42	89
SEP	43	91	45	93	43	91	47	91
DEC	42	87	4	5	9	2	4	8
FEB	41	88	41	91	46	91	46	92

1 EACH YEAR A NEW GROUP OF OYSTERS WERE PLACED AT EACH STATION. EACH TABLED VALUE USUALLY REPRESENTS THE MEAN OF 50 OYSTERS BUT VARIED FROM 30 TO 60.

2 STATION LOCATION CHANGED SLIGHTLY

In order to visually assess changes at heated stations relative to the control, we have plotted the station differences (control-heated) for average weight and length in Figures 15 and 16, respectively. All three heated stations had oysters with average weights or lengths either nearly equal to or larger than those exhibited by oysters at Giants Neck during both the 1971-1972 and 1973-1974 periods. However, similar difference patterns were evident during preoperation except for the Fox Island station. During a long portion of 1972-1973 the reactor was not operational and the difference patterns obtained show slightly smaller animals at the heated stations relative to those from Giants Neck.

FIGURE 15. Difference Between Average Weight (g) for Adult Oyster at Giants Neck and Other Stations

FIGURE 16. Difference Between Average Length (mm) for Adult Oysters at Giants Neck and Other Stations

During the four "growing seasons" mean weights at Giants Neck declined (47, 46, 44, and 40 grams for the four respective growth seasons) while the weights for animals from heated stations generally either did not decline as far or actually increased relative to preoperational values (Table 13) except for 1972-1973 when the reactor was not operating for a long period. Without data from an additional control site, we cannot be sure that the declining weights at Giants Neck were normal for unheated areas. There is, however, the suggestion based only on a qualitative examination of the data that oyster growth was unaffected by the operation of the Millstone Plant. However, we cannot validate such an assertion.

Since both weight and length measurements were collected on the same animals over the entire study period, we investigated the linear relationships between the two measurements for each station to assess the usefulness of obtaining both measurements. Tabular results are in Table 14 and the data as well as an overall linear regression relationship are plotted in Figure 17. The latter regressions were calculated even though we realize that the independent variable (weight) was not measured without error which may invalidate t-test used.

TABLE 13. Statistics for "Growing Season" Weights and Lengths of Oysters at the Millstone Point Area

Date Sampled	Giants Neck		White Point		Fox Island		Quarry Cut	
	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)	Weight (g)	Length (mm)
<u>1970-1971</u>								
Average	46.8	83.5	47.3	85.5	42.3	83.0	46.8	82.5
Standard Deviation	3.43	2.95	3.93	4.14	3.20	4.29	5.34	4.46
<u>1971-1972</u>								
Average	46.5	90.3	51.8	96.0	50.0	96.5	52.8	87.8
Standard Deviation	4.04	3.10	7.11	6.29	5.83	5.05	7.08	2.48
<u>1972-1973</u>								
Average	44.0	96.0	44.2	99.0	43.5	96.5	40.2	94.4
Standard Deviation	2.35	4.30	4.66	4.24	--	--	3.70	1.52
<u>1973-1974</u>								
Average	39.8	88.2	41.5	89.8	42.8	88.8	43.8	89.8
Standard Deviation	3.06	1.94	3.78	2.56	3.66	2.14	5.12	1.72

TABLE 14. Linear Regressions for Average Adult Oyster Weight on Oyster Length at Four Millstone Point Area Stations

<u>Stations</u>	<u>Intercept</u>	<u>t-Statistic</u>	<u>Slope</u>	<u>t-Statistic</u>
Giants Neck	91.6	6.92**	-0.57	-0.19
White Point	69.7	6.96**	0.489	2.28*
Fox Island	48.8	4.91 **	0.921	4.19**
Quarry Cut	91.9	12.50**	-0.075	-0.48
All Combined	76.8	15.00***	0.291	2.61**

Estimates are significantly different from zero (*, $P < 0.05$; **, $P < 0.01$).

FIGURE 17. Relationship Between Average Weight (g) and Length (mm) for Adult Oysters at the Millstone Point Area (1970-1974)

The estimated linear regression slopes for Fox Island and White Point were positive and statistically significant while those for Giants Neck and Quarry Cut were not significantly different from zero. Intercept values were significantly different from zero, so that zero weight would not result in a zero length prediction for any station which is biologically impossible and indicates the linear regression model is incorrect. We did not recalculate the relationship with zero intercepts or investigate a power function model sometimes used in such comparisons. Since weights and lengths were poorly related at Giants Neck and Quarry Cut but significantly related at the other two stations, it was appropriate to measure and evaluate both variables to assess change due to the operation of Millstone. However, the poorer relationship at the former two stations leads us to question the "representativeness" of animals grown at both these stations. The linear regression in Figure 17 indicates that deviations are extremely large and that any conclusions are tenuous.

Summary

The analysis of oyster weight data suggest that Millstone operations had no effect on oyster growth. We could not statistically validate this conclusion. Length and weight data were significantly correlated at two of four stations so both variables should be measured.

TRACE METALS

After Millstone Power Plant became operational, studies were initiated to determine trace metal levels in oysters, mussels and seawater. Mussels were indigenous to the Millstone area but apparently did not grow near the discharge station (Quarry Cut or Effluent Station) since no sample values were reported from that location. Oysters were not a normal resident so they were artificially maintained as biological monitors for trace metals. The data for the three trace metals found in highest concentrations in oysters are in Table 15 and the complete data set including mussel and seawater levels for the same metals are plotted in Figures 18-20. These figures show that the metal concentrations (ppm) in seawater would be difficult to quantitatively relate to those of either mussel or oyster tissue.

The reason(s) is probably related to the fact that animals are subjected to amounts of trace metals in water which vary over orders of magnitude between quarterly sampling dates and that other metabolic factors related to season and life stage of the animal are involved. Interestingly, seawater from the Quarry location usually had soluble iron, copper and zinc levels no higher than Giants Neck whereas the Giants Neck station seawater was highest in insoluble iron for two of the three years sampled. In this latter case, concentrations ranged over two orders of magnitude over the three year period.

TABLE 15. Metal Concentrations (ppm) for Tray Grown Oysters Tissue at Millstone Nuclear Power Station

Date Sampled	Copper			Iron			Zinc			Value Plotted ¹ (Figure)
	Giants Neck	Fox Island	Quarry Cut	Giants Neck	Fox Island	Quarry Cut	Giants Neck	Fox Island	Quarry Cut	
1972										
May	-	155	525	-	45	53	-	2440	1870	QC-FI
Sept	75	-	205	50	-	58	1240	-	1595	QC-GN
1973										
May	113	119	202	35	51	43	1090	1490	1430	QC-GN
July	95	75	370	48	37	87	1270	890	1440	QC-GN
Sept	100	159	470	50	62	112	1282	2283	2058	QC-GN
Dec	130	140	430	46	43	82	1650	1860	2150	QC-GN
Feb	104	40	247	26	23	35	1800	620	1270	QC-GN
1974										
May	-	107	216	-	33	113	-	1495	1645	QC-FI
July	-	67	248	-	31	64	-	1080	1790	QC-FI
Sept	-	110	330	-	60	170	-	1740	2320	QC-FI
Dec	-	98	357	-	46	60	-	1530	2440	QC-FI

¹QC = Quarry Cut
FI = Fox Island
GN = Giants Neck

FIGURE 18. Levels of Copper (ppm) in Oysters, Mussels and Seawater at Several Stations at Millstone Nuclear Power Station

FIGURE 19. Levels of Zinc (ppm) in Oysters, Mussels and Seawater at Several Stations at Millstone Nuclear Power Station

FIGURE 20. Levels of Iron (ppm) in Oysters, Mussels and Seawater at Several Stations at Millstone Nuclear Power Station

A visual appraisal of the tissue concentrations in mussels and oysters (Figures 18-20) indicated that Quarry Cut oysters seemed to exhibit higher values than the control station. We calculated the concentration differences for Quarry Cut and Giants Neck, but used metal concentration in oyster from Fox Island when no data were reported for Giants Neck (Figure 21). The upper panel shows the large difference for copper concentration which was apparent in Figure 18 but the middle panel also shows that iron concentrations were consistently higher at the Quarry Station which was not clear from a cursory examination of Figure 20. Finally, the lower panel indicates tissue zinc values may be higher for oysters grown at the Quarry station but our use of Fox Island concentration data when Giants Neck values were unavailable may have affected the results (see Figure 19). The fact that a 95% confidence interval (use the summary statistics in Figure 21) does not include zero can be used as evidence to support an assertion that both copper and iron concentrations in oysters were significantly higher at the Quarry station than at Giants Neck, but that zinc concentrations lacked consistency and were not significantly different. However, the unknown serial correlation structures of the differences may invalidate the confidence intervals.

FIGURE 21. Differences (ppm) Between Copper, Zinc and Iron Levels in Oysters at Giants Neck or Fox Island and Quarry Cut Stations

Summary

We could not relate oysters and mussels tissue levels of copper, iron and zinc to those of seawater at any station. Both copper and iron levels were significantly ($P < 0.05$) higher at the Quarry station compared to the control station. However, levels in organisms grown at Fox Island were sometimes substituted when the data were unavailable at Giants Neck (control), so our results can be questioned.

SHORE-ZONE FISH (BEACH SEINING)

The total number of shore-zone fish caught in beach seines for the six years of data collection are arranged by species and station in Table 16. Equal fishing effort was expended at each station in each year. Only the fourteen most numerous species are listed even though twenty additional species were caught. However, only 84 individuals or less of these latter species were caught during the entire six years of study. We have evaluated data obtained at Giants Neck, Bay Point, Jordan Cove and White Point because these stations were monitored for the entire study period. Table 16 shows more fish were caught at Jordan Cove while catches at White Point and Giants Neck were of intermediate size and Bay Point was clearly the location where the fewest shore-zone fish were caught. Even though similar sized catches were obtained at Giants Neck and White Point, they were composed of differing numbers of the same or of completely different species. For example, Figures 22 and 23 show that the temporal catch distribution was different at White Point and Giants Neck for total catch of Menidia menidia and Fundulus majalis respectively [i.e., the total numbers of either species caught at White Point or Giants Neck on the same sampling date differed markedly and disproportionately (with respect to total catch) on that date]. The reason for the lack of temporal and spacial consistency are probably related to differences in habitat and characteristics of each station (Table 17). The quantitative problems in assessing change (already formidable with species such as fish because catch data are variable) relative to a control station are even more difficult than usual when such large differences in station characteristics (and thus species likely to frequent each area) are

TABLE 16. Totals for the Most Numerous Species Caught in Seine Hauls¹ at the Millstone Point Area

Species	Giants ² Neck	Bay ² Point	Jordan ² Cove	White ² Point	seaside ³ Point	Crescent ³ Beach	sandy ⁴ Point	Total
<u>Menidia menidia</u>	8050	700	40807	5080	341	212	1978	57168
<u>Fundulus majalis</u>	261	1	4173	711	1	1	789	5937
<u>Brevoortia tyrannus</u>	95	1357	1180	1679	2	1	--	4314
<u>Fundulus heteroclitus</u>	159	1	3345	444	--	147	1598	5694
<u>Menidia beryllina</u>	580	16	633	534	84	74	729	2650
<u>Apeltes quadracus</u>	8	3	1163	17	1	3	241	1436
<u>Pungitius pungitius</u>	9	--	727	4	--	3	--	743
<u>Ammodytes americanus</u>	170	5	--	3108	75	10	4	3372
<u>Mugil cephalus</u>	1231	--	279	--	12	1	--	1523
<u>Cyprinodon variegatus</u>	287	--	240	45	2	2	8	584
<u>Gasterosteus aculeatus</u>	22	2	175	31	24	--	1	255
<u>Anguilla rostrata</u>	35	--	127	1	--	--	2	165
<u>Synbranchus fucus</u>	25	23	15	16	4	12	8	103
<u>Aloea aestivalis</u>	1	55	--	1	--	27	--	84
TOTALS	10933	2163	52864	11671	546	473	5358	84028

¹ Efforts (Number of Samplings) were the same in each year (4, 5, 5, 5, 5, and 6 sampling dates per year for 1969-1974).

² Sampled since May 1969.

³ Sampled since February 1973.

⁴ Sampled since February 1975.

FIGURE 22. Total Numbers of Menidia menidia Caught Using Bag Seine Collections at Four Stations During 1969-1974 in the Millstone Point Area

FIGURE 23. Total Number of *Fundulus majalis* Caught Using Bag Seine Collections at Four Stations During 1969-1974 in the Millstone Point Area

TABLE 17. Physical Characteristics of Beach Seine Stations at Millstone Point Area

Location	Exposure Direction	Wave Action	Bottom	Vegetation	Comments
Giants Neck	Southern	Protected	Medium to coarse Some Rocks	Algae and detritus	Control-Public Beach Comparable to White Point
Bay Point	South-Southwest	Heavy	Coarse Sand Rock Rubble	None	Most Exposed to Surf
Jordan Cove	Southeast	Little	Silt, Sand, and Few Rocks	Eel Grass	Some Freshwater Runoff; Bottom Often Exposed
White Point	Southeast	Moderate-Breakwater	Medium Sand	Little	Some Brackish Freshwater Runoff
Seaside Point	South	Heavy	Medium to Fine Sand	None	---
Crescent Beach	Eastern	Moderate	Medium Sand	None	---

superimposed on the experimental design. On the other hand, selection of such different areas probably assured that almost all shore-zone fish species present in the Millstone areas would be identified, but reduced sampling frequencies, compared to those actually used, could have been employed for this purpose. Figures 22 and 23 also show that seining in February and May of each year did not result in a large enough catch of either species to be useful in assessing change. This point is emphasized in Figure 24 where total fish caught are plotted as a function of time for the control (Giants Neck) and most productive heated stations (Jordan Cove). Again, similar numbers of fish were usually not caught at the same time at the two stations and the numbers caught during February and May sampling periods were small. Moreover, this figure also indicates that a single December effort does not give catches large enough to be useful in detecting changes. In order to obtain adequate numbers of fish whereby an existing change could be detected, it appears that seining effort should be allocated to the July through September period.

FIGURE 24. Total Fish Caught in Three Seine Hauls at Giants Neck and Jordan Cove (1969-1975)

In order to assess changes in shore-zone fish numbers which might be associated with Millstone operations, we calculated the ratio of Giants Neck to Jordan Cove or White Point catches for total fish, the two major species (Fundulus majalis and Menidia menidia) and one "less abundant" species (Gasterosteus aculeatus). These results are shown in Table 18. A t-test of logarithmically transformed ratios showed no significant differences between the preoperational and operational periods (not an unexpected finding considering the size of the coefficients of variation shown in Table 18). However, the mean Giants Neck - Jordan Cove ratio increased during the operational period compared to the preoperational for total fish and the two "abundant" species. In two of three similar comparisons the Giants Neck - White Point ratio also increased. Still, the data were statistically inconclusive when viewed as station ratios compared for the two periods, and because of the large coefficients of variation, they would likely remain so even with more sampling dates within the preoperational and operational periods. However, if data for additional sampling stations had been available for control-heated stations pairs, and the increases noted above were also observed, a nonparametric test could possibly be used which might potentially detect such a change. Ratios calculated for the less abundant species were not useful because fish were usually caught at one station but not the other (i.e. resulting in zero or infinite ratios).

TABLE 18. Arithmetic Means of Preoperational and Operational Beach Seine Station Ratios for Three Selected Species and all Fish at Millstone Point Area

Period	Statistics	Total Fish (All Species)		Fundulus majalis (Striped Killifish)		Menidia menidia (Silverside)		Gasterosteus aculeatus (Three-spine Stickleback)	
		GN/JC ¹	GN/WP	GN/JC	GN/WP	GN/JC	GN/WP	GN/JC	GN/WP
Preoperational	Average	2.05	18	.070	.059	0.251	0.412	0.79	1.17
	Standard Deviation	2.97	38	.061	.042	0.265	0.307	1.101	-
	n	7	5	5	3	8	7	3	2
	Coefficient of Variation	119	216	87	71	106	75	151	-
Operational	Average	19.7	2.81	3.17	5.28	2.38	5.95	0.50	1.3.
	Standard Deviation	38.1	3.75	7.13	11.25	5.01	12.59	-	-
	n	17	17	8	7	28	24	1	2
	Coefficient of Variation	193	133	225	213	211	212	-	-

¹ GN = Giants Neck
JC = Jordan Cove
WP = White Point

Another, more common way to evaluate the data, is to compare yearly averages for preoperational and operational years for each station. One should expect high coefficients of variation because "seasonal" effects are included (which may be removed by time-series methods when many cycles of data with seasonal components are available). We have calculated the means and standard deviations for two preoperational and one operational year (Table 19). Except for data obtained at Bay Point in 1960, the coefficients of variation would be greater than 100% and are not markedly different from those in Table 18. We also calculated means for the summer period of 1974 to attempt to remove "seasonal variability" since more fish were caught during this time than in the other months. Table 19 shows that even though mean values were much larger, respective standard deviations were still very large (i.e. greater than 100% of the means). Thus, further statistical analysis of this data is probably unwarranted.

Summary

It appears that statistical variation was so high, that a very large sampling effort would be necessary to detect a change in shore-zone fish numbers which could be attributed to the operation of Millstone. Continued sampling at the current level of effort probably is not worthwhile. If detecting change in numbers of these fish is deemed important, a considerably expanded program will be necessary, but the program should be intensive in July-September and should include additional control-heated stations pairs. We are not aware of any economical or cost-effective way to assess the meaning of changes in shore-zone fish numbers collected to changes in populations.

TABLE 19. Yearly and Summer Means [Total of three (30 m) Seine Hauls] for Total Fish Caught at the Millstone Point Area

All Data															
	<u>SEASIDE</u>			<u>WHITE POINT</u>			<u>JORDAN COVE</u>			<u>BAY POINT</u>			<u>GIANTS NECK</u>		
<u>Year</u>	<u>n</u>	<u>$\bar{x}$</u>	<u>SD</u>	<u>n</u>	<u>$\bar{x}$</u>	<u>SD</u>	<u>n</u>	<u>$\bar{x}$</u>	<u>SD</u>	<u>n</u>	<u>$\bar{x}$</u>	<u>SD</u>	<u>n</u>	<u>$\bar{x}$</u>	<u>SD</u>
1969	-	-	-	4	405	455	4	1081	1349	4	6.5	4.2	4	216.5	309.3
1970	-	-	-	5	243	329	5	792.8	1081	5	260	572	5	159	179.3
1974	8	8.0	12.2	8	203.9	376	8	840	1331	8	19.0	41.3	8	295	418
June Through September															
1974	4	14	15	4	355	512	4	1683	1714	4	35	58	4	493	531

IMPINGEMENT

The data for the most important (economically) fish species impinged/day as well as all organisms impinged/day are arranged by month for 1972-1974 in Tables 20-22. Over the three year period nearly one-fourth of the total organisms impinged were made up of those economically important fish species, but in certain months they represented differing fractions of total impingement depending on the observational year (Figure 25). If numbers of shellfish and squid as well as other fish species impinged are summed, about 80% of the total impingement for all three years can be accounted for (Tables 23-25). These tables also show that a larger fraction of shellfish and economically important fish were impinged compared to other fish during the three year study period. However, the two classifications, over 7.6 cm contained a smaller fraction of shellfish except in 1972 when a large fraction (52%) was impinged. When total catch/per day was computed for each year and for all three years, no particularly discrepant values were observed (i.e. 67.31/day overall and 56.9, 88.5 and 53.8 organisms/day for 1972-1974, respectively). No extremely divergent values were observed when data were examined monthly (clear bars in Figure 25). Catches of over 100 organisms/day generally occurred in the summer, but in no particular month was special. During 1971, a large summer impingement of menhaden (50 million) was observed, so extraordinary impingements have occurred. Finally, we have prepared Figures 26-28 which summarize the percentage values shown at the bottom of Tables 23-25. Economically important fish constitute a large fraction of the greater than 15.2 cm category, but represent few fish per day (10, 6, and 5 fish/day for 1972-1974). Shellfish survive at a high rate after impingement so the numbers of these species impinged may be of little biological importance.

Summary

Maximum numbers of organisms/day were impinged during 1973. Lesser numbers were caught per day in other years. Over 20% of the total organisms survive impingement at a high rate (shellfish) and only 20-30% were economically important fish species. The importance of the observed impingement is

TABLE 20. Total Impingement/Month and Average Impingement/Day for the Most Numerous Economically Important Fish Species for 1972 at Millstone Nuclear Power Station

<u>MONTH</u>	<u>ATLANTIC MENHADEN</u>	<u>WINTER FLOUNDER</u>	<u>WINDOWPANE ROUNDER</u>	<u>BLUEBACK HERRING</u>	<u>TOTAL</u>	<u>NO. OF DAYS</u>	<u>TOTAL ECONOMICALLY IMPORTANT FISH/DAY</u>	<u>TOTAL ALL ORGANISMS/DAY</u>
JANUARY	0	117	0	33	150	11	14	16
FEBRUARY	0	35	0	0	35	7	5	8
MARCH	0	266	14	38	318	13	24	57
APRIL	19	324	18	22	383	23	17	32
MAY	344	292	52	3	691	28	25	45
JUNE	13	188	385	0	586	30	20	84
JULY	9	82	250	4	345	25	14	79
AUGUST	38	93	508	900	1539	30	51	127
SEPTEMBER	0	106	260	188	554	19	29	83
OCTOBER	1	251	68	450	770	29	27	60
NOVEMBER	0	37	0	66	103	30	3	21
DECEMBER	0	119	0	2	121	30	4	14
TOTAL	424	1910	1555	1706	5595	275	20	57

TABLE 21. Total Impingement/Month and Average Impingement/Day for the Most Numerous Economically Important Fish Species for 1973 at Millstone Nuclear Power Station

<u>MONTH</u>	<u>ATLANTIC MENHADEN</u>	<u>WINTER FLOUNDER</u>	<u>WINDOWPANE FLOUNDER</u>	<u>BLUEBACK HERRING</u>	<u>TOTAL</u>	<u>NO. OF DAYS</u>	<u>TOTAL ECONOMICALLY IMPORTANT FISH/DAY</u>	<u>TOTAL ALL ORGANISMS/DAY</u>
JANUARY	32	874	11	0	918	27	34	56
FEBRUARY	86	872	26	2	986	28	35	60
MARCH	22	894	13	2	931	31	30	56
APRIL	1	325	17	1	344	30	11	69
MAY	0	199	17	4	220	31	7	79
JUNE	1	39	26	1	67	30	2	64
JULY	1	86	46	9	142	31	5	61
AUGUST	1	23	11	48	83	31	3	36
SEPTEMBER	8	17	0	8	33	30	1	22
OCTOBER	1	20	3	10	34	31	1	26
NOVEMBER	30	223	17	23	293	30	10	67
DECEMBER	7	147	25	5	184	31	6	39
TOTAL	190	3719	213	113	4235	361	12	53

TABLE 22. Total Impingement/Month and Average Impingement/Day for the Most Numerous Economically Important Fish Species for 1974 at Millstone Nuclear Power Station

MONTH	ATLANTIC MENHADEN	WINTER FLOUNDER	WINDOWPANE FLOUNDER	BLUEBACK HERRING	TOTAL	NO. OF DAYS	TOTAL ECONOMICALLY IMPORTANT FISH/DAY	TOTAL ALL ORGANISMS/DAY
JANUARY	72	1200	5	0	1277	31	41	63
FEBRUARY	43	1530	13	1	1587	28	57	89
MARCH	10	1622	74	13	1719	31	55	97
APRIL	50	818	113	20	1001	30	32	96
MAY	4	276	159	10	729	31	24	102
JUNE	1	90	76	3	170	30	6	85
JULY	16	36	46	2	100	31	3	41
AUGUST	609	69	57	34	769	29	27	93
SEPTEMBER	111	63	36	31	241	26	9	136
OCTOBER	212	93	48	86	439	29	15	150
NOVEMBER	237	90	58	58	443	28	16	90
DECEMBER	82	268	30	0	380	30	13	51
TOTAL	1447	6155	715	258	8575	354	24	90

FIGURE 25. Monthly Estimates of Average Economically Important Fish and Total Organisms Impinged/Day at the Millstone Nuclear Power Station

TABLE 23. Numbers of the Most Numerous Species Impinged by Size Categories for Millstone Unit 1, in 1972 (275 Days Monitored)

SPECIES	SIZE RANGE			SPECIES TOTAL
	0-7.6 cm	7.6-15.2 cm	15.2 cm AND OVER	
ATLANTIC MENHADEN	0	0	424	424
BLUEBACK HERRING	1636	68	3	1707
WINTER FLOUNDER	122	742	1046	1910
WINDOWPANE ROUNDER	3	109	1443	1555
ATLANTIC SILVERSIDE	3%	191	0	541
GRUBBY	77	129	4	210
THREESPINE STICKLEBACK	217	8	0	225
BLUE CRAB	112	1762	148	2022
AMERICAN LOBSTER	9	619	348	976
ROCK CRAB	4	4	0	8
GREEN CRAB	208	30	0	238
LADY CRAB	1842	78	0	1920
JONAH CRAB	364	109	65	538
SPIDER CRAB	762	11	0	21
HERMIT CRAB	1	20	0	21
HORSESHOE CRAB	1	0	19	20
SQUID	0	0	0	0
TOTAL SIZE CATEGORIES	5708	3880	3500	13088
PERCENTAGE OF ALL	95.5	77.2	75.5	83.7
PERCENTAGE ECONOMIC FISH	29.8	18.3	62.9	35.8
PERCENTAGE OTHER FISH	10.9	6.5	0.1	6.2
PERCENTAGE SHELLFISH	55.9	52.4	12.5	41.7

TABLE 24. Numbers of the Most Numerous Species Impinged by Size Categories for Millstone Unit 1, in 1973 (361 Days Monitored)

SPECIES	SIZE RANGE			SPECIES TOTAL
	0-7.6 cm	7.6-15.2 cm	15.2 cm AND OVER	
ATLANTIC MENHADEN	1113	276	58	1447
BLUEBACK HERRING	38	120	100	258
WINTER FLOUNDER	2382	2179	1594	6155
WINDOWPANE FLOUNDER	26	175	514	715
ATLANTIC SILMRSIDE	303	640	126	1069
GRUBBY	835	429	7	1271
THREESPINE STICKLEBACK	1309	0	0	1309
BLUE CRAB	301	522	63	886
AMERICAN LOBSTER	1182	53	1	1236
ROCK CRAB	966	58	0	1024
GREEN CRAB	737	5	0	742
LADY CRAB	2739	56	0	2795
JONAH CRAB	0	0	0	0
SPIDER CRAB	85	31	13	129
HERMIT CRAB	11	0	0	11
HORSESHOE CRAB	4	0	16	20
SQUID	2000	3130	1499	6629
TOTAL SIZE CATEGORIES	14,031	7674	3991	25,696
PERCENTAGE OF ALL	84.3	85.5	63.1	80.4
PERCENTAGE ECONOMIC FISH	21.4	30.6	35.8	26.8
PERCENTAGE OTHER FISH	14.7	11.9	2.1	11.4
PERCENTAGE SHELLFISH	37.3	8.1	1.5	21.4

TABLE 25. Numbers of the Most Numerous Species Impinged by Size Categories for Millstone Unit 1, in 1974 (361 Days Monitored)

SPECIES	SIZE RANGE			SPECIES TOTAL
	0-7.6 cm	7.6-15.2 cm	15.2 cm AND OVER	
ATLANTIC MENHADEN	151	22	17	190
BLUEBACK HERRING	59	43	6	113
WINTER ROUNDER	1154	1088	1527	3719
WINDOWPANE ROUNDER	14	17	182	213
ATLANTIC SILVERSIDE	377	760	2	1139
GRUBBY	658	3%	9	1063
THREESPINE STICKLEBACK	1104	0	0	1104
BLUE CRAB	275	359	204	838
AMERICAN LOBSTER	1379	13	0	1392
ROCK CRAB	568	11	0	579
GREEN CRAB	796	3	0	799
LADY CRAB	2108	26	0	2134
JONAH CRAB	22	1	1	303
SPIDER CRAB	208	94	1	303
HERMIT CRAB	3	0	0	3
HORSESHOE CRAB	1	58	0	59
SQUID	337	613	433	1383
TOTAL SIZE CATEGORIES	9214	3459	2381	15,054
PERCENTAGE OF ALL	86.2	79.3	59.5	79.0
PERCENTAGE ECONOMIC FISH	12.9	25.8	43.3	22.2
PERCENTAGE OTHER FISH	20.0	26.5	0.3	17.3
PERCENTAGE SHELL FISH	50.2	12.9	5.1	32.2

FIGURE 26. Percentage Distribution of Impingement by Size Categories for the Most Numerous Species Impinged at Millstone Nuclear Power Station in 1972

FIGURE 27. Percentage Distribution of Impingement by Size Categories for the Most Numerous Species Impinged at Millstone Nuclear Power Station in 1973

FIGURE 28. Percentage Distribution of Impingement by Size Categories for the Most Numerous Species Impinged at Millstone Nuclear Power Station in 1974

unknown relative to fish populations around Millstone, but seems trivial. Whether or not the extraordinary impingement of menhaden in 1971 was trivial will probably remain an open question.

EXPOSURE PANEL

In a draft report, Brown and Moore (1976) provided several statistical analyses of most of the species presence/absence data obtained from 1968-1975. In the same document the authors question the usefulness of percent organism coverage estimates as a possible indicator of change due to Millstone operations. Their rejection of these data for quantitative analyses was based on three factors: 1) the percent coverage estimates were subjective and were supposedly accurate to $\pm 5\%$ (no explanation is given as to how this value was obtained or for its meaning), 2) the majority of the percent coverage estimates were 5% or less per panel per organism, and 3) the coverage estimates on each panel after 12 months were dependent on the time of settlement of initial organisms. We have not attempted a statistical analysis for the same reasons and believe the data are only useful in a qualitative manner for narrative descriptions of temporal changes at the sampling stations. It would be extremely difficult to relate any qualitative changes to Millstone operations because the station sites were ecologically different and only one control site (Giants Neck) was sampled. In addition, only one year of preoperational data was available for this station. Battelle (1975) used a chi-square analysis to determine whether categorized percent coverage was dependent on site, year, or month of occurrence. Results were presented descriptively for the site analysis only and no chi-square values were given. The meaning of the chi-square analysis above with regard to the question of changes(s) attributable to Millstone operations is not clear to us. Another caveat, in addition to those above, could be added relative to assumptions implicit in the use of Chi-square. We restate our agreement with Brown and Moore that this data should not be used in an attempt to quantitatively assess change.

■ , Species presence/absence data were evaluated by Brown and Moore (1976)
using three different statistical tests (four if time series analysis was
.

included). All three analysis gave the same result, i.e., no statistical differences in numbers of species counted per month per panel could be associated with Millstone operations. Since station differences of 3.5 species per month were detectable, these authors infer that any effects due to Millstone operations must be smaller than this value. On the other hand, Battelle (1975) reports that significant positive regressions of total number of different species observed per year versus year observed were obtained ($P < 0.01$, for data from 1968 to 1975) for Fox Island North, Giants Neck, and White Point. We could not ascertain whether these increases were due to increased occurrence of infrequent organisms, a reflection of better and more accurate identifications during the course of the study or a reflection of increased occurrence of abundant organisms. Since the change occurred at the control station also, it would be incorrect to attribute the change to the operation of Millstone.

Species diversity indices were computed using the same presence/absence values. The use of diversity and/or similarity indices to ascertain change in this study and in other studies at Millstone as well, led us to prepare a supplemental study on the usefulness of similarity measures as quantitative tools to detect changes in species composition. The results of that study, Johnston (1977a, 1977b), indicate that similarity indices are not useful for assessing changes in species composition.

Summary

Only the presence/absence data were useful in a quantitative assessment of changes in numbers of boring and fouling species. Regression analyses of species presence/absence data showed no differences attributable to Millstone operations.

WNIER FLOUNDER MODEL

An extensive effort has been made to devise a model to predict the effects of larval entrainment at Millstone on winter flounder population. Three submodels were used (coupled) to accomplish this goal. The hydrodynamic section simulates local tidal circulation, the concentration

submodel mimics dispersal of larvae, and the population submodel for flounder is of the "box and arrow" type and incorporates a Ricker type stock-recruitment curve.

Our evaluation of the biological portions of the model indicates that the assumptions made are logical and that "if" the model represents the real world, we believe the results (projections) may be conservative. This latter belief is based on the fact that no density dependent mortality features for most life stages are included in the model and because alternate areas are available to spawning females and are undoubtedly used. These factors would be expected to reduce the impact on the winter flounder populations.

When the calculated entrainment value (1%) for winter flounder larvae (see section following) is used in conjunction with the model output, predicted impacts (slightly over 5% of the local adult population would be lost over 35 yr) are an order of magnitude below levels which would be considered ecologically detrimental. Since the assumptions used in the model appeared conservative and since the larvae entrainment estimate is thought to be conservative, it does not appear that the flounder population is in jeopardy due to the operation of Millstone 1. However, it is nearly impossible (beyond the state-of-the-art) to construct a model for most ecological populations in which we can have complete confidence. The reasons, at least for longer lived species, are usually lack of data and more importantly a lack of understanding as to how the species functions during all life stages. Thus, models, including this one, should not be considered quantitative and as such we prefer to call the output from such exercises projections. In addition, in the case of the flounder model projections, we cannot separate Millstone effects from other life span insults such as oil pollution, changed fishing pressures, and carrying capacities. Another factor confounding the results is the inability to identify subpopulations.

In spite of the above caveats on the models' limitations, we believe its projections can be useful in the decision process. Apparently flounder larvae entrainment was thought to be a serious problem, so appropriate field studies were required and a simulation model devised. The results and understandings now available can be used to aid in designing additional field

sampling programs to obtain needed information identified in building and running the model (i.e. life stages, behavior, etc.). Additional changes in model structure can be made until the results are "satisfactory". Since mimicing real data is not necessarily proof of model validity, some sort of stopping rule should be agreed to so field studies are not continued indefinitely. In our discussion above, we found that projected population effects appeared to be an order of magnitude below those which are considered ecologically detrimental. Perhaps after x-years of model refinement and field studies, an impact estimate that is an order of magnitude below an assumed ecologically detrimental level could be a point where studies should be terminated.

Summary

We have discussed the projections obtained from use of the winter flounder model in light of both its limitations and those of such models in general. We conclude that the projected effect of larval entrainment on adult flounder populations was likely conservative, but that there is no way to assess the reliability of such a statement. We proposed that the model can be used to aid the field sampling design. In addition, we have proposed a rule whereby field sampling might be ended after an appropriate number of seasons.

ENTRAINMENT

Studies were conducted on entrainment of zooplankton, phytoplankton, and ichthyoplankton from 1971-1975 by personnel of the Wood's Hole Oceanographic Institution. In addition, an off-shore sampling program for zooplankton and ichthyoplankton has been conducted by Northeast Utilities (1975) since 1973. In 1975 a third consultant was appointed to carry out entrainment monitoring at Millstone for both Units 1 and 2. In order to be sure data collected in this latter program would be comparable to prior studies, an extensive program of parallel testing of methods and critical review of prior data was initiated, Northeast Utilities (1975). Problems were identified and discussed and best estimates of temporal numbers and/or weight per m³

were usually made for the intake, discharge or Quarry Cut (but principally the discharge). Estimates of daily entrainment were made by multiplying the maximum 24 hr flow through the reactor by the abundance/ m^3 and using this value to represent daily totals between different sampling days (usually not less than 4 or more than 17). In this way monthly and yearly numbers entrained could be obtained by summing over appropriate intervals. We have previously noted, Gore et al. (1976a), that such a procedure can sometimes introduce a large bias when daily "catch" varies widely.

In order to estimate the fraction of the available organisms entrained, an assessment of the population in a defined source area is needed. This can be accomplished for some fish species either by sampling the source area (fraught with sampling and interpretive difficulties) or by using estimates of numbers of spawning females, associated fecundities, and hatching success to obtain a yearly estimate. This latter method of calculating the population value is questionable because the estimates used in its construction are often qualitative estimates. In the latter case, variability of fraction entrained would be expressed from year to year while the use of sampling methods gives more within year estimates (an expensive proposition). In the case of Millstone 1, the only estimate we found was 1.1% for winter flounder, Northeast Utilities (1975) and was based on estimated adult population parameters as outlined above. Arguments are presented that this is a conservative estimate. The meaning of such an entrainment to the flounder population is unknown. However, a population model (discussed in the previous section) indicates little effect, particularly if this entrainment estimate is actually conservative. If, in addition, the other aspects of the flounder model are conservative, then no effect would be projected due to Millstone 1 operations.

Using surface outflow from Long Island Sound, the flow through the Millstone stations, data on zooplankton numbers (cells/m^3), and a 70% mortality estimate, between 0.08 and 0.27% of the surface zooplankton population was apparently killed by Millstone operations. Use of some alternative

assumptions about flow can result in slightly higher estimates. Some reservations about the accuracy of the zooplankton data have been expressed, Northeast Utilities (1975). The questions principally concern flow measurements taken in conjunction with zooplankton sampling. If the mortalities from the operation of other power plants located on the Sound are added to the above value then larger fractions of the Sound's surface populations are undoubtedly killed. Since zooplanktons reproduce rapidly, such entrainment levels appear easily tolerated.

Summary

Initial estimates of the fraction of flounder and zooplankton entrained and killed were made. Such factors as net avoidance and extrusions were not considered. Additional estimates for different times and other fish species should be made to identify peculiarities of season and to obtain a notion of the range of values. It appears that the use of these values in "population models" may be useful in assessing possible population effects, at least on an order of magnitude basis. Once adequate estimates of the entrained fraction are obtained then these studies should be terminated.

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