Entergy

Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station
600 Rocky Hill Road
Plymouth, MA 02360

J. F. Alexander
Director
Nuclear Assessment

December 8, 2000
ENV1.00.020

Mr. David Webster, Manager
Massachusetts State Program Office
U. S. Environmental Protection Agency
Region 1
1 Congress Street, Suite 1100
Boston, MA 02114-2023

Re: Response to 6/9/00 §308 Letter and to Other §316(b) Questions Raised at the Meeting of 9/27/00

Dear Mr. Webster:

Consistent with our meeting of September 27, 2000, Entergy Nuclear Generation Company (ENGC) hereby responds to the U. S. EPA's §308 letter of June 9, 2000 and to additional questions raised at our meeting held at your office on September 27, 2000. ENGC is also taking this opportunity to submit the results of the Winter Flounder Larvae Transport Study (larvae to larvae study) and the associated Winter Flounder Entrainment Statistical Analysis Report.

A) <u>Winter Flounder Larvae Transport Study (larvae to larvae study)</u>

In ENGC's February 14, 2000 letter detailing the 2000 Marine Fisheries Monitoring Programs and Plans, we reported that we would be conducting winter flounder larvae field sampling studies to determine the relationship of larvae entrained at Pilgrim Station to the amount of larvae passing the Station in offshore Cape Cod Bay waters (a.k.a., the larvae to larvae study). The study was conducted in May, and we plan to include the results in our annual Marine Ecology Studies report due in April 2001.

In an effort to facilitate your review of our §316 Demonstration, ENGC is also including the larvae to larvae study final report as Attachment #1 to this letter. The results of this study confirm and strengthen the conclusion reached in our §316 Demonstration report; i.e., that the present cooling water intake structure configuration at Pilgrim Station does not have an adverse environmental impact on the winter flounder larval population. The report concludes that the effect of entrainment at Pilgrim Station on the winter flounder larval population can be conservatively estimated at <1%.

Please note that ENGC is in the process of copyrighting this report, and we request that EPA treat this report as such.

B) Winter Flounder Entrainment Statistical Analysis Report

In conjunction with the larval transport study, ENGC was asked to perform a statistical analysis to determine whether the data collected during the current entrainment sampling schedule (3 times per week during spawning season) is sufficiently representative of actual entrainment variation to provide an accurate estimate of the overall entrainment rate. Sampling data from the May 2000 larvae to larvae study was compared to data from the long-term entrainment monitoring program from May 1994-2000. This analysis was performed by ENSR and is included as Attachment #2 to this letter.

The report concludes that the long-term monitoring program (May 1994-2000) is conservatively representative of the population sampled in the focused entrainment monitoring program conducted as part of the larvae to larvae study in May 2000.

C) June 9, 2000 §308 Letter

In your June 9th letter you requested that ENGC conduct population model impact assessments for winter flounder which include:

- Eggs per Recruit
- Spawning Stock Biomass per Recruit
- Production Forgone
- Completely Mixed Model

The requested models were run by Marine Research, Inc. for ENGC and the results are detailed in MRI's report entitled: "PNPS Impact Assessment Models", October 30, 2000, which is included as Attachment #3 to this submittal. These modeling runs are essentially mathematical exercises, which result in projections or discrete values (e.g., production foregone), the significance of which correlates to other studies, such as the absolute abundance area swept population estimate, submitted as part of our semi-annual report on Marine Ecology Studies and the "larvae to larvae" study, discussed in detail further on in this submittal.

EPA further requested that ENGC rerun the RAMAS model using certain Cape Cod Bay (as opposed to available data from Narragansett Bay) parameters relating to the stock-recruitment function as input data where practicable. At the time of the request, it was believed that this data could be obtained from the Massachusetts Division of Marine Fisheries (DMF). Subsequent discussions by Mike Scherer of MRI with DMF revealed that Cape Cod specific data is not available from any source to rerun the RAMAS Model. Based upon these representations by DMF staff, no revised RAMAS models are provided. Further, we understand that the use of the existing data is consistent with established industry practice.

Finally EPA posed two questions relative to the variable speed pump analysis in our 316 Demonstration Document. The questions and responses are detailed below:

Question A: How was the reduction in conditional mortality calculated using variable speed pumps as best technology available (BTA) under §316(b)?

Response: We understand from ENSR that the reduction in conditional mortality using variable speed pumps was determined for each species using a direct proportional relationship based on historical entrainment and impingement data using the following conservative assumptions and established calculation procedures:

Assumptions:

- Levels of entrainment and impingement vary between species and life stage. Based on the historical data, four months during the spring (i.e. March through June) correspond with the peck entrainment period of several representative species (RIS).
- Variable speed pumps would be used to reduce flow during the selected period. It was assumed that variable speed pumps would reduce flow by 25%.
- Conservatively assuming that larval density is constant, a 25% reduction in flow would equate to a 25% reduction in entrainment rates during the reduced flow period.
- Finally and again conservatively, 100% mortality was assumed for all entrained or impinged organisms.

Calculation Procedure:

1. The proportion of ichthyoplankton entrained or RIS impinged between March and June versus the remainder of the year was calculated for each species based on monthly entrainment or impingement rates obtained from the annual monitoring program.
   Example: Based on 1997 and 1998 entrainment monitoring data, the percentage of rainbow smelt larvae entrained during March through June was approximately 90% of the annual total.

2. Consistent with the above, a 25% reduction in flow during the four months of spring equated to a 25 % reduction of organisms entrained/impinged within that time period.
   Example: A 25% reduction in flow between March and June would equate to

25% less smelt larvae entrained during that period. Therefore, a 22.5% (25% of 90) reduction could be expected in all rainbow smelt larvae entrained for the year resulting in a 22.5% reduction in conditional mortality from entrainment.

3. The reduction in mortality determined in Step 2 was then used to calculate the reduction in conditional mortality under existing station operations. *Example: Under existing station conditions, conditional mortality of the rainbow smelt population as a result of entrainment was estimated between .00001-3%. A 22.5% reduction in conditional mortality equals .00008-2.3%.*

Question B: It has been demonstrated that more ichthyoplankton are entrained at night rather than during daytime hours. What are the ramifications of using variable speed motor controllers on each pump on a diel and on a seasonal basis?

Response: Pilgrim Station has been conducting day/night entrainment sampling since 1994, and the data from this long-term sampling does not support the premise that more ichthyoplankton are entrained at night than during the daytime at the station. Therefore, an analysis of diel cycling of variable speed pumps would not be appropriate. However, use of variable speed pumps on a seasonal basis was discussed in the 316 Demonstration report.

D) Response to Questions Raised at the September 27th Meeting

1) Condenser Sensitivity Analysis

We understand from our meeting that EPA seeks an incremental improvement in conditional mortality, which EPA has suggested may be achieved by a reduction in cooling water flow, subject to recognized limitations; e.g., the effect such a flow reduction may have on condenser performance. EPA also inquired whether an increase in ΔT would facilitate taking a reduction in flow.

ENGC then responded that we would have our Engineering Department do a condenser performance sensitivity analysis to address these questions. Engineering has concluded that condenser performance modeling is required to adequately evaluate the consequences of flow reduction, an evaluation that ENGC cannot perform in-house. Heat Exchanger Systems, Inc. (HES), a condenser specialty contractor, will be retained for this analysis. HES will perform this analysis using a two-phase approach. Phase 1 is a "screening level" approach, which will take approximately 3 to 4 weeks to complete. It is hoped that Phase 1 will provide enough information to form a conclusion on condenser performance. However, if it does not, a Phase 2 analysis using a much more sophisticated modeling approach could be used. If a Phase 2 analysis is required, it would take approximately 6 to 8 weeks to complete. Further, subsequent evaluations may then be needed to determine the impact of flow reduction on unit reliability, operational procedures and on erosion/corrosion of the cooling water piping.

2) Alternative Flow Reduction Options

Relative to a reduction in flow, EPA also proposed a "performance standard" approach rather than requiring a specific technology such as variable speed pumps, and requested ENGC's feed-back on such a proposal. ENGC appreciates and currently is studying EPA's proposal, including what practical options, in addition to variable speed pumps, are available for flow reduction. Some innovative options, which were not conceived of at the time of the 316 Demonstration, include throttling of the existing condenser outlet valves and the use of stop-logs in the outlet canal.

For instance, our Engineering Department has contacted the manufacturer of the condenser outlet valves and has asked if the design of these valves will accommodate the stresses involved with throttling to reduce flow by 5 to 25%. We expect to receive an answer in December 2000. If throttling of the outlet valves or the use of stop-logs are determined to be practical options for flow reduction, further analysis will be required to determine if use of these options will detrimentally impact circulating water pump reliability and/or longevity.

In addition, potential alternatives for flow reduction require assessment from a multi-discipline perspective, especially if they require design changes. Design changes require the development of conceptual designs, costing of equipment, development of an implementation plan, estimation of impacts on operations and outage schedules, and a full cost assessment.

ENGC will endeavor to expedite the analyses mentioned above, and will inform EPA of the final schedules and the results, as they become available.

3) Various Questions Relative to the §316 Demonstration Submittal

EPA had various questions about information contained in ENGC's §316 Demonstration submittal of April 2000. ENSR has addressed these questions, and their responses are included as Attachment #4 to this letter.

4) Further Gunderboom Information

EPA asked for further information regarding the feasibility of using of a gunderboom in an open ocean application such as Pilgrim Station. Mr. Hal Dreyer of Gunderboom Inc. was contacted, and confirmed that the gunderboom has not been deployed at any nuclear power plants. Gunderboom was contacted about the use of the technology at one nuclear plant, but the client quickly abandoned the concept, apparently in part because the facility had no back up source of cooling water; i.e., heat sink. It should be noted that the "heat sink" at a nuclear power plant is a license requirement, and any modification that might restrict access to the heat sink must be reviewed and approved by the NRC. According to Mr. Dreyer, Gunderboom has not had any discussions with the NRC about the licensing or safety implications of using this technology at a nuclear plant.

Mr. Dreyer stated that the gunderboom has only been used at one facility drawing water from the near-shore ocean, but that facility was not a power plant. Mr. Dreyer explained that the use of the gunderboom in an ocean environment requires the design and construction of wave attenuators, the feasibility of which at a site such as Pilgrim is questionable. A site-specific feasibility determination would be required for the proposed application.

ENGC also has determined that a NRC licensee would have to clear numerous regulatory hurdles before deploying a gunderboom at a nuclear power plant. The licensee would have to prepare a 10 CFR 50.59 analysis, which would almost certainly indicate an unreviewed safety question. This finding would necessitate, at very least, NRC review and approval through a Safety Evaluation Report and a license amendment.

If you need further information or clarification of anything contained in this submittal, please call Jay Scheffer at (508) 830-8323.

Sincerely,

John F. Alexander

cc: Jack Paar
U. S. EPA New England Regional Lab

Gerald Szal
MA DEP
Division of Watershed Management

Robert Lawton
MA Division of Marine Fisheries

Carolyn Griswold
National Marine Fisheries Service

Dr. Todd Callaghan
Office of Environmental Affairs
Coastal Zone Management

Robert Maietta
MA DEP
Division of Watershed Management

Paul Hogan
MA DEP
Permit Program

Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station

Attachment #1

Study of Winter Flounder Transport in Coastal Cape Cod Bay and Entrainment at Pilgrim Nuclear Power Station

Entergy Nuclear Generation Company

Study of Winter Flounder Transport in Coastal Cape Cod Bay and Entrainment at Pilgrim Nuclear Power Station

Prepared for:
Entergy Nuclear Generation Company

Prepared by:
ENSR and Marine Research, Inc.

November 2000
Document Number 8734-188-300

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Winter flounder (*Pseudopleuronectes americanus*) are commercially important in Cape Cod Bay and are a dominant species collected in entrainment monitoring at Pilgrim Nuclear Power Station (PNPS). The objective of this study is to evaluate the impact of winter flounder larvae entrainment at PNPS through direct field measurements. An approach was applied whereby field measurements were collected to determine the relative amount of net volumetric flow and winter flounder larvae entrained into the PNPS cooling water system compared to the net volumetric flow and amount of winter flounder larvae passing PNPS in offshore Cape Cod Bay waters.

The field program was designed to collect sufficient measurements to determine the flux of winter flounder larvae moving along the Plymouth coast and the flux of winter flounder entering the PNPS. To determine larvae flux, larvae concentration and volumetric flowrate of water are required. The field program featured collection of larvae concentration measurements and water velocity measurements along the Plymouth coast in Cape Cod Bay and collection of larvae concentration measurements at the PNPS cooling water system.

The field program was conducted over a four-week period and consisted of the following three elements:

- Field sampling of four stages of winter flounder larvae at five stations along a Plymouth coast transect in Cape Cod Bay.
- Water velocity measurements at three stations along a Plymouth coast transect in Cape Cod Bay, using bottom mounted Acoustic Doppler Current Profiler (ADCP) units.
- Sampling of four stages of winter flounder larvae entrained into the PNPS cooling water flow.

Larvae and water velocity measurements were collected concurrently throughout May 2000 to support determination of larvae flux. Larvae sampling was conducted along the Plymouth coast and at the PNPS system during four surveys - once per week – during the month of May 2000. For each survey, larvae samples were obtained four times – twice during the day, and twice during the night - during a one-day period. Water velocity measurements were collected continuously during the month of May 2000.

The field larvae data were combined with the current measurements to determine the flux of larvae along the coast of Cape Cod Bay, for each of the four daily measurement periods. These values were then compared to the amount of larvae entrained into the PNPS cooling system, as determined from the entrainment study, during the same four daily measurement periods.

Section 2 of this report describes the field sampling program. Section 3 provides the field study results. Section 4 provides an analysis of the study results. Section 5 provides the study conclusion and an overall assessment of the entrainment impact of PNPS on winter flounder larvae in Cape Cod Bay based on the study results.

2.0 FIELD SAMPLING PROGRAM

2.1 Winter Flounder Larvae Sampling

Larval winter flounder were collected at five stations along a single transect located in Cape Cod Bay (Figure 2-1). Stations are defined as segments located along the transect line which began at Rocky Point and projected perpendicular to the shoreline to the 120' contour line of Cape Cod Bay. The total transect length was approximately five nautical miles. The same transect line was used for the hydrodynamic measurements described below. The close proximity of the larvae sampling stations to the hydrodynamic measurements facilitated correlation of the acquired hydrodynamic data with biological sample data to formulate an estimate of the population of winter flounder contained in Cape Cod Bay coastal waters flowing towards and past PNPS.

The five sampling stations were identified as Stations A through E in order of increasing distance from the shore, with each station having a segment length of approximately one-half nautical mile. The ranges of water depths along the station segment lengths were approximately as follows: Station A: 25'- 37'; Station B: 43' - 60'; Station C: 75' - 100'; Station D: 105' - 115'; Station E: 118' - 125'. As shown on Figure 2-1, the stations were positioned such that the inshore stations were more closely spaced than the offshore stations. Tow duration for each sample was approximately six to eight minutes, which provided sample volumes ranging from 85 to 150 cubic meters and an overall average of 120 cubic meters.

Four weekly field surveys (cruises) were completed during the month of May 2000 – May 8, 9, May 15, 16, May 22, 23, and May 30, 31. Each survey was structured to capture the ebb and flood tides of two tidal cycles on each sampling day (4 sampling events per survey, 2 during the day and 2 during the night). Sampling was conducted at each station using 60-cm diameter "bongo" nets rigged with 0.202-mm and 0.333-mm nylon mesh plankton nets.

At all five stations, A, B, C, D, and E, stratified oblique tows were performed, by partitioning the water column into three equal-depth layers and completing one oblique tow in each layer so that samples were obtained from surface, mid-depth and bottom layer. Stations were initially located using GPS bearings during deployment of the ADCP units. At that time for each station Loran C coordinates were determined and used to locate each station for subsequent tows. Filtration volumes were determined using General Oceanics 2030R flow meters installed in the mouth of the plankton net.

After the completion of each sample tow, the net was washed down from the outside and the contents were transferred to one-liter bottles containing sufficient formalin to produce a 10% solution with seawater. A waterproof tag listing the station, date, start and end time of the collection, the flow-meter readings, and the net was placed into each sample container. Samples were then delivered to the lab for microscopic analysis where all winter flounder larvae were identified and counted within four developmental stages. Only the 0.202-mm mesh samples were analyzed; the 0.333-mm mesh samples were archive. Due to the abundance of zooplankton some samples were split in half using a plankton splitter patterned after (Motoda 1959, see also VanGuelpin et al. 1982). Counts were converted to numbers per 100 cubic meters of water based on the flow-meter readings.

2.2 Entrainment Monitoring

In conjunction with each offshore sampling series, ichthyoplankton samples were also taken from the PNPS cooling water discharge. Sampling was conducted near the center of the discharge canal approximately 30 meters downstream from the headwall to assess the impacts of entrainment on winter flounder populations. Samples were collected using a 60-cm diameter plankton net constructed of 0.202-mm nylon mesh. On each of the four May occasions 2 day and 2 night samples were taken approximately centered in time on each of the offshore sampling series for a total of 4 per survey. Each collection was made by streaming the net for 10 to 30 minutes depending on tide stage, longer sampling intervals being required to collect samples near high water. Exact filtration volumes were determined using a General Oceanics 2030R2 flowmeter mounted in the mouth of the net.

After sample collection, the net was rinsed from the outside using seawater to wash all plankton into the cod end of the net. The sample was then transferred into a 1-liter wide mouth bottle and preserved using sufficient buffered Formalin to obtain a 10% solution. A waterproof tag listing the station, date, time of collection, and the flow-meter readings was placed into each sample container. Samples were returned to the laboratory and processed as described above for the offshore samples.

2.3 Hydrodynamic Measurements

The hydrodynamic measurement component of the field program was designed to support determination of the total volumetric flux of water along the Plymouth coast. The hydrodynamic surveys were scheduled concurrently with winter flounder larvae sampling surveys to support determination of winter flounder larval flux along the Plymouth coast.

As shown in Figure 2-2, hydrodynamic measurements were collected along an east-west transect extending from Rocky Point in Plymouth to a depth of 130 feet, approximately 5 nautical miles offshore. The location of this transect was selected to capture dominant longshore currents flowing in a north-south direction. The hydrodynamic field program consisted of two components, a long-term survey and a synoptic survey. The long-term survey featured deployment of hydrodynamic instruments and continuous collection of measurements at three locations (designated locations #1, #2, and #3 in Figure 2-2) along the Rocky Point transect for a period of one month. The synoptic survey featured collection of hydrodynamic measurements from a boat transiting the entire Rocky Point transect. The long-term and synoptic surveys were successfully collected the data required to support the impact assessment and are described below.

2.3.1 Long-term Hydrodynamic Survey

Hydrodynamic measurements were continuously collected at three locations (denoted #1, #2, and #3) along the Rocky Point transect (Figure 2-2). At each hydrodynamic sampling location, the following measurements were collected for a period of one month.

- Water velocity measurements throughout the water column using a bottom-based acoustic Doppler current profiler (ADCP). ADCP measurements were acquired at one-meter intervals throughout the full depth of the water column. The ADCP measures the magnitude and direction of water movement through transmission of acoustic signals and interpretation of Doppler frequency shifts in acoustic returns.
- Water level of the sea surface using a tide gauge.

The long-term hydrodynamic field data collection program achieved 100% data recovery, as planned. A description of long-term survey deployments, equipment, and data collection is provided below for each location.

Location #1: Data Collection Summary

Deployment Information:

- Instrument deployment coordinates: 41° 57.366'N, 70° 34.616'W
- Instrument deployment depth: 44 feet of water
- Deployment date/time: 06 May 2000 at 1254
- Recovery date/time: 09 June 2000 at 1730
- Deployment duration: 34-days, 4 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 600kHz frequency (serial #0633).
- Water velocity data collection: ADCP measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10209).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

Location #2: Data Collection Summary

Deployment Information:

- Instrument deployment coordinates: 41° 57.761'N, 70° 32.305'W
- Instrument deployment depth: 98 feet of water
- Deployment date/time: 06 May 2000 at 1331
- Recovery date/time: 09 June 2000 at 1243
- Deployment duration: 33-days, 23 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 300kHz frequency (serial #0880).
- Water velocity data collection: Measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10603).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

Location #3: Data Collection Summary

Deployment Information:

- Instrument deployment coordinates: 41° 58.370'N, 70° 29.108'W
- Instrument deployment depth: 129 feet of water
- Deployment date/time: 06 May 2000 at 1408
- Recovery date/time: 09 June 2000 at 1136
- Deployment duration: 33-days, 21 hours

Equipment and Data Collection Configuration:

- Water velocity meter specification: RD Instruments, Workhorse Sentinel ADCP, 300kHz frequency (serial #0896).

- Water velocity data collection: Measurements collected and recorded every 10 minutes throughout the water column.
- Tide gauge specification: Coastal Macrowave Non-directional Wave Gauge (serial #10301).
- Tide gauge data collection: Water level measurements collected and recorded every 10 minutes.

All instruments were successfully recovered and 100% of data was achieved, as planned. Processing, analysis and application of the long-term hydrodynamic measurement data is described in Section 3.

2.3.2 Synoptic Hydrodynamic Survey

Synoptic boat-based water velocity measurements were collected using an ADCP instrument on 09 June 2000. The boat-based ADCP survey featured measurement of water velocities (direction and magnitude) at one meter intervals throughout the water column. Two transits of the Rocky Point transect were performed, once each during ebb and flood tide. The ADCP unit was rigidly mounted in a frame suspended over the side of the survey vessel. The synoptic survey transits were performed at the times indicated below:

- Ebb tide survey date/time: 09 June 2000 from 10:12 to 11:20
- Flood tide survey date/time: 09 June 2000 from 14:34 to 15:44

The synoptic survey achieved the 100% data collection goal. Processing, analysis and application of synoptic hydrodynamic measurement data is described in Section 3.

2.4 Water Column Monitoring

Measurements of temperature (± 0.1° C), salinity (± 0.1 o/oo), and dissolved oxygen (± 0.1 ppm) were recorded at each station immediately preceding the surface tow using a Hydrolab Quanta instrument. Readings were recorded at surface, mid-depth and at a depth within 1-meter of the bottom.

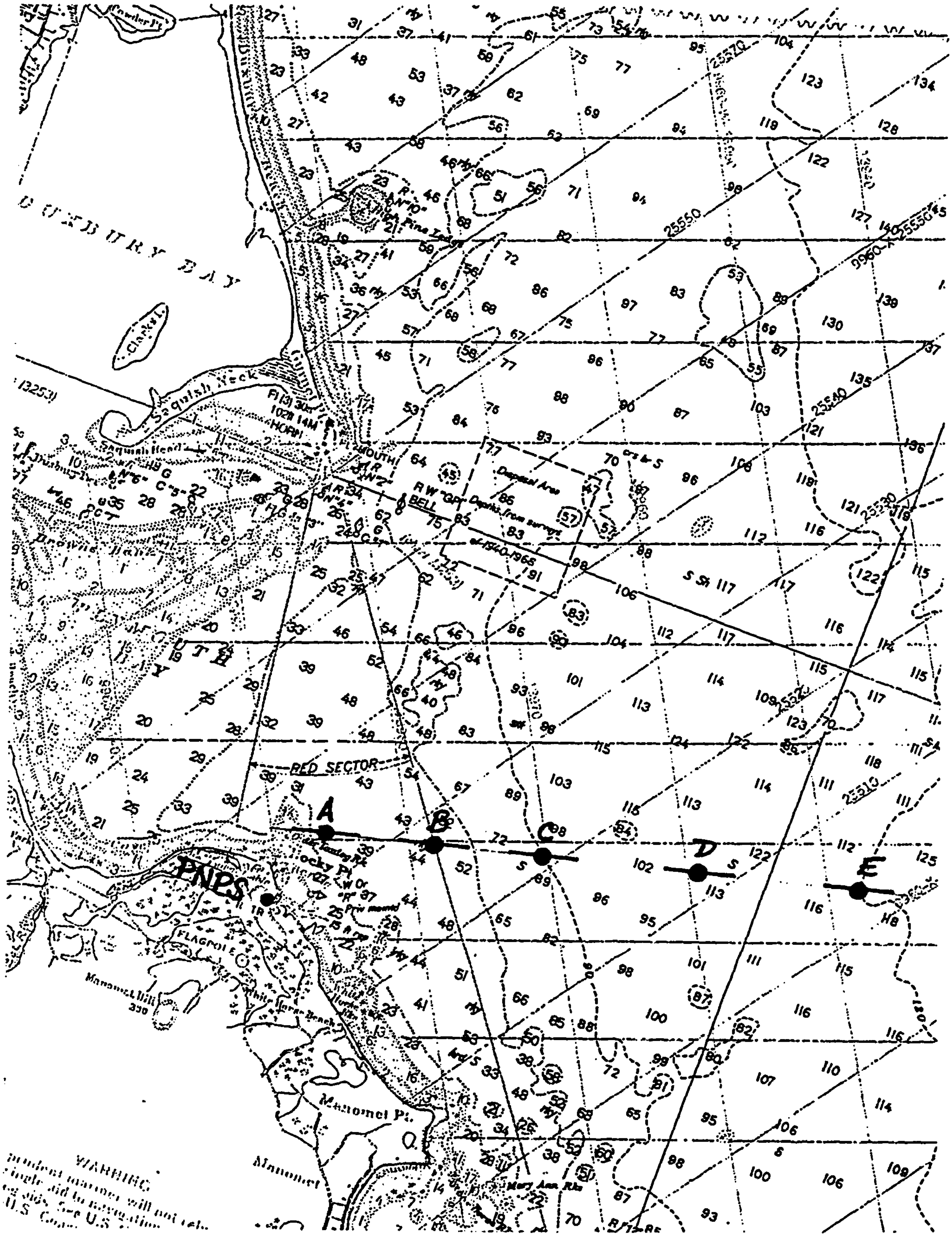


Figure 2-1
Station Transects for the Collection of Winter Flounder Larvae Samples

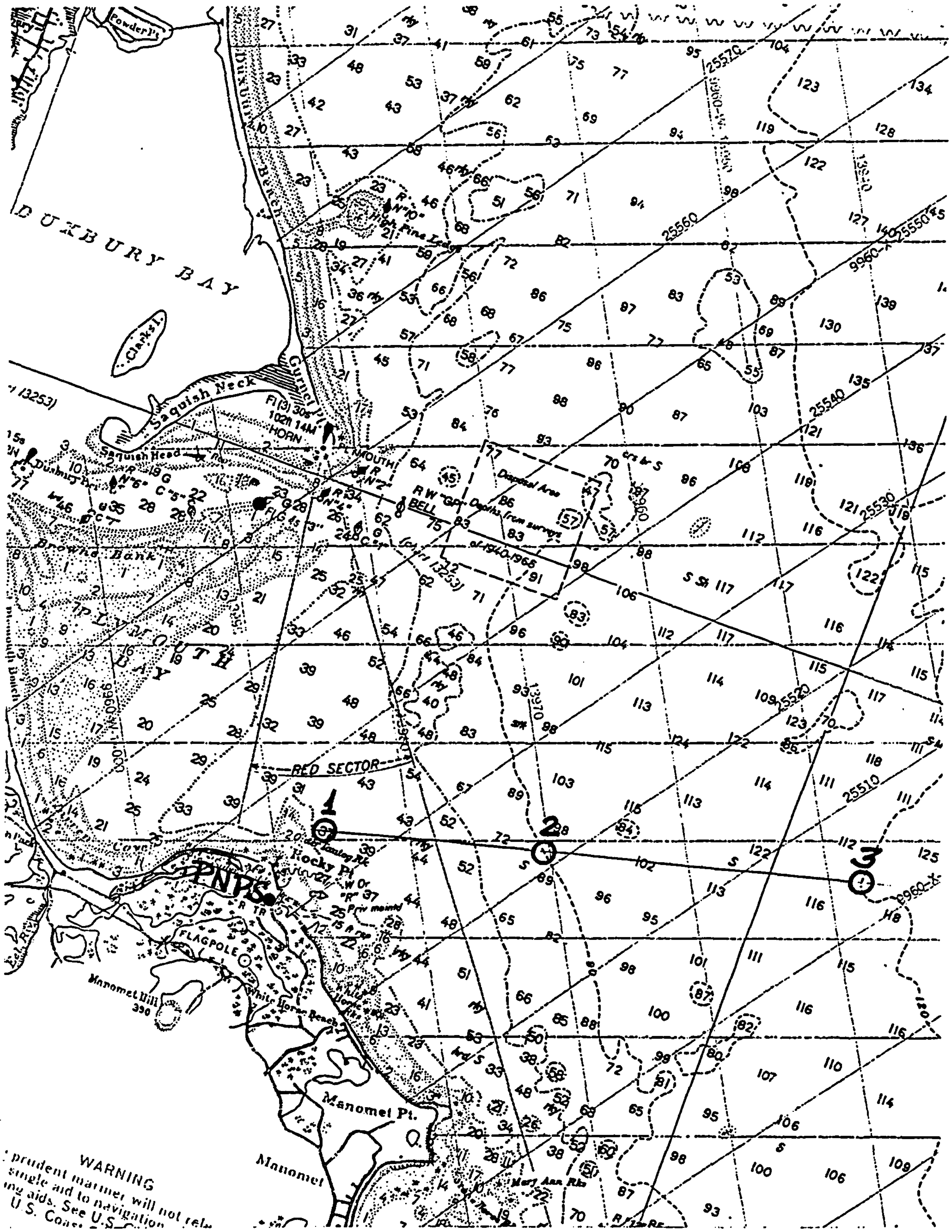


Figure 2-2
Deployment Sites for ADCP/Tide Gauge Instrumentation Packages

3.0 STUDY RESULTS

3.1 Larvae and Entrainment Sampling Results

Densities of larval flounder per 100 m^3 of water by developmental stage for each sample appear in Appendix A. Larval flounder were present on each sampling occasion. Averaged over all samples taken within each of the four cruises, larvae were most abundant during the May 22, 23 series, least abundant during the May 30, 31 series, and found in nearly equal numbers during the first two series. Overall mean densities were 22.1, 22.2, 35.5, and 11.5 per 100 m^3 of water, respectively. Stage 1, yolk-sac larvae accounted for 34 and 35% of the total during the first two cruises then declined to 17% and 1% of the total during the third and fourth cruises, respectively. Stage 2 and 3 larvae clearly accounted for the majority of flounder collected; together they accounted for between 65 and 98% of the total. Older Stage 4 larvae, those nearing metamorphosis, were relatively uncommon, being absent during the first and second cruises, accounting for less than 1% on the third and fourth cruises.

3.2 Hydrodynamic Monitoring Results

3.2.1 Long-term Hydrodynamic Survey

Data from each of the three locations was inspected, processed, and exported for further analyses using RD Instruments WinADCP software. Figure 3-1 through 3-3 contain WinADCP plots of the ADCP time series of North velocities at each of the three stations, for May 8 and 9, the time of the first larvae sampling event. Since the study transect is along an East-West line, the North component of velocity gives the flow perpendicular to the study transect. The conversion of the water velocity vectors (magnitude and direction) to North velocity means that all velocities and water fluxes are reported such that positive values are flowing North, and negative values are flowing South.

The ADCP data shows that flood tides are associated with southerly water flow across the study transect. Ebb tides are associated with either northerly water flow, or southerly water flow of reduced speed, across the study transect. Over the duration of the ADCP deployment, observed velocities perpendicular to the study transect ranged, in meters per second:

- from 0.342 (North) to -0.396 (South) with an average of -0.017 at Station 1,
- from 0.531 (North) to -0.540 (South) with an average of -0.047 at Station 2, and
- from 0.491 (North) to -0.764 (South) with an average of -0.035 at Station 3

RD Instruments SURFACE software was used to process the ADCP data to determine the height of the water surface above the bottom. These heights were used to determine the depths and areas in the water and larval flux calculations presented in Section 4. Hydrodynamic data are provided in Appendix C.

3.2.2 Synoptic Hydrodynamic Survey

Data from the two boat-based ADCP tows was inspected using RD Instruments WinRiver software. The ADCP transect tows of June 9, 2000 are presented in Figures 3-4 (10:12-11:20) and 3-5 (14:34-15:44). These figures again show the North component of velocity, perpendicular to the study transect.

The results of the synoptic surveys show that the current profiles vary smoothly across the transect, validating the choice of the three long-term ADCP stations. The two tows occurred under different current scenarios, the earlier flowing North and the later flowing South, yet show consistent results in terms of smooth transitions of velocity across the transect.

3.3 Water Column Monitoring Results

Water temperature, salinity, and dissolved oxygen data recorded at each station are tabulated in Appendix B for each of the four cruises. Based on average readings across station for each cruise, surface water temperatures (Figure 3-6) ranged from 9.8° C on the first cruise to 12.8° C on the fourth. Bottom readings (Figure 3-6) ranged from 6.5° C on the first to 7.9° C on the fourth however bottom readings actually averaged somewhat higher (8.1° C) on the second cruise. Along the sampling transect both surface and bottom water averaged higher at inshore Station A then further offshore, the difference between location being more pronounced in bottom water due to the increasing depth along the transect.

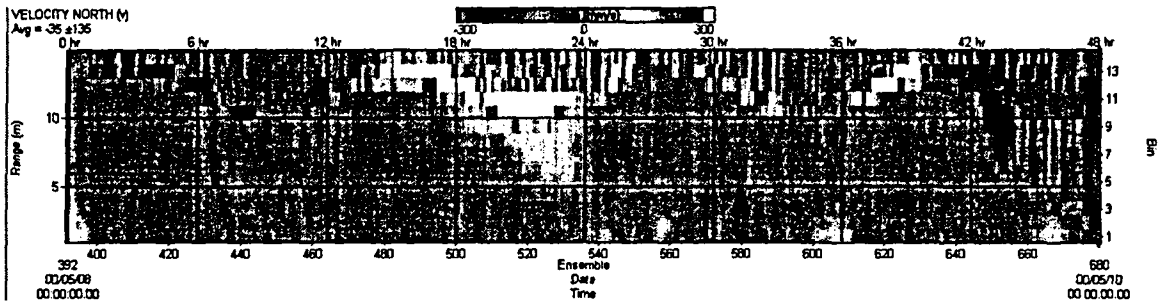


Figure 3-1 ADCP at Station 1 May 8-9, 2000

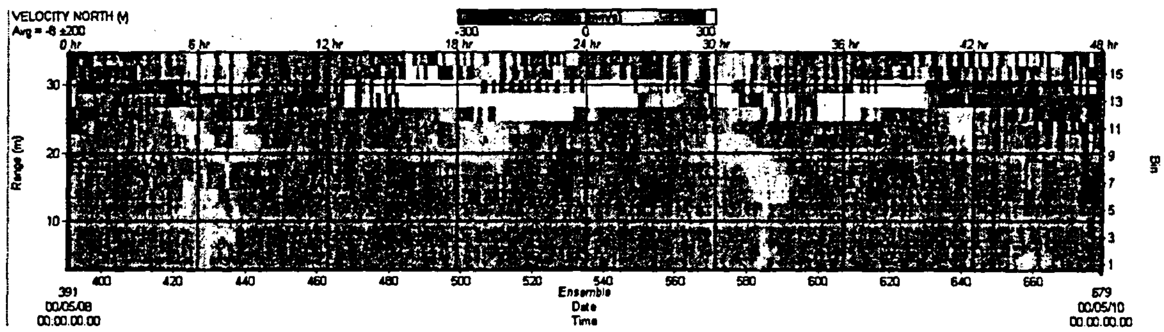


Figure 3-2 ADCP at Station 2 may 8-9, 2000

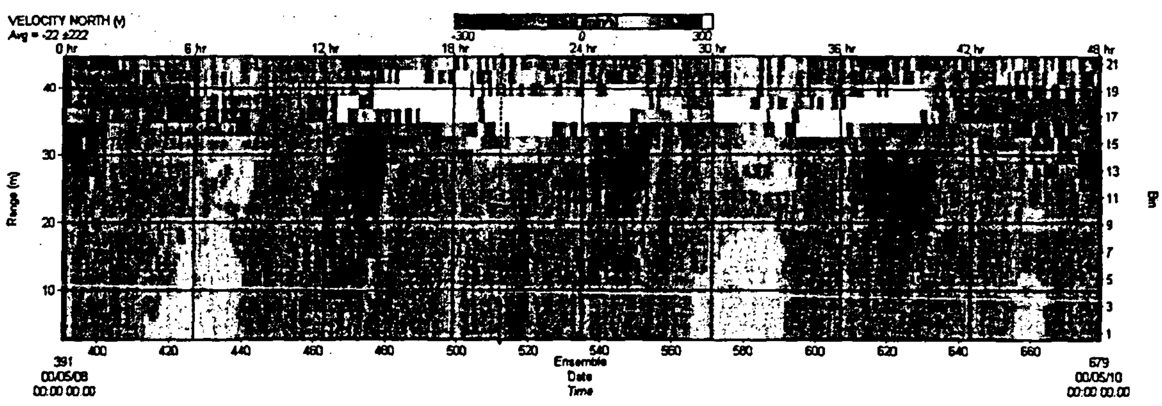


Figure 3-3 ADCP at Station 3 May 8-9, 2000

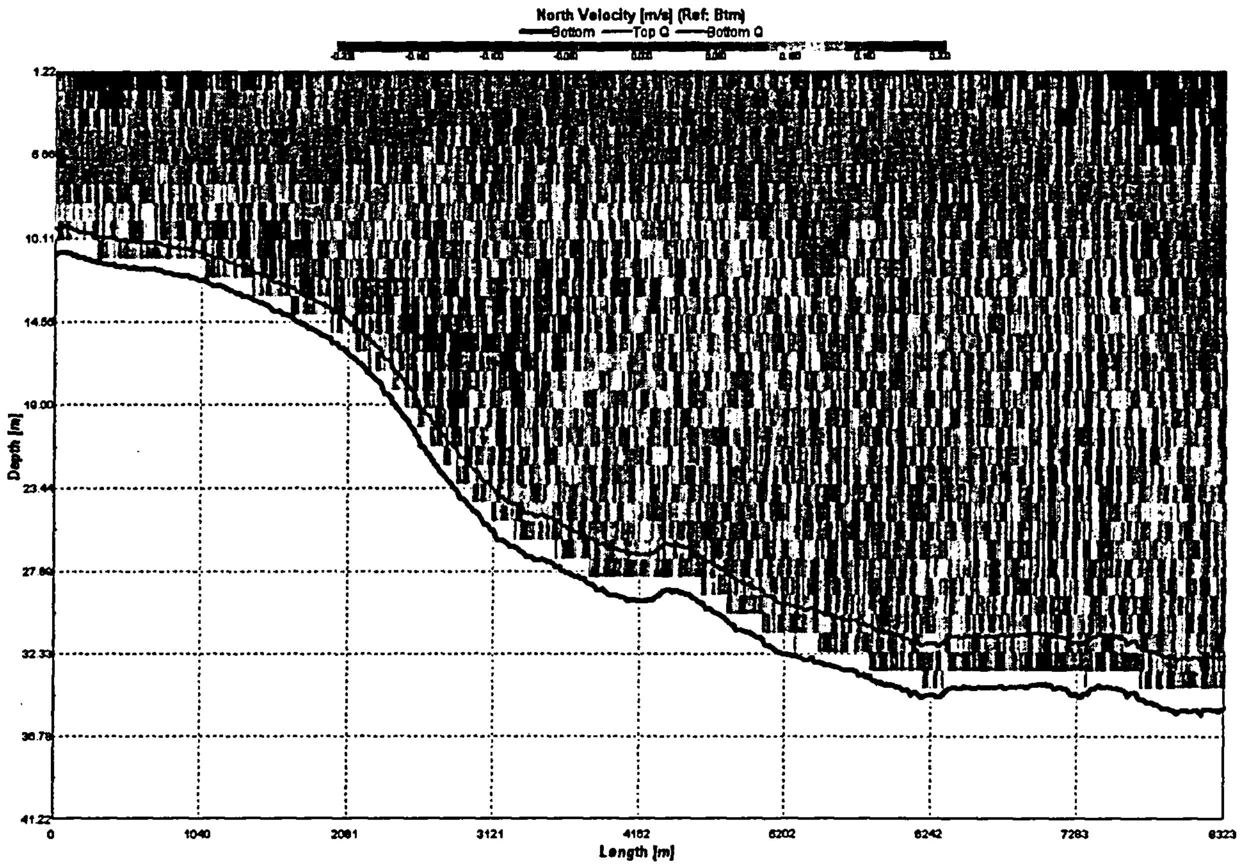


Figure 3-4 Towed ADCP Data June 9, 2000 10:12-11:20

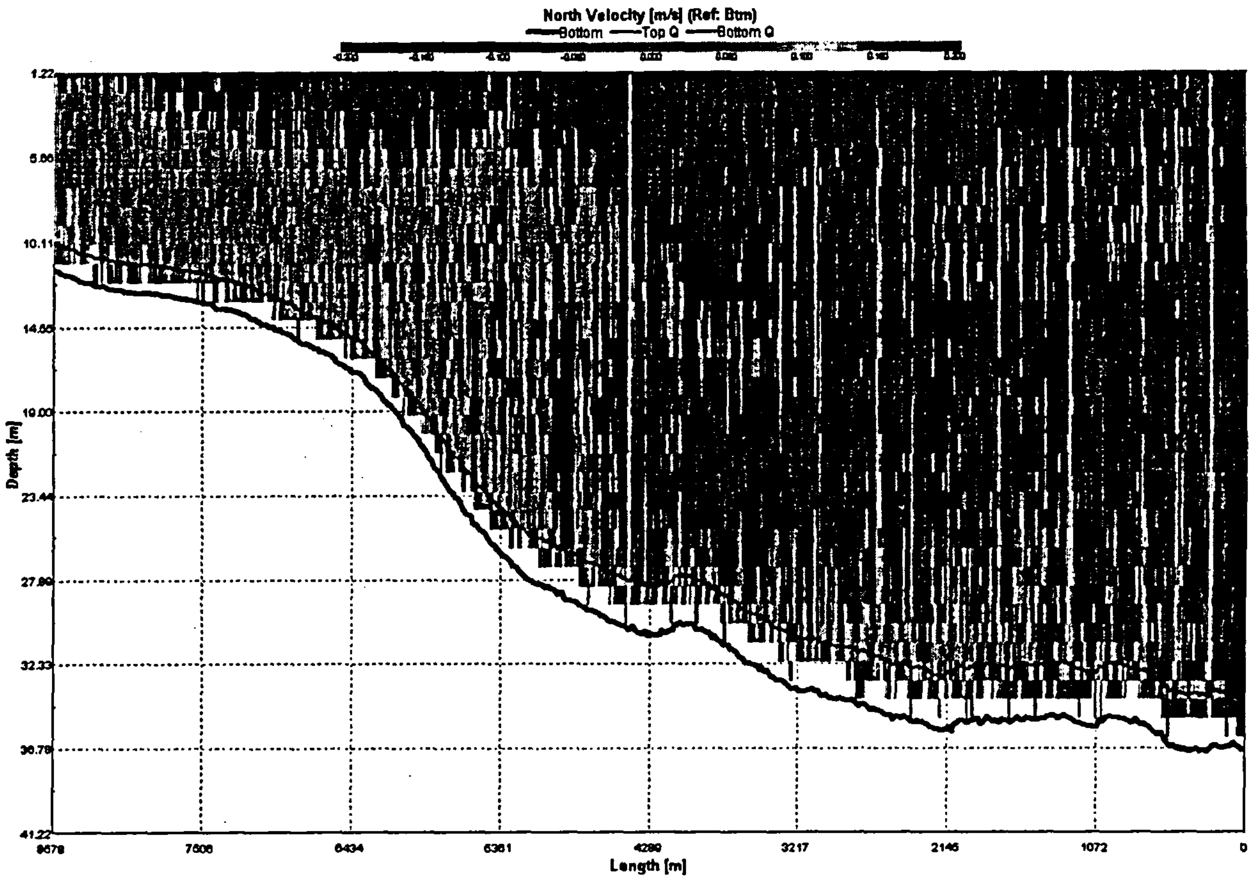
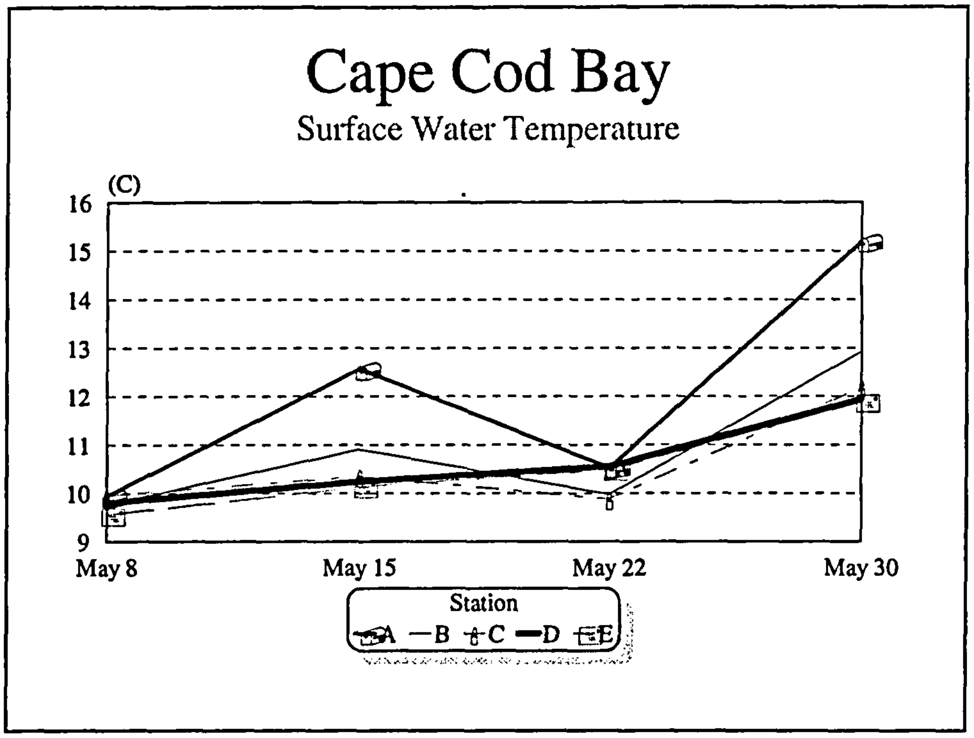


Figure 3-5 Towed ADCP Data June 9, 2000 14:34-15:44



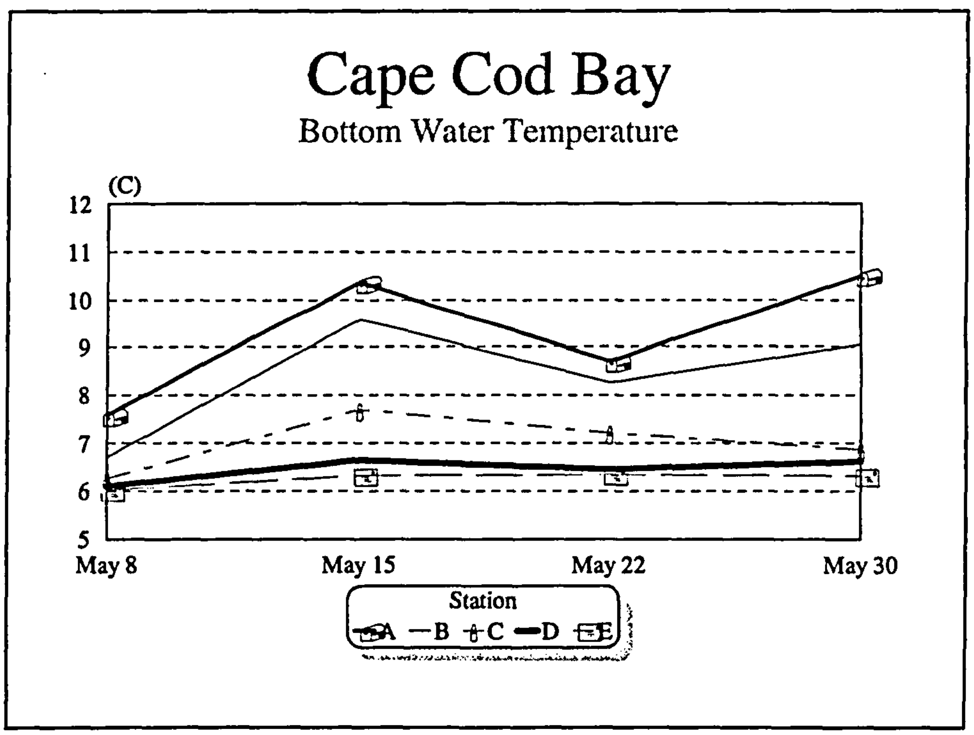


Figure 3-6 Mean Surface (top) and Bottom Water Temperatures Recorded at Each of Five Stations in Cape Cod Bay During Four May Cruises

4.0 DATA ANALYSIS AND ASSESSMENT

The data discussed above were analyzed to allow a determination of (1) the percentage of net volumetric flow in nearby coastal Cape Cod Bay waters withdrawn by PNPS and (2) the percentage of winter flounder larvae in the net coastal flow entrained by PNPS. This allows an evaluation of the overall effect of winter flounder larvae entrainment at PNPS.

A separate calculation of the percentage of coastal flow withdrawn and larvae entrained by PNPS was performed for each of the four sampling events, for which the sampling study was conducted. In addition, the volumetric flow analysis was performed over the entire monthly period that the hydrodynamic measurements were conducted. The larval analysis was performed for each of the four winter flounder larvae life stages and for total larvae. Details of the analysis procedures and results are discussed below.

4.1 Volumetric Flux Analysis

In order to correlate the three continuous-depth ADCP stations with the five discrete-depth larvae sampling stations, the ADCP water velocity data was processed in the following manner:

- At each ADCP station, the velocity values were segmented into thirds based on total depth at the time of the reading. The North component of the velocity was averaged over the ADCP data in each third of the water column, for each 10-minute ensemble of data.
- Since two of the larvae sampling stations (B and D) were between ADCP stations (A and C, and C and D, respectively), the North velocities were estimated by the average of the North velocities at the adjacent stations (*i.e.*, B is average of A and C).

Figure 4-1 contains plots of water depth and the average North velocities for the three depth intervals at each ADCP station during each larvae sampling period. The results of this process are 15 time series of North velocity (3 depths by 5 stations) to characterize the flow across the study transect.

The flux of water from North to South was then calculated by multiplying each of the 15 North velocity series by the estimated cross-sectional area of the transect represented by that value. The cross-sectional areas were determined for each segment by multiplying one-third of the water depth at the station by one-half of the combined distance to the two adjacent stations.

In order to correlate the ADCP time series with the discrete larvae sampling events, the ADCP-based water flux data was averaged over the duration of each tidal phase. The tidal phase was defined as the time between the maximum and minimum tide heights at the station. The sum of the fluxes during the four tidal phases also was the basis for daily estimates of water flux across the study transect. Table 4-1 compares the daily water fluxes during the sampling events with the average daily water flux during the study period, May 8-31, 2000. The percentage of the volumetric flow withdrawn by PNPS (assuming full pump operation) was determined to range from 0.08% to 0.59% for the four larvae sampling days, and to be 0.21% for the entire monthly study period (see Table 4-1).

4.2 Larval Entrainment and Flux Analysis

4.2.1 Larval Transport Analysis

The flux or transport of winter flounder larvae flowing along the coast was determined for each of the four study days using larvae density and hydrodynamic measurements. This approach integrated current velocity, water depth and larval stage density over the cross-sectional area of the transect over the time of each tidal phase. The calculation was performed for each of the four winter flounder larval stages and the total winter flounder larvae concentration at each of the 4 time series that constituted one 24-hour period. For each study day, the net larval flux was determined by taking the sum of the net larval flux over each tidal period.

The net larval flux over a given 6 hours tidal period was determined by multiplying the concentration of larvae (larvae/m^3) times the flux of water (m^3/s) to yield larvae/second over a 6 hour period. All the larvae data in each series (except for series 3 and 4 on May 30-31) were collected across an ebb and flood cycle. Therefore, to obtain consistent results the following averaging method was used for the larval data:

- The tidal phase corresponding to the time of collection of the first larvae sample of the first series for each round was used as the tidal phase for the whole series. If station A, series 1, was collected first and this was during the flood period then the rest of the series was considered a flood. The second series would then be an ebb, the third a flood, the fourth an ebb.
- Within each data series each station A-E was determined to have been sampled during the Ebb or Flood by checking the sampling period against the ADCP tidal record.
- If the pre-determined series tidal phase matched the actual tidal phase of the discrete sample in a given series, then the larvae concentration used was the discrete number given (no average taken). If the two phases did not match, then the larvae concentration used was determined by averaging the discrete number in the given series with the corresponding larvae concentration as found in the series preceding the one in question. If the series was the first series in a date then the concentration would be averaged with the appropriate sample for the series following it. This analysis is appropriate because, as shown in Section 4.3, the larvae vertical distribution does not vary with tidal stage.

The larval flux during each tide phase was summed to provide an estimate of the number of larvae passing the study transect during each 24-hour period covered by the sampling round. These values are presented in Table 4-2.

4.2.2 Larval Entrainment Analysis

The number of winter flounder larvae entrained by PNPS during each of the four sampling events was determined from the station flow rate and the four larval entrainment samples collected during the day specifically for this study. The calculation was performed for each of the four winter flounder larval stages, by multiplying the number of larvae for each stage entrained by the station by the station flow rate for the 6hour tidal cycle over which the ambient flounder samples were collected. The sum of each of the 6 hour periods became the total entrainment per day.

The percentage of each larval stage entrained was determined by dividing the number of larvae entrained during the day by the number of larvae carried past the station in the net longshore current (and then multiplying by 100 to obtain a percentage). The larval entrainment results are presented in Table 4-2.

In general, the results in Table 4-2 indicate that PNPS entrains a very small percentage of the winter flounder larvae in the coastal flow of Cape Cod Bay. On the first 3 sampling days, the percentage of total (all larval stages) winter flounder larvae entrained ranged from 0.07% to 0.21%. Stage 1 and 2 larvae entrained ranged from 0.02% to 0.16%. Stage 3 larvae entrained ranged from 0.13% to 0.27%. No Stage 4 larvae were entrained during this period. For the fourth sampling day, No Stage 1 larvae were entrained. Stage 2 and 3 larvae entrained were 0.29% and 1.24%, respectively. Stage 4 larvae were entrained at 5.1%. It is possible that this value is anomalously high due to sampling gear inefficiency; i.e. the inability of the plankton trawls to sample many of the Stage 4 larvae in the bay which are likely located at or near the bottom. The total larvae entrained for the fourth sampling period was 1.05%, which is also potentially skewed high due to the Stage 4 value.

In summary, the percentage of larvae entrained by PNPS was generally much less than 1%. On one out of the four sampling days, one of the four larval life stages was entrained at a rate greater than 1%, and this value may be suspect due to inherent sampling inefficiency. Based on this analysis, it is concluded that the percentage of winter flounder larvae transported in coastal Cape Cod Bay waters that is entrained by PNPS may be conservatively estimated at less than 1%.

4.3 Statistical Analysis of Larval Variability

Two statistical analyses of winter flounder larvae variability were performed:

1. The variation in the vertical larval distribution throughout the tidal cycle was examined to evaluate the potential for larvae to use the vertical distribution as a retention mechanism.

2. The effect of wind speed and direction on the distribution of larval densities was evaluated.

4.3.1 Variation in Vertical Distribution of Larval Densities

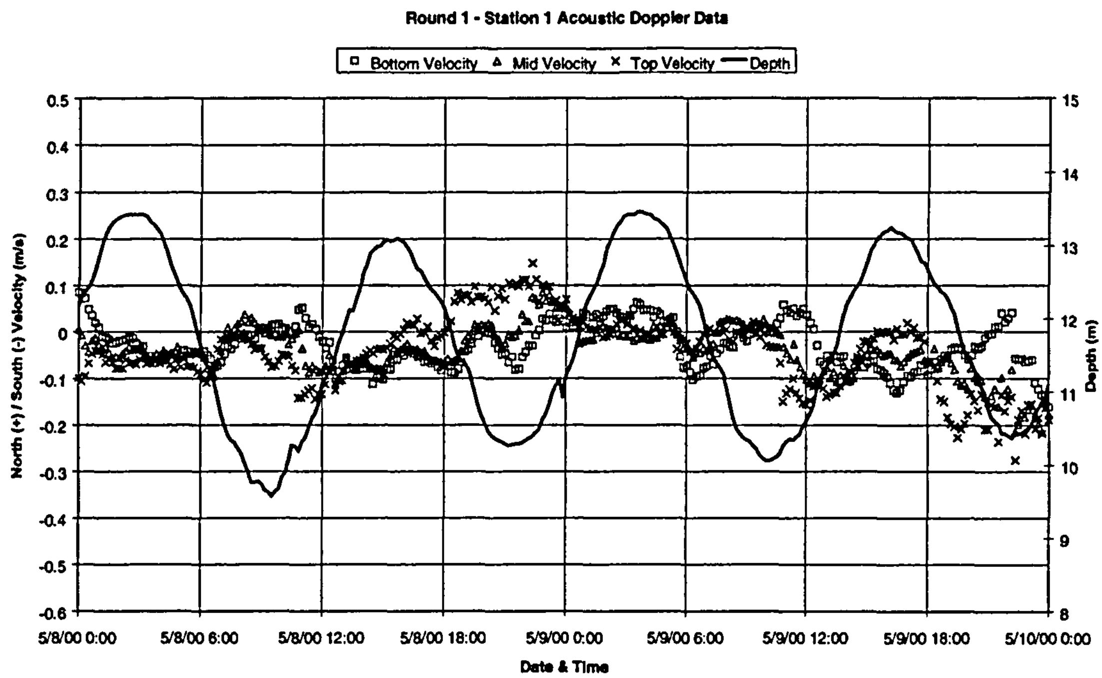
The possibility exists that winter flounder larvae can maintain their position within a localized region of Cape Cod Bay by using one of two retention mechanisms. One of the potential mechanisms is transport within localized gyres; however, there is no evidence that such gyres exist in Cape Cod Bay. The other potential retention mechanism is the control by larvae of their vertical location in the water column during various tidal phases (flood versus ebb) in order to preferentially control their transport and maintain a position within a localized area. If larvae are using such a mechanism, their vertical distribution in the water column would vary throughout the tidal cycle.

In order to evaluate whether the vertical distribution of winter flounder larvae varies throughout the tidal cycle, an ANOVA (analysis of variance) test was performed on the vertical distribution of larval densities during flood and ebb tides collected during this study. The test was performed as follows:

- Discrete larvae concentrations were sorted for their location in an ebb or flood tidal phase and their location as a surface or bottom sample.
- A ratio between the surface larvae concentrations and the bottom total larvae concentrations was calculated for the ebb samples and the flood samples.
- A one-way ANOVA test was performed on the ratio of the surface to bottom values for the ebb and flood tides. The results (shown on Table 4-3) indicate that there is no difference between the means of the data set given. This indicates that winter flounder larvae do not vary their location in the water column with tidal phase or use such a mechanism to control their transport.

4.3.2 Effect of Wind Speed and Direction on Larval Density Distribution

There is a potential that localized winds may control the larval density distribution by transporting water to or from shore depending on whether the wind is onshore or offshore. In order to evaluate the relationship between wind speed and direction and larval density distribution, a correlation analysis was performed by plotting winter flounder larval densities versus wind speed (with offshore winds specified as positive and onshore winds as negative) for the larvae sampling stations that were the nearest to and furthest from the shore. If a correlation between winds and larvae distribution existed, it would be expected that nearshore densities would decrease for an offshore wind and increase for an onshore wind, with the opposite effect for the furthest offshore station. The results of the analysis (shown on Figure 4-2) indicate that there is essentially no correlation between winds and the larval density distribution.



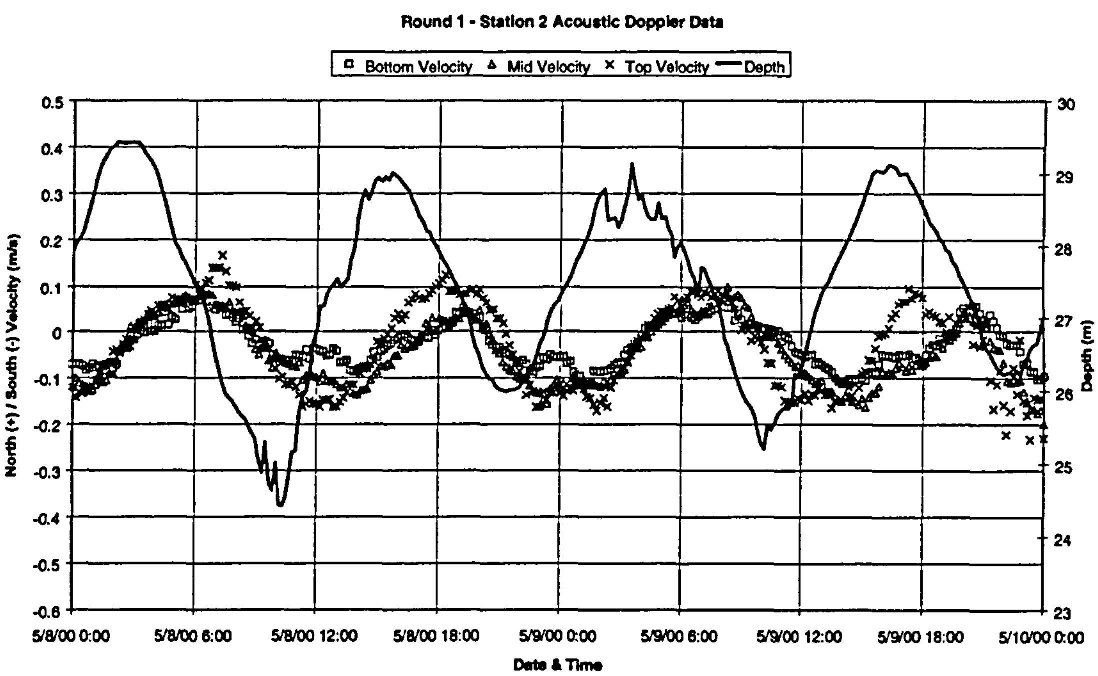
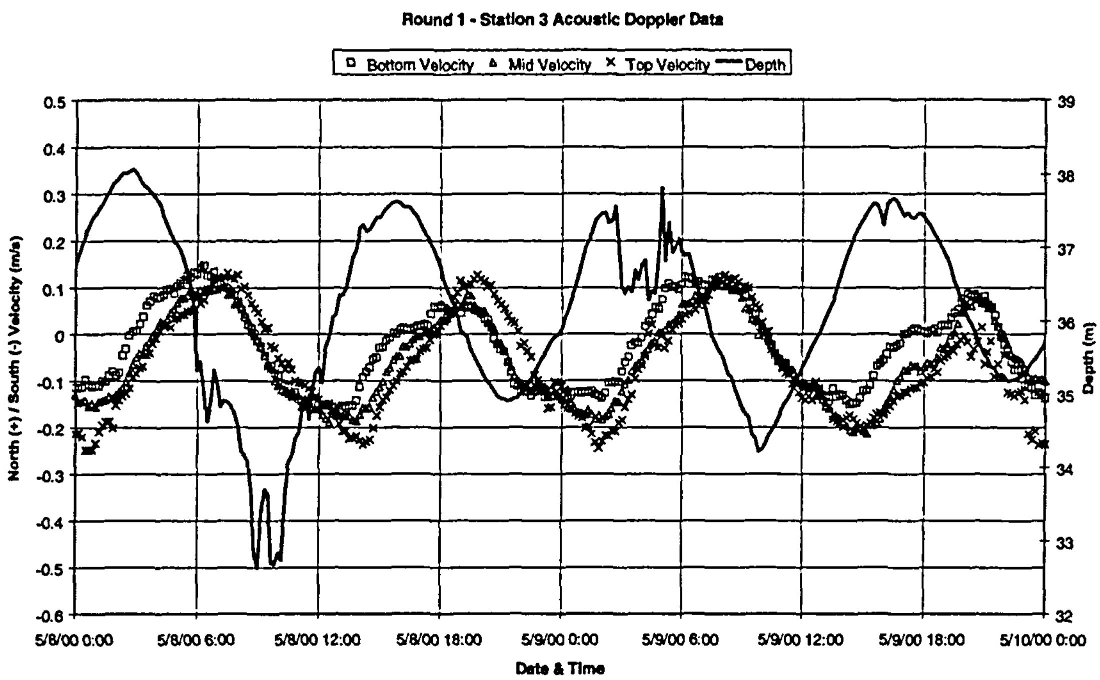


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth



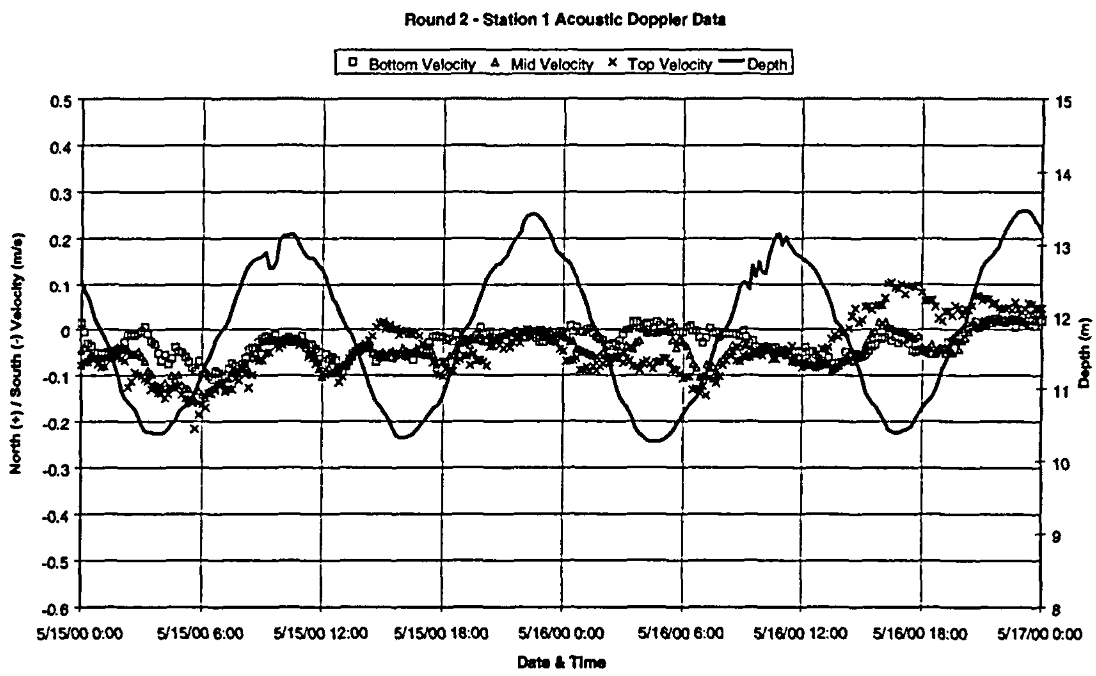
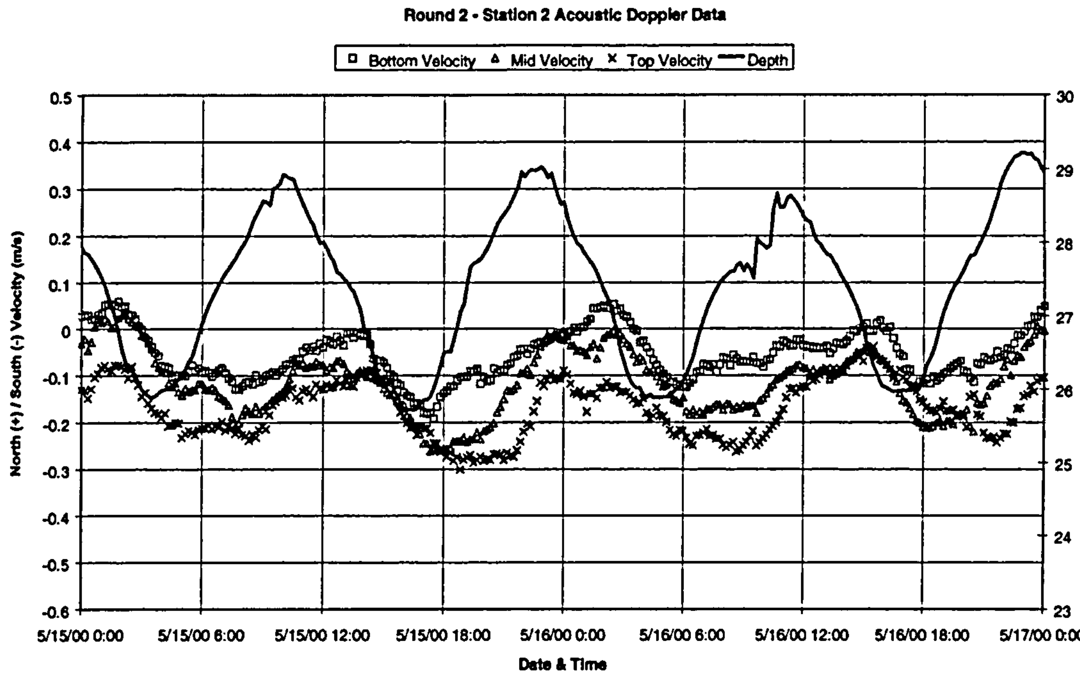


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



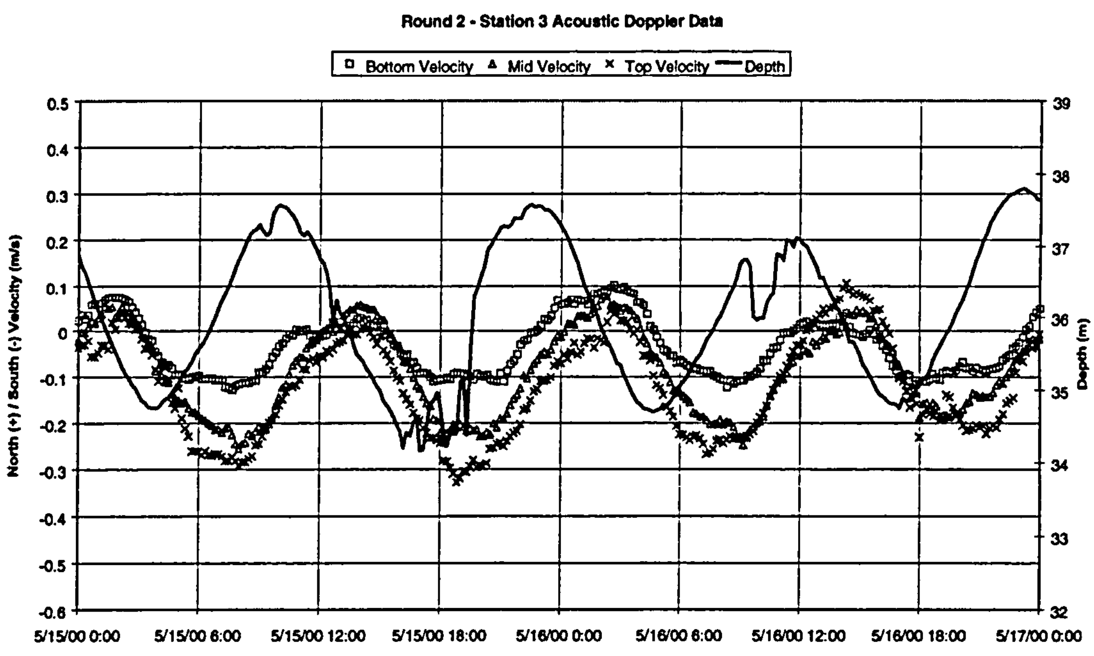
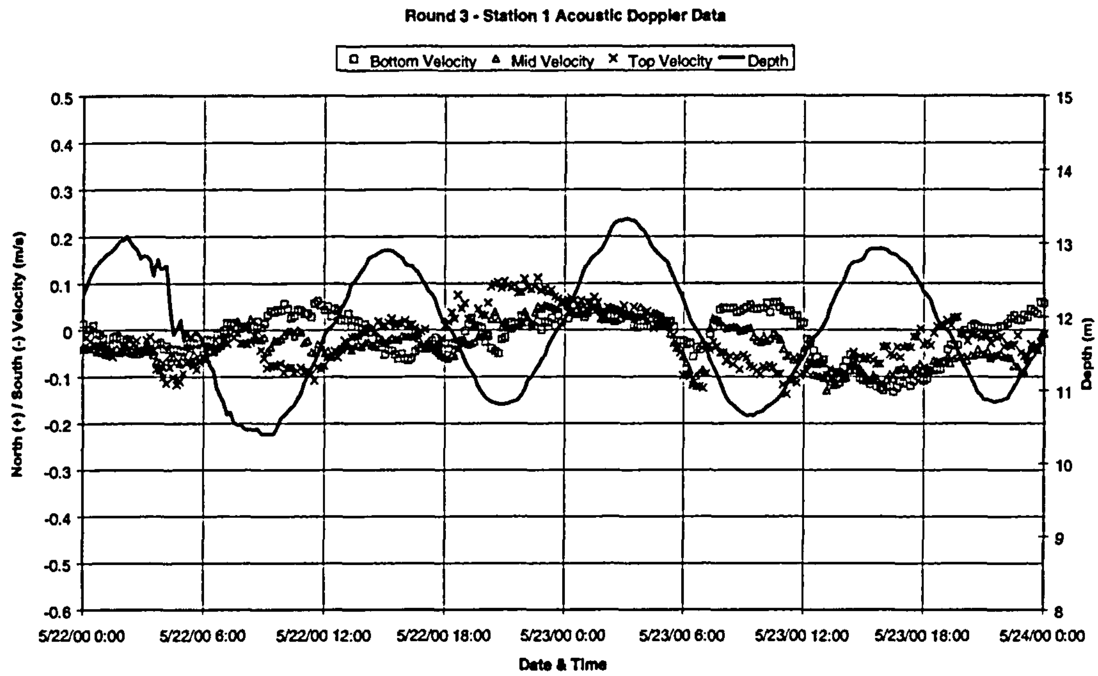


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



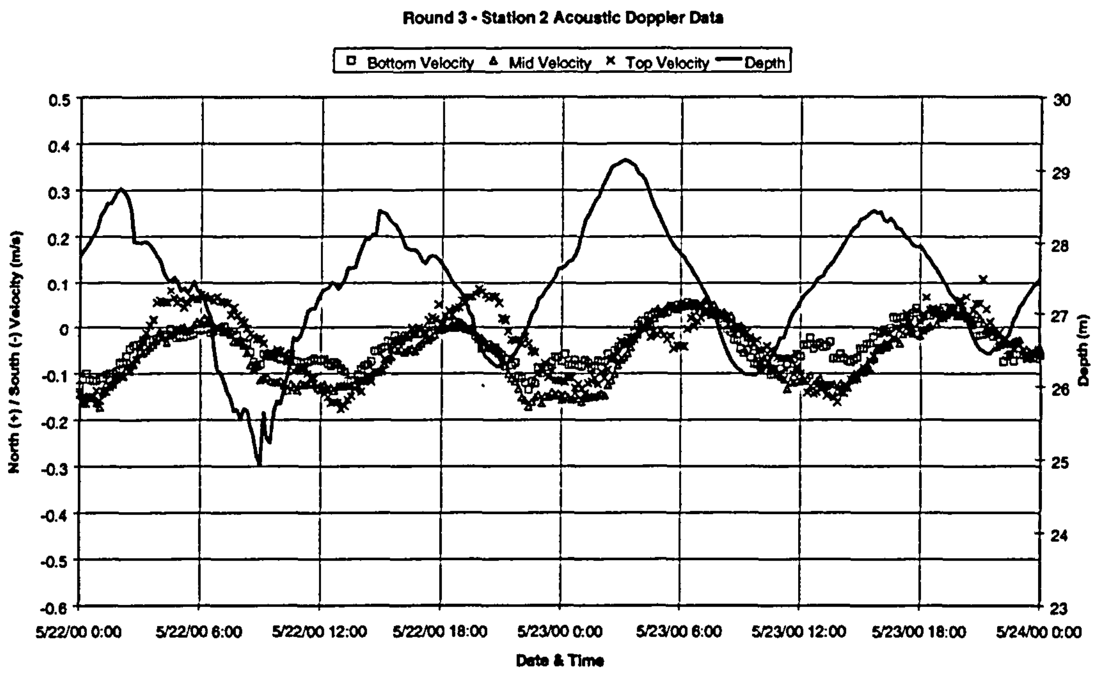
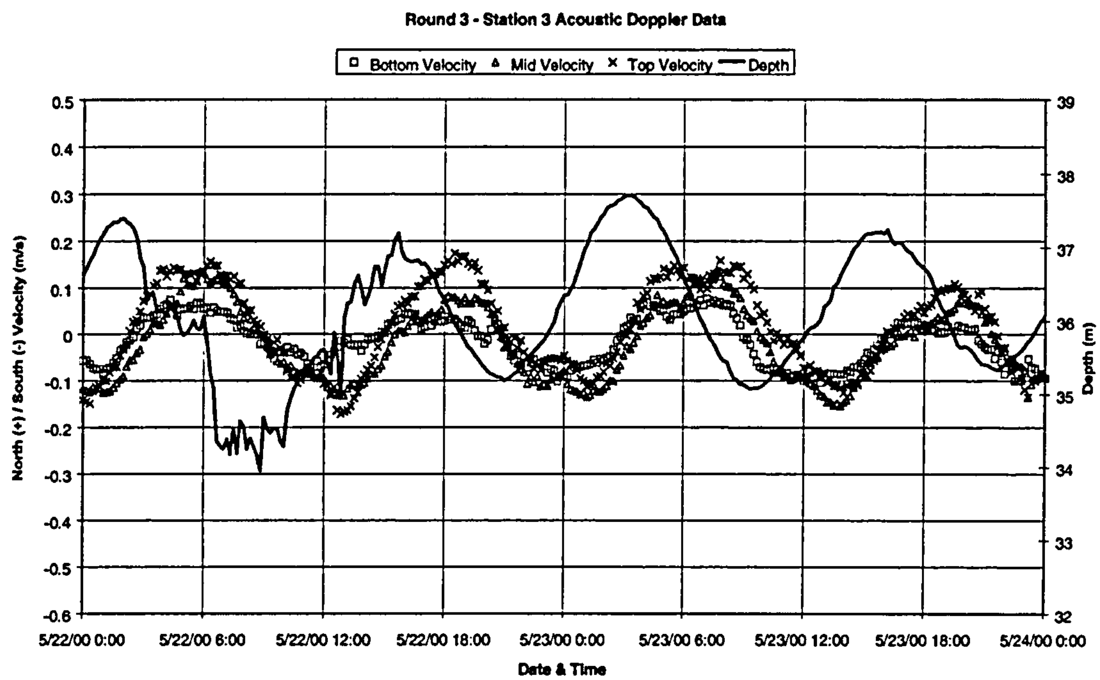


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



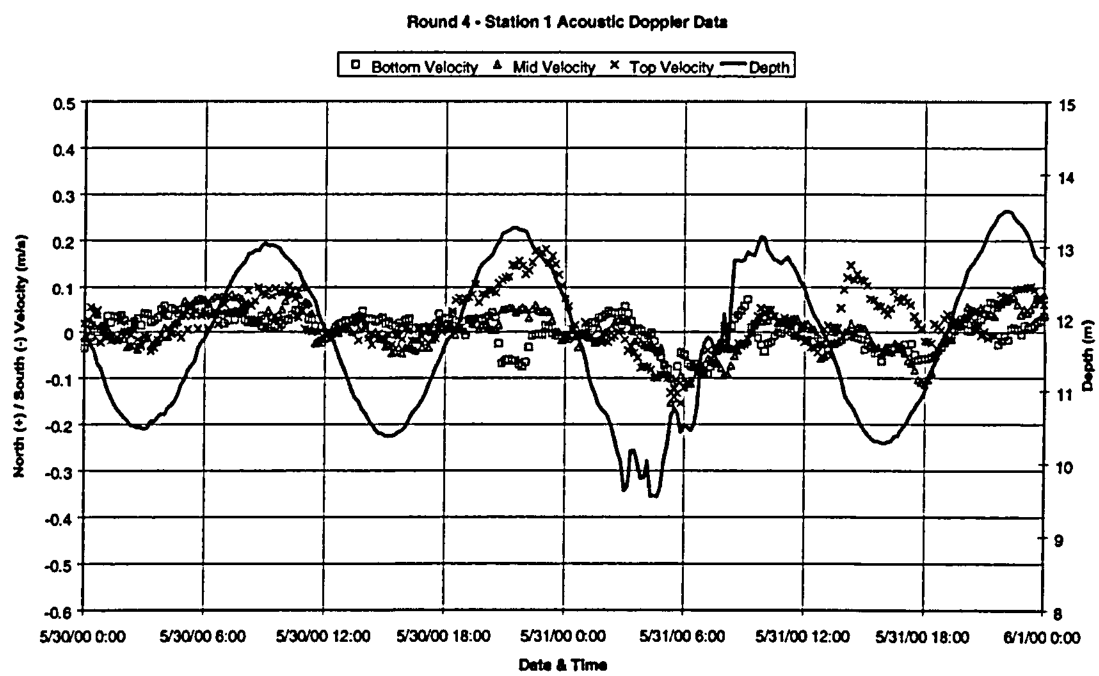
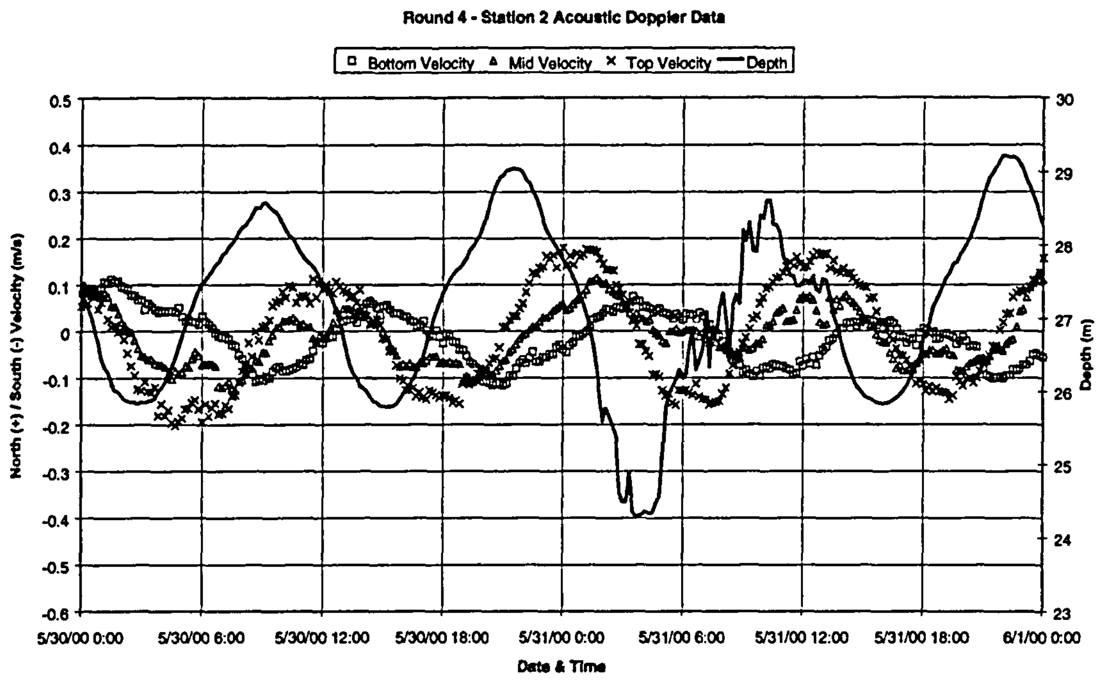


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)



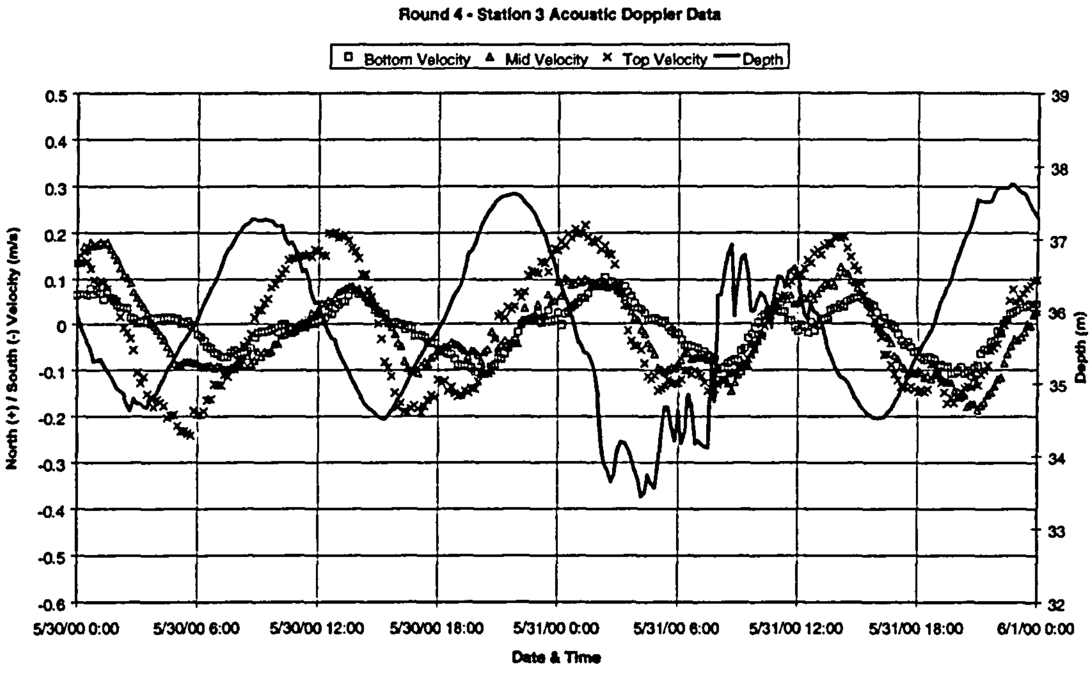


Figure 4-1 Surface, Mid, and Bottom North Velocity and Water Depth (continued)

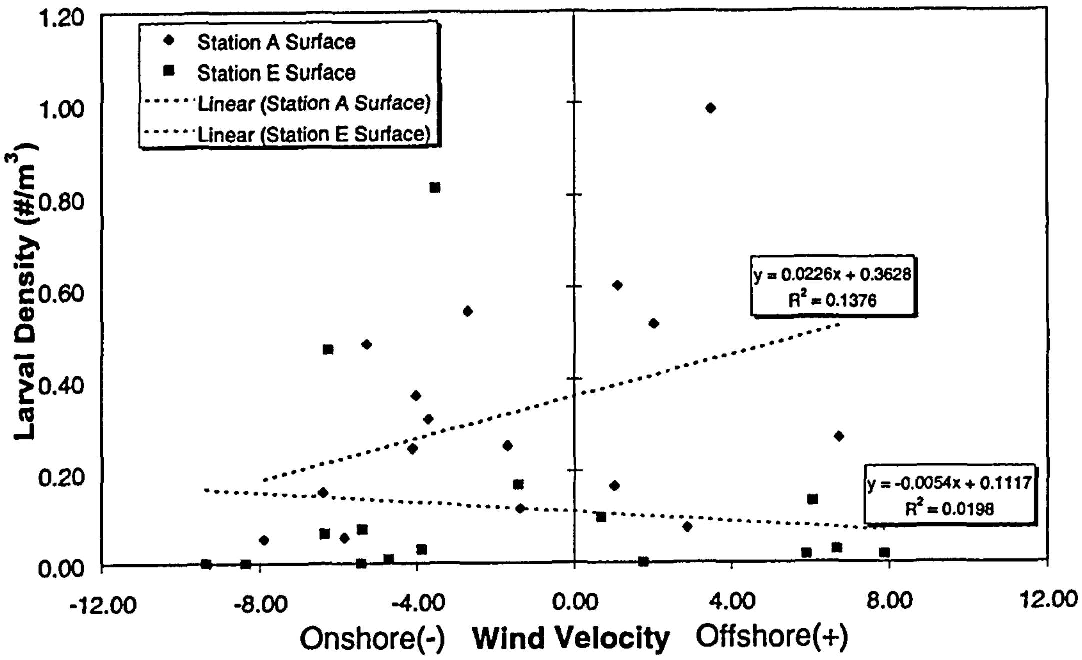


Figure 4-2 Wind Effects on Flounder Larval Densities

Table 4-1 Analysis of Volumetric Flow in Bay Study Area Compared to PNPS Withdrawal

	May 8-9	May 15-16	May 22-23	May 30-31	Study Duration
Net Volumetric Flow (m^3) in Bay Study Area for 1 Day	-8.75E+08	-2.21E+09	-5.35E+08	-2.88E+08	-8.21E+08
% of Volumetric Flow in Bay Study Area Withdrawn by PNPS* in 1 Day	0.19	0.08	0.32	0.59	0.21
* Assuming full pump operation at PNPS (19.56 m3/s)					

Table 4-2 Analysis of Larval Transport in Bay Study Area Compared to PNPS Entrainment

Day1 (May 8-9/2000)	Stage 1	Stage 2	Stage 3	Stage 4	Total
Net Larval Count in Bay Study Area	1.14E+07	4.05E+07	2.54E+07	0.00E+00	7.73E+07
Larval Entrainment at PNPS*	1.80E+04	5.22E+04	3.23E+04	0.00E+00	1.03E+05
% of Net Larval Flux Entrained by PNPS*	0.16	0.13	0.13	NA	0.13
Day2 (May 15-16/2000)					
Net Larval Count in Bay Study Area	8.51E+07	2.18E+08	2.95E+07	0.00E+00	3.33E+08
Larval Entrainment at PNPS*	1.33E+05	3.42E+05	2.12E+05	0.00E+00	6.87E+05
% of Net Larval Flux Entrained by PNPS*	0.16	0.16	0.72	NA	0.21
Day3 (May 22-23/2000)					
Net Larval Count in Bay Study Area	1.37E+07	1.73E+08	4.20E+07	4.50E+03	2.28E+08
Larval Entrainment at PNPS*	2.36E+03	3.91E+04	1.14E+05	0.00E+00	1.56E+05
% of Net Larval Flux Entrained by PNPS*	0.02	0.02	0.27	0.00	0.07
Day4 (May 30-31/2000)					
Net Larval Count in Bay Study Area	2.40E+05	6.17E+06	1.26E+07	6.21E+05	1.97E+07
Larval Entrainment at PNPS*	0.00E+00	1.76E+04	1.57E+05	3.17E+04	2.07E+05
% of Net Larval Flux Entrained by PNPS*	0.00	0.29	1.24	5.10	1.05
* Assuming full pump operation at PNPS (19.56 m3/s)					

Table 4-3 ANOVA for Flood and Ebb Larvae Concentrations

Alpha = 0.05
Null Hypothesis = The means of the two data sets are equal.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Ratio: Flood Surface to Bottom (larvae/m^3)	35	93.75	2.68	10.87
Ratio: Ebb Surface to Bottom (larvae/m^3)	38	88.02	2.32	10.73

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.39	1	2.39	0.22	0.64	3.98
Within Groups	766.66	71	10.80			
Total	769.05	72				

Since P-Value is > alpha, fail to reject the null hypothesis.
The means of the two data sets are equal.

5.0 CONCLUSIONS

The study results show that:

- There is a consistent net flow of water to the south along coastal Cape Cod Bay in the vicinity of PNPS.
- PNPS withdraws a relatively small percentage of the net flow – an average of approximately 0. 2%.
- Transport of winter flounder larvae follow a similar trend - there is consistently a net transport of larvae to the south.
- The amount winter flounder larvae entrained by PNPS is a relatively small percentage of the net larval transport – conservatively estimated at less than 1%.
- Winter flounder larvae do not appear to be using vertical transport in the water column as a retention mechanism to maintain position in a localized portion of Cape Cod Bay.
- Winds do not appear to have a significant influence on the density distribution of winter flounder larvae.

These results confirm the conclusion in the March 2000 316 Demonstration Report that entrainment at PNPS has not had any adverse impacts on the integrity of the winter flounder population. In fact, based on these results, the potential impact to the winter flounder population (less than 1%) is less than that stated in the 316 Demonstration (less than 5%).

6.0 REFERENCES

Motoda, S. 1959. Devices of simple plankton apparatus. Memoirs of the Faculty of Fisheries, Hokkaido University 7: 73-94.

Van Guelpen, L., D.F. Markle, and D.J. Duggan. 1982. An evaluation of accuracy, precision, and speed of several zooplankton subsampling techniques. International Council for the Exploration of the Sea 40: 226-236.

Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station

Attachment #2

Winter Flounder Larval Entrainment Statistical Analysis Report

Winter Flounder Larval Entrainment Statistical Analysis Report

Pilgrim Nuclear Power Station Plymouth, Massachusetts

November 2000

1.0 General

Winter flounder are commercially important in Cape Cod Bay and are a dominant species collected in entrainment monitoring at Pilgrim Nuclear Power Station (PNPS). Accurate estimates of larval entrainment at the Pilgrim Nuclear Power Station (PNPS) are important for evaluating the impact of entrainment on fisheries stocks in Cape Cod Bay. Previous statistical analyses of the entrainment monitoring data have focused on the power of the monitoring program to detect certain magnitudes of change in the rate of entrainment. These studies have made the assumption that the monitoring schedule followed until now has produced a random un-biased sample of the entrainment population. Since larval density is known to vary diurnally as well as seasonally, this assumption may be tested using data from a separate monitoring program focused on changes in larval entrainment over short (weekly, daily) periods of time. Although it is impossible to know what the "true" rate of entrainment is, the focused monitoring program should provide data that are closer to the real short-term variability than has been the case with normal monitoring schedules.

This study was designed to compare the entrainment data collected in the focused monitoring program (May 2000) with the long-term monitoring data, which has been collected 2 to 13 times a month for the last 20 years. A third data set made up of hourly samples collected on four days in 1977 was also analyzed. The study's objective was to determine whether the data collected during the current sampling schedule (3 times per week during the spawning period) is sufficiently representative of actual entrainment variation to provide an accurate estimate of the overall entrainment rate. If the current sampling schedule is not sufficiently representative of actual entrainment variation changes to the sampling frequency and/or schedule would be recommended.

2.0 Methods

Historically, routine entrainment sampling was completed twice per month during January and February, October through December and weekly during March through September. Triplicate samples were taken at low tide. This sampling regime was modified in 1994. From 1994 through 2000, single samples were taken at three separate times every other week during the fall and winter months, and three times each week from March through September. To maximize efficiency, the sampling schedule was linked to the impingement sampling schedule so that sampling was conducted on Monday mornings, Wednesday afternoons, and Friday nights, regardless of tide or light level.

A focused monitoring program was performed in May 2000 that consisted of four weekly sampling events, with each sampling event consisting of four samples throughout the day. For each of these events, larvae samples were obtained twice during the day, and twice during the night - over a 24-hour period.

An hourly entrainment sampling program was carried out in the spring of 1977 that was developed to investigate diurnal variability of larvae entrainment over a 24-hour period.

The statistical analyses focused on the May data for consistency and to account for seasonal trends in the magnitude of entrainment.

Four datasets were developed to represent:

1) the long-term entrainment results for the month of May from 1994-2000;

2) the results of the focused entrainment monitoring program in May 2000;
3) a subset of the long-term entrainment results for May 2000;
4) the results of the hourly sampling program in May 1977.

Figure 1 provides a plot of each of the four datasets, with larval density plotted versus day during May. Each dataset was characterized in terms of statistical distribution (normal, lognormal, etc) and distribution parameters (mean, variance, etc). Standard statistical tests (t-tests or non-parametric equivalents as appropriate) were then used to test Hypothesis 1 (H:1) that dataset 1 (long term dataset – May 1994-2000) is representative of the population sampled by dataset 2 (focused dataset – May 2000) at a 0.90 confidence level. If was determined that H:1 is rejected, then the same tests would be applied to datasets 1 and 3 to test Hypothesis 2 (H:2), that differences between dataset 1 and dataset 2 could be accounted for by differences in the time of sampling. If necessary (H:1 is rejected), time series analysis would be applied to each dataset in order to evaluate the significance of short-term periodicity in the monitoring results.

3.0 Statistical Analysis

The data were initially analyzed to determine if parametric or nonparametric tests were appropriate. For the parametric test to be applied, two assumptions must be met: (1) the data must be normally distributed; and (2) the variances must be equal. The Shapiro-Wilk's test was performed to determine if the data were normally distributed (Assumption 1). Since none of the datasets were found to be normally distributed, the data were transformed using the natural log of (X +1). The value of 1 was added to each entrainment value in order to account for entrainment values of zero. Datasets 2 and 4 were found to be log (X+1) - normally distributed. Datsets 1 and 3 were neither normal nor log-normally distributed. The data were then tested for equality of variance using the F-test (Assumption 2). The results of the F-test indicate that the variances of dataset 1 and 2 (log-transformed) were not equal and the variances of datasets 2 and 3 (log-transformed) were equal. Table 1 summarizes the results of this analysis.

Since dataset 1 was neither normal nor log-normally distributed, the nonparametric, Mann-Whitney test was performed on the data to test H:1. The nonparametric, Mann-Whitney test indicated that dataset 1 is representative of the population sampled by dataset 2 at a 0.90 confidence level ($p = 0.3868$, which exceeds the alpha value = 0.10). Therefore, H:1 was accepted. Table 1 summarizes the results of the statistical analysis and the detailed statistical output is presented in Appendix A.

Since H:1 was accepted, it was not necessary to test H:2 (dataset 2 vs. dataset 3) or perform time-series analyses on the datasets.

A graphical demonstration of the comparability of the datasets is provided on Figure 1. The figure shows that the larval densities from the May 2000 focused program and the detailed 1977 measurements are well within the range of densities from the long-term program. Comparison of data from the focused and long-term programs for May 2000 shows that on May 15 the long-term program value was lower than values from the focused program, but that on other dates the values from the two programs were within a comparable range. This indicates that in general the long-term program adequately represents the randomness of the larval data.

4.0 Conclusions

The results of the statistical analysis indicate that the population of winter flounder larvae sampled by the long-term entrainment monitoring program (May 1994-2000) is representative of the population sampled by the focused entrainment monitoring program (May 2000) at a confidence level of 0.90. Since the present monitoring schedule results in entrainment data representative of a more focused monitoring program, there is no reason to recommend changes to the present long-term entrainment sampling schedule.

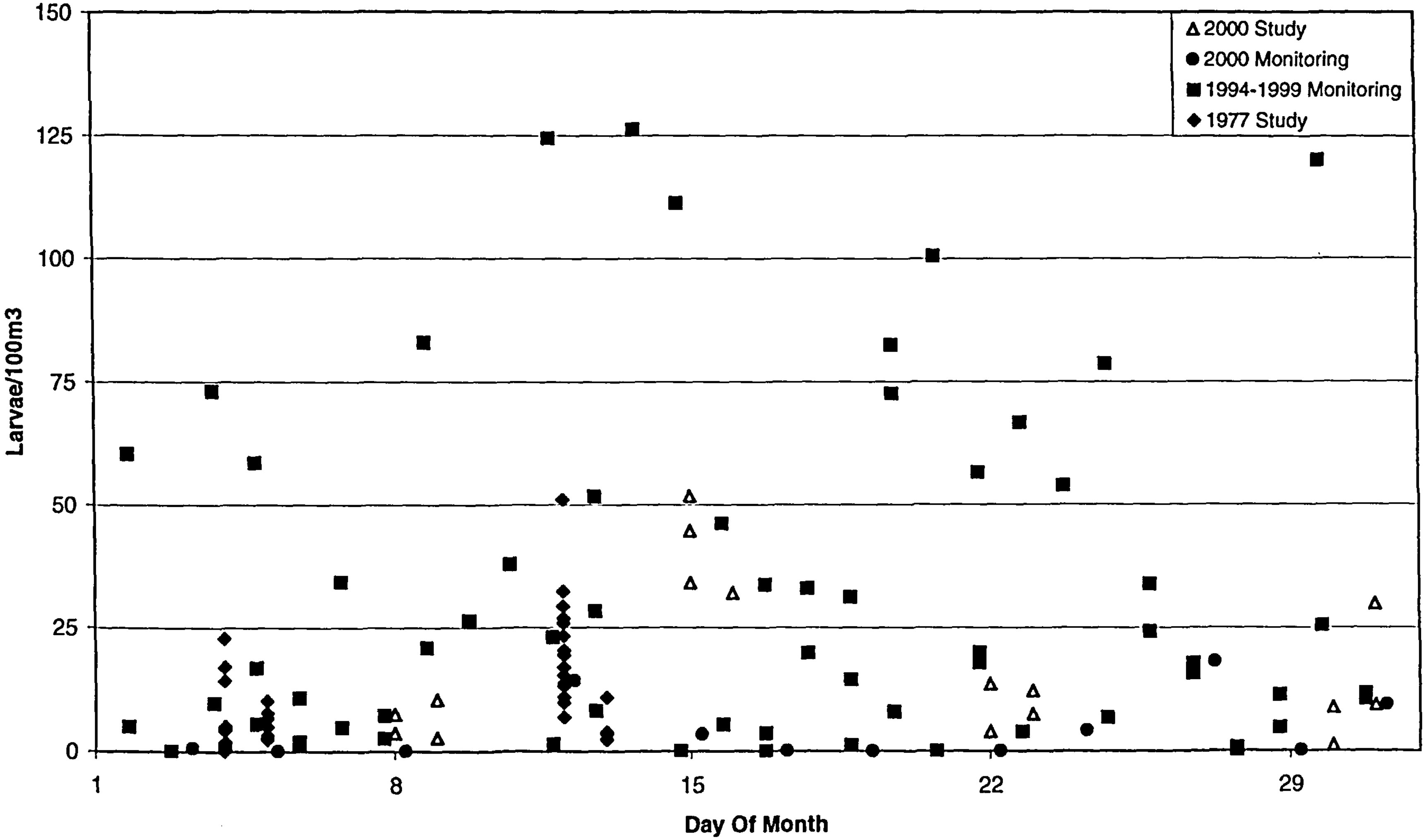
TABLE 1. Summary of Winter Flounder Larval Entrainment Statistical Analysis

Dataset	Date	Distribution
1	May 1994-2000 (Long-Term)	Not normal
2	May 2000 (Focused)	Log (X+1) normal
3	May 2000 (Long-Term)	Not normal
4	May 1977	Log (X+1) normal

Hypothesis	Comparison	Equality of Variance (F-test)	Test Used (Parametric/ Nonparametric)	Accept/Reject Hypothesis(1)
H:1	Dataset 1 vs. Dataset 2	Not equal	Nonparametric(2)	Accept
H:2	Dataset 1 vs. Dataset 3	Equal	NA	NA

Notes:
H:1 – Dataset 1 is representative of the population sampled by dataset 2.
H:2 – Differences between datasets 1 and 3 are accounted for by differences in the time of sampling.
(1) Hypotheses were accepted/rejected on basis of 0.90 confidence level.
(2) Since Dataset 1 was neither normal nor log-normally distributed the nonparametric test (Mann-Whitney test) was performed to test H:1.
NA – Since H:1 was accepted, it was not necessary to test H:2.

FIGURE 1
Flounder Densities By Day Of Month
May Sampling



APPENDIX A

STATISTICAL OUTPUT

TABLE A-1
RESULTS OF SHAPIRO-WILK'S NORMALITY TEST – RAW DATA

StatMost for Windows   Monday, November 13, 2000   5:33:45 PM

Normality Tests

Column Name: [1994-2000]
Sample Size = 80
Number of Missings = 0
Data Mean = 35.9416
Standard Deviation = 74.7894

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.4849
Probability = 0.0000

Column Name: [1977]
Sample Size = 48
Number of Missings = 0
Data Mean = 10.4720
Standard Deviation = 10.9181

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.8389
Probability = 0.0000

Column Name: [F2000] – 2000 Focused Study
Sample Size = 16
Number of Missings = 0
Data Mean = 17.0362
Standard Deviation = 16.0383

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.8326
Probability = 0.0071

Column Name: [M2000] – 2000 Long-Term Monitoring
Sample Size = 13
Number of Missings = 0
Data Mean = 3.8192
Standard Deviation = 6.1434

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.6952
Probability = 0.0003

StatMost Report Created by sjk, ensr

TABLE A-2
RESULTS OF SHAPIRO-WILK'S NORMALITY TEST – LN (X+1) DATA

StatMost for Windows Monday, November 13, 2000 5:36:37 PM

Normality Tests

Column Name: [ln(1994-2000)]
Sample Size = 80
Number of Missings = 0
Data Mean = 2.4753
Standard Deviation = 1.6159

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.9391
Probability = 0.0013

Column Name: [ln(1977)]
Sample Size = 48
Number of Missings = 0
Data Mean = 1.9620
Standard Deviation = 1.0460

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.9525
Probability = 0.0840

Column Name: [ln(F2000)] – 2000 Focused Study
Sample Size = 16
Number of Missings = 0
Data Mean = 2.4991
Standard Deviation = 0.9510

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.9584
Probability = 0.6119

Column Name: [ln(M2000)] - 2000 Long-Term Monitoring
Sample Size = 13
Number of Missings = 0
Data Mean = 0.8900
Standard Deviation = 1.1656

Shapiro-Wilk Normality Test:
Shapiro-Wilk's W = 0.7607
Probability = 0.0019

StatMost Report Created by sjk, ensr

TABLE A-3
RESULTS OF F-TEST FOR EQUALITY OF VARIANCE – RAW DATA

StatMost for Windows   Monday, November 13, 2000   5:39:00 PM

F-Test Analysis Results

Confidence Level = 0.90

1994-2000 vs. F2000:

	1994-2000	F2000	
Sample Size	80	16	
Number of Missings	0	0	
Standard Deviation	74.7894	16.0383	
Mean	35.9416	17.0362	Difference = 18.9054
Variance	5593.4584	257.2268	Ratio = 21.7452
Degree of Freedom	79	15	

F-Value = 21.7452   Probability = 6.07779E-008
Critical F-Value = 1.8025

F2000 vs. M2000:

	F2000	M2000	
Sample Size	16	13	
Number of Missings	0	0	
Standard Deviation	16.0383	6.1434	
Mean	17.0362	3.8192	Difference = 13.2170
Variance	257.2268	37.7413	Ratio = 6.8155
Degree of Freedom	15	12	

F-Value = 6.8155   Probability = 0.0019
Critical F-Value = 2.1049

StatMost Report Created by sjk, ensr

TABLE A-4
RESULTS OF F-TEST FOR EQUALITY OF VARIANCE – LN (X+1) DATA

StatMost for Windows   Monday, November 13, 2000   5:40:14 PM

F-Test Analysis Results

Confidence Level = 0.90

ln(1994-2000) vs. ln(F2000):

	ln(1994-2000	ln(F2000)	
Sample Size	80	16	
Number of Missings	0	0	
Standard Deviation	1.6159	0.9510	
Mean	2.4753	2.4991	Difference = -0.0238
Variance	2.6112	0.9043	Ratio = 2.8875
Degree of Freedom	79	15	

F-Value = 2.8875   Probability = 0.0245
Critical F-Value = 1.8025

ln(F2000) vs. ln(M2000):

	ln(F2000)	ln(M2000)	
Sample Size	16	13	
Number of Missings	0	0	
Standard Deviation	0.9510	1.1656	
Mean	2.4991	0.8900	Difference = 1.6092
Variance	0.9043	1.3586	Ratio = 0.6657
Degree of Freedom	12	15	

F-Value = 1.5023   Probability = 0.4515
Critical F-Value = 2.0171

StatMost Report Created by sjk, ensr

TABLE A-5
RESULTS OF MANN-WHITNEY TEST

StatMost for Windows   Tuesday, November 14, 2000   9:26:43 AM

Mann-Whitney Test Analysis Results

1994-2000 vs. F2000:

Column Name	1994-2000	F2000
Sample Size	80	16
Total Sum	2875.3300	272.5800
Mean	35.9416	17.0362

Minimum Sample Size = 16
U1 = 654.000000
R1 = 762.000000
Maximum Sample Size = 80
U2 = 626.000000
R2 = 3894.000000
Minimum U = 626.000000
Standard Deviation = 101.718566
z-score = 0.137635
Two-tailed P value = 0.890530

StatMost Report Created by sjk, ensr

Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station

Attachment #3

PNPS Impact Assessment Models

PNPS Impact Assessment Models

Prepared for

Entergy Nuclear Generation Company

600 Rocky Hill Road

Plymouth, MA 02360

by

Marine Research, Inc.

141 Falmouth Heights Road

Falmouth, MA 02540

October 30, 2000

Table of Contents

Figures

Tables

Introduction

Numbers of larval winter flounder entrained at PNPS have been assessed using hydrodynamic models (Leimkuhler 1974, Wang and O'Connor 1975, Stone and Webster Engineering 1975, Pagenkopf et al. 1976, MRI 1978), the equivalent adult methodology (see for example MRI 2000), and the Risk Analysis Management Alternatives System (RAMAS) software program (MRI 2000). This report summarizes an analysis of entrainment and impingement of winter flounder at PNPS using three additional analytical methods--a completely mixed model, production foregone, and eggs-per-recruit. These models represent an attempt to use additional mathematical tools available from the study of population dynamics to complete as many views of impact assessment as possible. These mathematical exercises result in calculated impact assessments or discrete values (e.g., production foregone), the significance of which is best determined in conjunction with earlier studies as well as results from current empirical studies, such as the recently completed larval transport study in Cape Cod Bay (ENSR and MRI 2000).

Completely Mixed Model

This highly simplistic model assumes that entrainable plankton are randomly distributed in the body of water from which a power plant's cooling water is withdrawn. The model also assumes that all entrainable organisms become available at a single point in time and that all are equally susceptible to entrainment at any point in time. While this is clearly not the case for winter flounder which spawn over several weeks and are not uniformly distributed throughout the Bay (Scherer 1984), this method permits a generalized assessment of the volume of water withdrawn by a power plant relative to the source water volume. Since the source water body is assumed to be closed with no exchange of water during the entrainment period, this model is very conservative for Cape Cod Bay which has an open boundary to the north and extensive tidal exchange. The model has the form:

$$cmr = 1 - \exp(-p/v)t \quad \text{where}$$

cmr is the conditional mortality rate attributable to entrainment .

p is the water withdrawal rate of the plant .

v is the volume of water from which circulating water is withdrawn i.e. the source water volume and

t is time.

For application to PNPS, p was set equal to the maximum circulating water flow for the station of 17,461, 100 m^3 units of seawater per 24-hour day. This value is based on two circulating water pumps each rated at 155,000 gpm and four salt service water pumps each rated at 2500 gpm.

Since the true value of v is unknown, the volume of Cape Cod Bay was used as an upper limit (450,000,000, 100 m^3 units, Collings et al. 1981). For perspective PNPS would require 70 years to circulate a volume of water equal to the volume of Cape Cod Bay. The value of cmr was determined for decreasing values of v and increasing values of t from 6 days to 70 days. As an example, Figure 1 illustrates conditional mortality rates over time as entrainment occurs continuously for 6 to 70 days with the volume of source water equal to 6 and 10% of the volume of Cape Cod Bay. Figure 2 shows the corresponding decline in numbers of larvae in the source water beginning with an arbitrary total of 1000 larvae in the source water subject to entrainment.

A realistic estimate of the entrainment interval for a winter flounder larva is 55 days. This is based on Laurence (1975) who reared larvae from hatch to metamorphosis in 49 days at 8 C and 80 days at 5 C. Mean monthly water temperature recorded in the PNPS intake from 1990-1999 (Anderson 2000) ranged from 6.5 C in April to 9.8 C in May, the two months when larval flounder are most abundant. Figure 3 shows values of conditional mortality (cmr) after 55 days for source water portions of Cape Cod Bay ranging from 2 to 20% (0.02 to 0.2). Clearly, as the portion of Cape Cod Bay contributing to entrainment decreases, the mortality rate within that portion increases. The smaller the portion of Cape Cod Bay contributing to PNPS the larger the impact.

To provide one empirical estimate of the source pool for PNPS the area considered by the winter flounder area-swept program was examined. That area, estimated to be 267,391,500 m^2, was established by simple modeling of the distance larval flounder might drift before reaching PNPS (see Lawton et al. 2000). Based on NOAA nautical chart 13246, a mean depth of 67 feet (20.4 m) was calculated over that area providing a volume of 2,673,915,000 m^3 or 5.9% of the volume of Cape Cod Bay. With an entrainment period of 55 days and a source volume of 6% the completely mixed model suggests a conditional mortality rate of 3.5%. Additional estimates of conditional mortality rates for 40 to 70-day periods and source water volumes ranging from 2 to 10% of Cape Cod Bay are provided in Table 1.

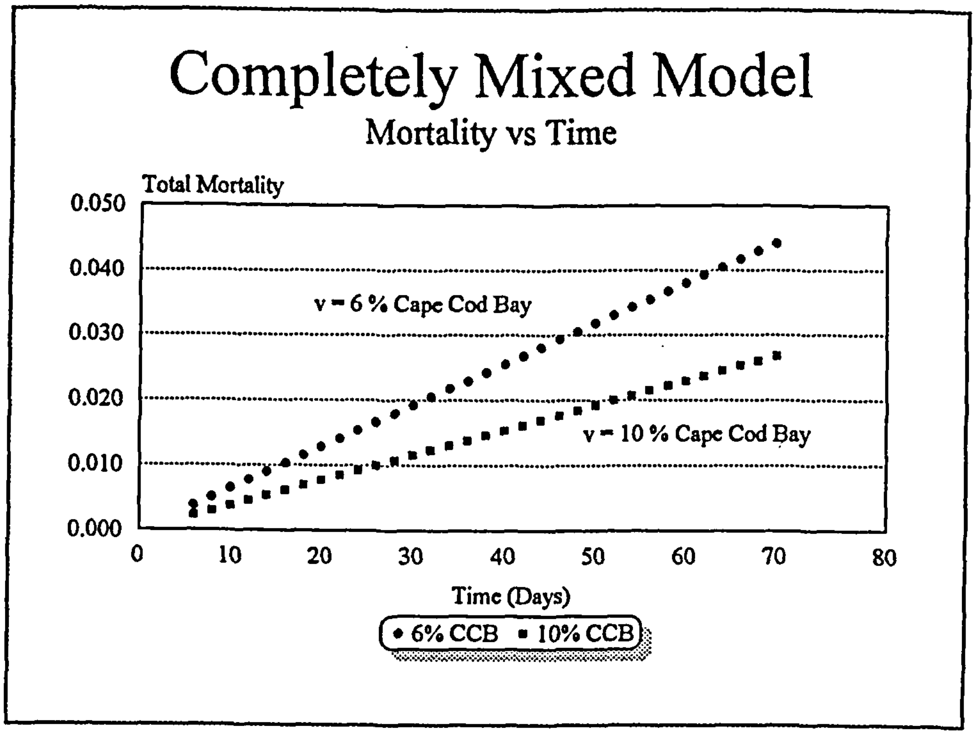


Figure 1. Conditional mortality as a function of entrainment periods ranging from 6 to 70 days long and circulating water volume equal to 6% and 10% of the volume of Cape Cod Bay.

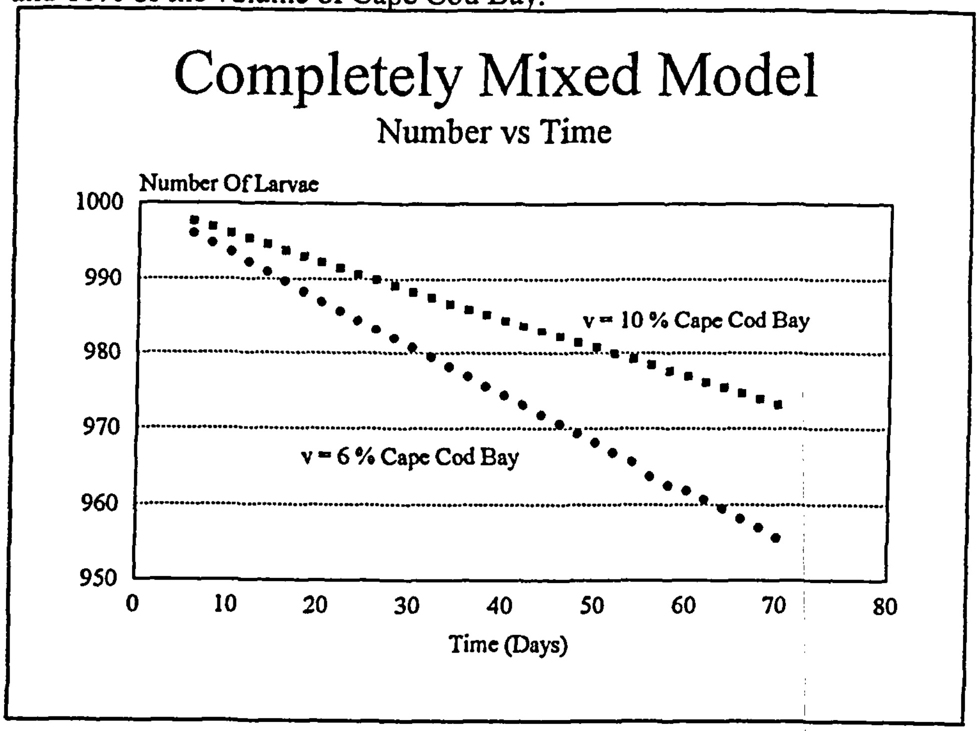


Figure 2. Decline in the number of larvae with time in source water volumes equal to 6 and 10% of the volume of Cape Cod Bay.

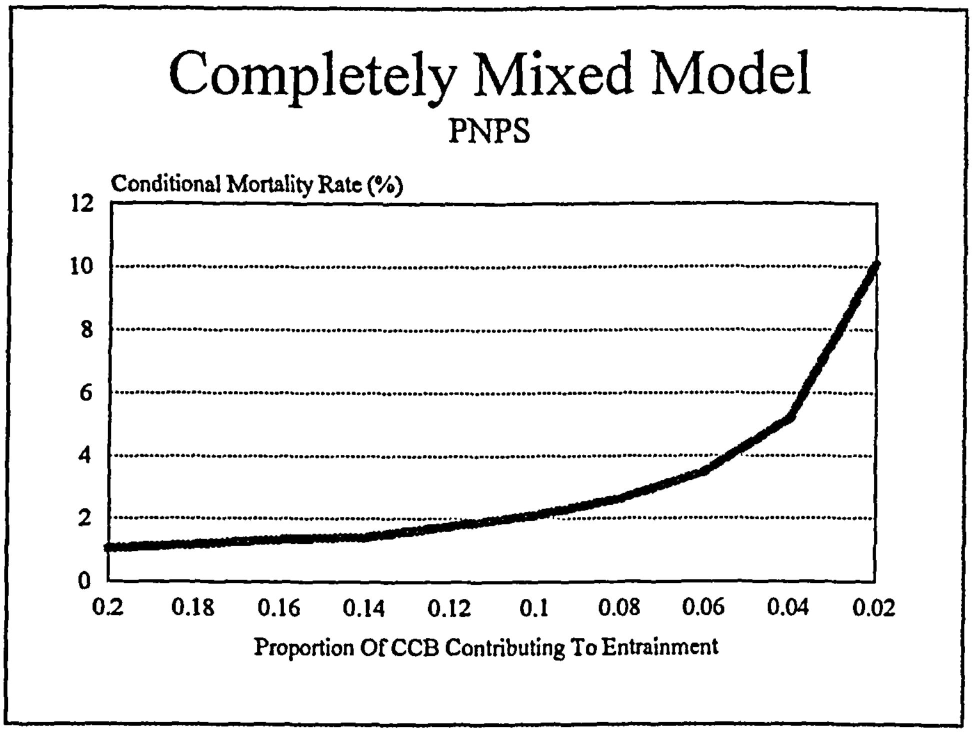


Figure 3. Conditional mortality rate as a function of the volume of source water expressed as a percentage of Cape Cod Bay for a 55-day entrainment period.

Production Foregone Model

The production foregone methodology (Rago 1984) estimates losses of biomass resulting from mortality of early life history stages, in this case from power plant entrainment and impingement. In particular the approach projects biomass which becomes unavailable to an aquatic system assuming some loss of fish eggs, fish larvae, and young fish. A fish larva lost to entrainment effects would have added biomass with time as it grew had it not been entrained. The model addresses the question - what biomass would that individual have produced as it increased in size (weight) over the remainder of its life span. A production foregone model predicts biomass which could have been produced by a fish population considering rates of growth in weight as that is offset by rates of mortality. The formulation for each age group or cohort considered is:

$$P_i = G_i * B_i \quad \text{where}$$

G_i = the instantaneous rate of growth for cohort i = Loge (average weight per individual at time t + 1 divided by average weight per individual at time t) and

B_i = average biomass of cohort i over the interval of production.

Applied to a life stage or cohort of any duration

$$Pi = \frac{G_i N_i W_i (\exp(G_i - Z_i) - 1}{G_i - Z_i} \quad \text{where}$$

G_i is as defined above.
N_i = the number of cohort i lost.
W_i = mean weight of an individual in cohort i.
Z_i = the instantaneous mortality rate of cohort i.

Key assumptions of the production foregone model include that population productivity decreases in direct proportion to entrainment and impingement losses. It is further assumed that reduction in one year's cohort does not reduce the number of adults in subsequent years. Mortality and growth which clearly vary from year to year are also held constant in the model. Consistent with all models used to assess PNPS, a mortality rate of 100% was assumed for all entrained eggs and larvae.

For the winter flounder population at PNPS production foregone was estimated for numbers of eggs and larvae entrained as well as numbers of young fish impinged over the 1980 through 1999 period (Table 2). Values of G, W and Z for each life stage and the source for each parameter estimate appear in Table 3 while annual totals appear in Figure 4 and Table 4. Entrainment of stage 1 and 2 larval flounder account for a relatively small proportion of the production foregone based on time series averages (0.4 and 4.1%). Lost production attributable to stage 1 larvae averaged 147 pounds and that attributable to stage 2 larvae1,410 pounds. These individuals have a high mortality rate and relatively few reach the point where rapid growth in weight occurs. Entrainment of stage 3 larvae account for 73% of the lost production, averaging 25,500 pounds annually over the 1980-1999 period. Stage 4 individuals, although they numbered only about 600,000 each year, accounted for an average of 7,800 pounds annually or 22.4% of the total (Figure 5). These larvae have survived the early, high mortality larval stages and grow rapidly in weight. The production foregone per individual entrained is therefore relatively high for stage 3 and 4 larvae (Figure 6). Lastly, impinged fish have high mean weights relative to larval flounder and rapid growth rates. While they are impacted in small numbers and contribute only an average of two pounds per year to the lost production, their production on an individual basis is relatively high.

The production foregone model is useful in identifying the impacted life stages which contribute most to biomass production and may therefore be useful in planning mitigation measures (Rago 1984). Lost production occurring between larval stages (Figure 7, Table 5) is difficult to relate to in a meaningful way since that production is utilized by low trophic levels such as bacteria, zooplankton, and planktivorous macroinvertebrates such as mollusks. A portion of the larval stage production foregone could be available to planktivorous fish. Once in the juvenile size classes, production may become available to macroinvertebrates, and piscivorus fish and birds. Examination of the production which would have occurred at marketable sizes is similar to the adult equivalent procedure and can be compared to recreational and commercial landings.

Rago (1984) explored model sensitivity to the large array of parameters required by conducting runs with an array of values in stepwise fashion. He reported that the model was most sensitive to changes in post-yolk-sac larval (winter flounder stages 2 through 4) and juvenile survival rates. These life stages account for the majority of impacted individuals. The model was insensitive to changes in weight of early larval stages but was sensitive to changes in weight of age 3 and 4 fish. This makes intuitive sense as larvae have relatively little biomass while young adult fish add biomass rapidly. As Rago points out, the model is most sensitive to parameters which are difficult to estimate and the production foregone values become more prone to error the further into the future (i.e. the maximum age of the modeled fish) the estimates are carried.

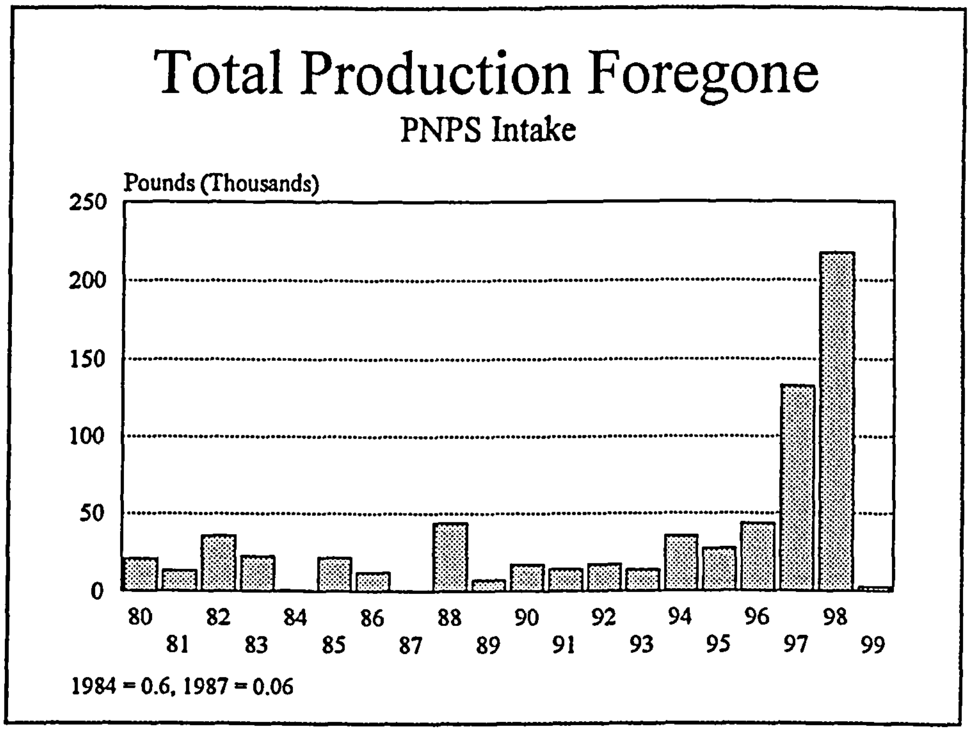


Figure 4. Total production foregone by year attributable to numbers of winter flounder entrained and impinged at PNPS, 1980-1999.

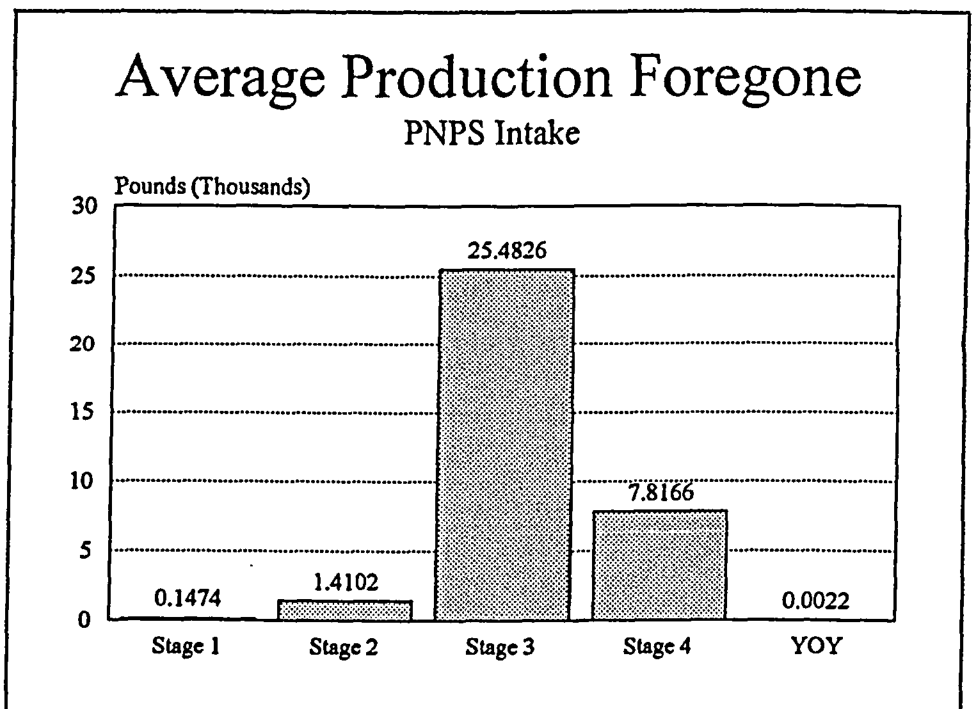


Figure 5. Average production foregone attributable to entrainment and impingement of winter flounder at PNPS by life stage, 1980-1999.

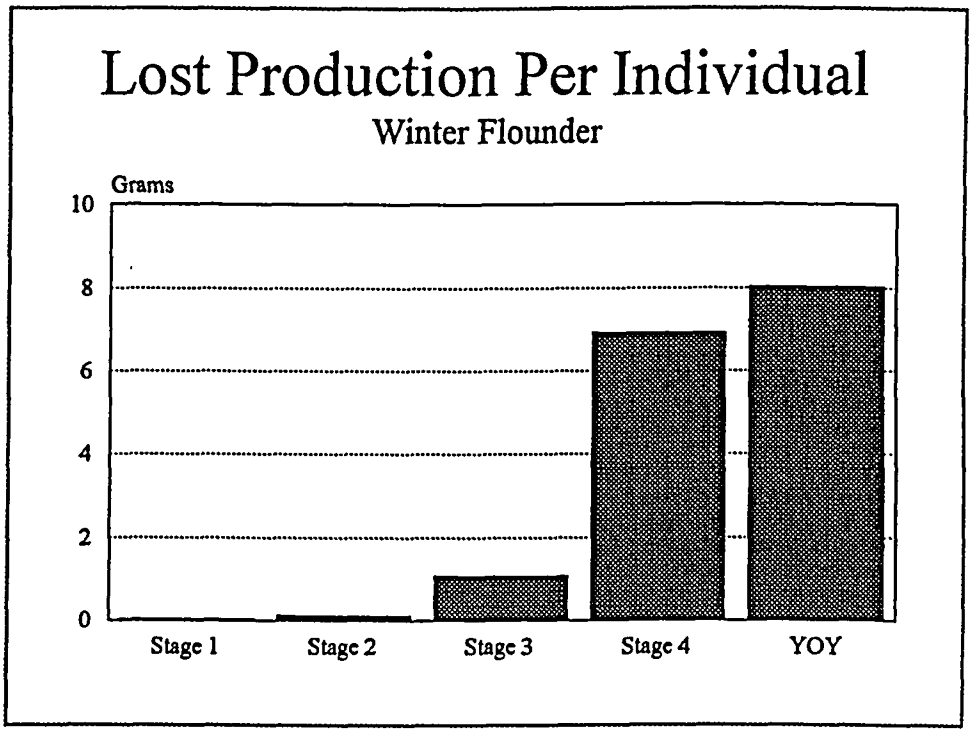


Figure 6. Average lost biomass production per individual entrained and impinged at PNPS, 1980-1999.

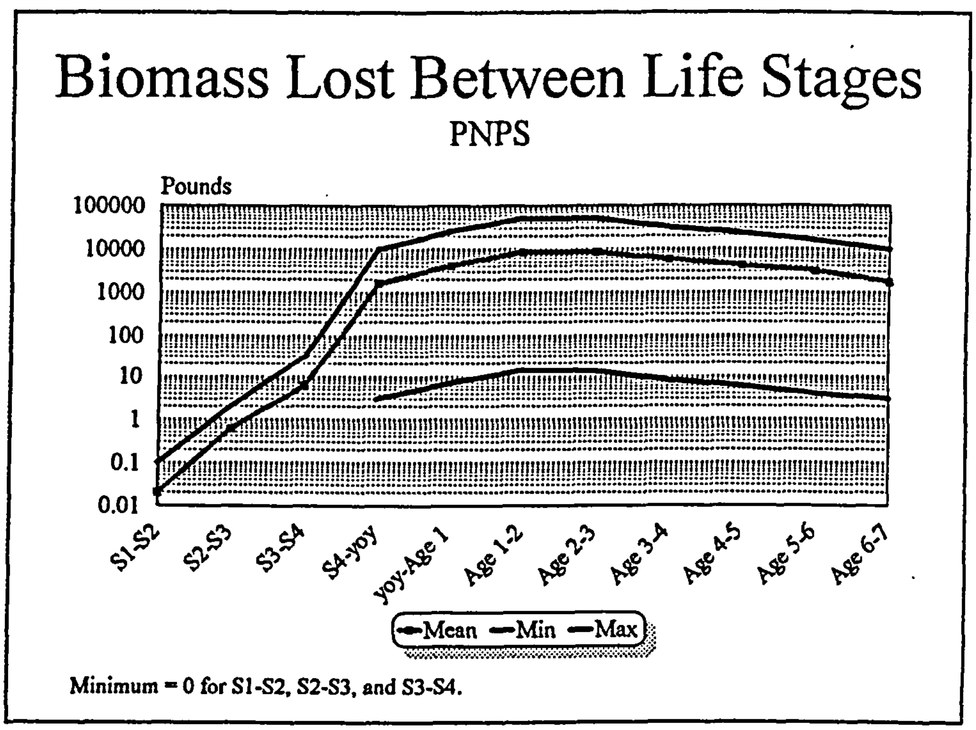


Figure 7. Average, minimum, and maximum biomass lost between life stages of winter flounder entrained and impinged at PNPS, 1980-1999.

Reproductive Potential Models

Eggs-Per-Recruit (EPR)

This model projects the number of eggs produced by an adult female fish during her lifetime under different rates of natural and fishing mortality. Mortality is assumed to be independent of population density. Since the determination of potential number of eggs produced begins with the age at which a female begins to spawn i.e. the age of recruitment, the approach is referred to as the eggs per recruit or EPR model (Goodyear 1988, Boreman et al 1993). The total number of eggs that an age-1 female winter flounder can be expected to produce in her lifetime (E) is the sum of the number of eggs produced at each spawning age (i) times the probability of surviving to that age.

$$E = \sum_{i=1}^{n} Ri * Fi * \prod_{i=1}^{n-1} Si$$ where:

E = lifetime egg production.
R = the proportion of age i females that are mature.
F = fecundity at age i.
S = the probability of survival to age i.
n = maximum age.

The survival rate S can be expressed with three components:

$$S_j = e^{-(Fi + Mi + Pi)}$$ where:

F is the instantaneous fishing mortality rate at age i.
M is the natural mortality rate at age i and
P is the instantaneous mortality rate at age i due to other sources.

In the above formulation other sources of mortality (P_i) can be varied to explore the effects of changes in mortality rate resulting from such things as habitat alteration or stock enhancement (Boreman et al. 1993). The effects of entrainment of eggs and larvae can also be explored by varying P_o. If it is assumed that the population is neither increasing nor decreasing over some time interval, then survival during the first year of a fish's life from a spawned egg to age 1, before recruitment occurs (S_o) will be:

$$S_o = 2/E$$

assuming an even sex ratio.

In applying the EPR model to an understanding of the potential impacts of PNPS, entrainment of eggs and larvae and impingement of young-of-the-year (age 0) fish reduces the overall survival rate of age 0 individuals (S_0). Changes in S_0 can be compared with corresponding changes in fishing mortality (F) which would be necessary to maintain a stable population. If S_0 declines, then eggs per recruit must increase to compensate. Fishing mortality directly affects the number of eggs produced per recruit by reducing the probability that a given female will spawn each year of her life.

Estimates of mean length and weight at age, fecundity at age derived from length and weight, and mortality rates are listed in Table 6. Emax, the total number of eggs potentially produced by a female winter flounder during her lifetime, in the absence of fishing mortality is 3,729,081. The most recent estimates of fishing mortality rates at age (1997, NFSC 1999) produce an estimate of eggs per recruit of 1,057,900 or 28.4% of Emax. This is consistent with Goodyear (1993) who recommended that the ratio of EPR for a fished stock relative to EPR for the same stock in the absence of fishing should not drop below 20%. Estimates of survival from spawned egg to age 1 (S_0) are 5.3633E-07 for the unfished population and 1.8905E-06 for the population subject to 1997 fishing mortality rates. It is likely that fishing mortality rates for 1998 and 1999 were somewhat lower than those in 1997 (Steve Correia, Massachusetts Division Of Marine Fisheries, personal communication). As an estimate of more recent rates, F was reduced by 10% for ages 1 through 5. This produced an EPR value of 1,154,644 eggs, 31.0% of Emax, and an S_0 estimate of 1.7321E-06.

Estimates of Emax, EPR, and S_0 under different levels of fishing mortality are dependent upon estimates of fecundity. However, the EPR model's primary focus is on the relative change in EPR and corresponding changes in fishing mortality required to offset changes in S_0. Table 7 presents an estimate of Emax and EPR with 1998 and 1999 fishing mortality rates with an alternate fecundity vector obtained from Correia (1998). The higher fecundity estimates provided by Correia provide EPR estimates about 1.3 times greater than the fecundity estimates provided by Boreman et al. (1993). Necessary changes in fishing mortality required to offset changes in S_0 remain unchanged however.

While the true value of S_0 under the influence of entrainment and impingement is currently unknown it is reasonable to suggest that it might range between 1 and 15%. By varying Po from 1 to 15% corresponding changes in fishing mortality required to maintain a stable population were determined.[1] As indicated in Figure 8, consistent with Boreman et al. (1993), these values are nearly equal. For example, to offset a conditional mortality rate of 5%, a 5.3% reduction in fishing mortality would be required. The larval abundance and distribution study recently conducted in Cape Cod Bay during May 2000 suggested that conditional mortality attributable to entrainment was less than 1% (see ENSR and MRI 2000). To offset such a small change in S_0 would require correspondingly small changes in fishing mortality.

---

[1] Note that the survival rate $s = e^{-z}$. Recall from above that Z the instantaneous rate of mortality = F + M + P. For age 0 individuals F is assumed to be 0. If M remains unchanged, then a 5% conditional mortality rate corresponds to an instantaneous rate of 0.0513.

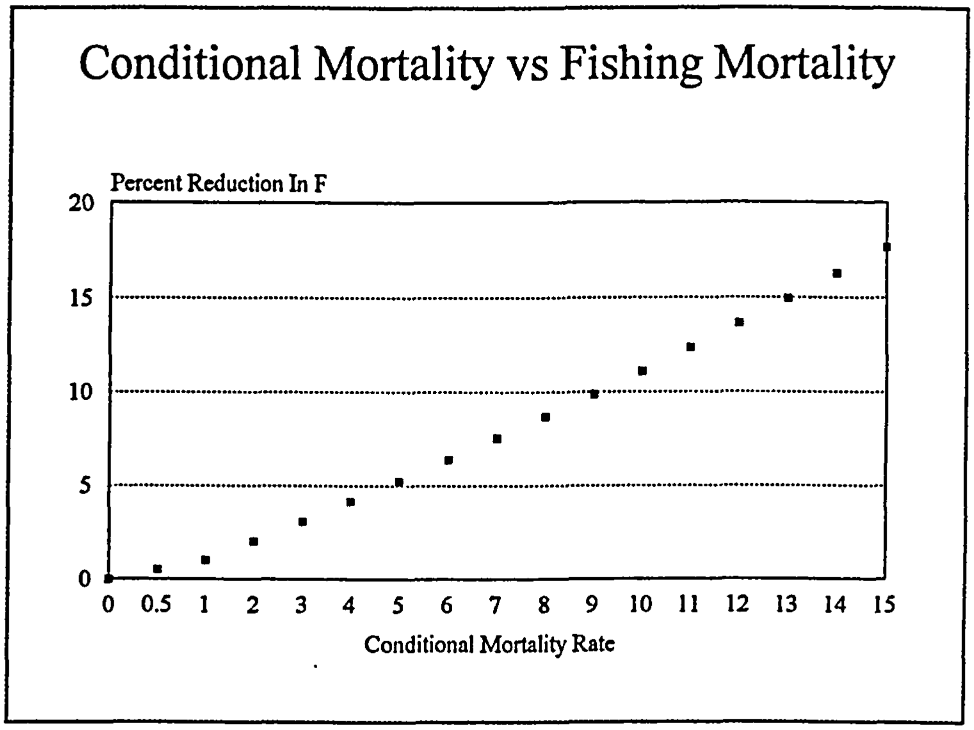


Figure 8. Percent reduction in fishing mortality rate required to offset conditional mortality rates ranging from 0.5 to 15%.

Spawning Stock Biomass Per Recruit (SSBR)

Spawning stock biomass per recruit is another expression of reproductive potential similar to eggs per recruit (Shepherd 1982, Gabriel et al. 1989, Goodyear 1993, Boreman 1997). Rather then estimating the number of eggs which a female may produce in her lifetime, it is a measure of the weight of spawning age fish which would be produced by a recruit. Using the same parameters as for the eggs-per-recruit calculation, an age 1 winter flounder would be expected to produce 587 gms of spawning-age fish under 1997's fishing mortality rate and 640 gms under the somewhat lower estimated 1998-99 fishing mortality rate. These values provide spawning potential ratios $SSBR_{fished}/SSBR_{unfished}$ (Goodyear 1993) equivalent to the proportion of Emax using the eggs-per-recruit values (0.284 and 0.313, respectively). Conditional mortality of eggs, larvae, and juveniles resulting from entrainment and impingement, if offset by decreases in fishing mortality, would have corresponding, equivalent changes in spawning stock biomass (Table 8).

Table 1. Conditional mortality rate (m) for 40 to 70 day entrainment periods based on a completely mixed model with the PNPS source pool volume estimated at 2 to 10% of the volume of Cape Cod Bay.

	PNPS Source Pool As Percent Of Cape Cod Bay				
Entrainment Period (Days)	2	4	6	8	10
40	0.075	0.038	0.026	0.019	0.015
42	0.078	0.040	0.027	0.020	0.016
44	0.082	0.042	0.028	0.021	0.017
46	0.085	0.044	0.029	0.022	0.018
48	0.089	0.045	0.031	0.023	0.018
50	0.092	0.047	0.032	0.024	0.019
52	0.096	0.049	0.033	0.025	0.020
54	0.099	0.051	0.034	0.026	0.021
55	0.101	0.052	0.035	0.026	0.021
56	0.103	0.053	0.036	0.027	0.021
57	0.105	0.054	0.036	0.027	0.022
58	0.106	0.055	0.037	0.028	0.022
59	0.108	0.056	0.037	0.028	0.023
60	0.110	0.057	0.038	0.029	0.023
62	0.113	0.058	0.039	0.030	0.024
64	0.117	0.060	0.041	0.031	0.025
66	0.120	0.062	0.042	0.032	0.025
68	0.124	0.064	0.043	0.032	0.026
70	0.127	0.066	0.044	0.033	0.027

Table 2. Numbers of winter flounder eggs and winter flounder larvae by stage entrained at PNPS annually along with numbers impinged, 1980 - 1999.

		Number Of Larvae Entrained Stage					
Year	**Eggs**	**1**	**2**	**3**	**4**	**Total**	**yoy**
1980	3,513,717	8,694,456	12,714,822	7,317,129	0	28,726,407	218
1981	9,674,954	7,606,942	19,133,121	3,073,126	43,304	29,856,494	229
1982	7,001,776	2,706,834	6,724,795	11,583,134	425,011	21,439,774	344
1983	1,305,735	1,933,453	2,246,172	7,558,534	260,350	11,998,508	230
1984	513,589	166,925	0	164,036	15,729	346,690	42
1985	35,167,263	1,039,001	2,312,789	8,025,452	130,786	11,508,028	735
1986	5,118,035	5,397,403	5,783,669	3,963,747	77,005	15,221,823	653
1987	20.782.324	0	5,613	23,555	0	29,168	166
1988	3,494,771	1,995,968	1,656,376	15,079,960	511,009	19,243,314	184
1989	6,423,987	1,668,823	5,755,240	2,224,675	39,114	9,687,851	595
1990	48,501	643,683	1,155,404	6,846,718	33,002	8,678,807	295
1991	1,217,178	3,471,022	3,908,488	5,188,056	37,717	12,605,283	1,171
1992	4,124,308	873,660	876,914	7,034,690	26,192	8,811,456	817
1993	3,078,941	1,595,700	3,540,750	4,934,952	88,617	10,160,019	1,171
1994	2,530,707	1,034,617	6,433,716	13,060,373	172,606	20,701,312	1,069
1995	2,766,716	1,632,907	2,820,023	8,826,496	375,857	13,655,283	1,326
1996	4,896,687	504,810	5,818,499	11,329,855	995,127	18,648,292	866
1997	3,609,393	2,225,634	9,537,788	41,484,016	2,126,280	55,373,718	770
1998	1,035,001	3,111,891	20,282,772	58,546,916	4,904,482	86,846,061	1,493
1999	1,409,453	2,030,743	496,056	977,373	1,345	3,505,517	1,353
Mean	4,846,536	2,416,724	5,560,150	10,862,140	513,177	19,352,190	686
s.e.	1,734,188	534,790	1,341,946	3,278,894	263,245	4,605,533	106

Notes:

Labrid egg mesh factors = 1.24 applied to eggs, 1980-1996, 1.14 applied in 1996, and 1.1 applied from 1997-1999.
Mesh factor = 1.62 applied to larvae Stages 1 and 2 prior to 1995.
Larval densities recorded in 1984, 1987, and 1999 are believed to be low relative to densities in surrounding waters.
All impinged winter flounder were assumed to be young-of-the-year (yoy) since they account for the vast majority of those impinged. An 80% impingement survival rate was assumed (Anderson 2000).

Table 3. Parameter values used for production foregone estimates, PNPS entrtainment and impingement, 1980 - 1999.

Life Stage	Average Length (mm)	Average Weight (mg)	Average Weight (g)	Instantaneous Growth Rate (G)	Instantaneous Mortality Rate (Z)	Survival Rate (S)
Eggs					1.609	0.200
S1	2.5	0.004		1.322	1.444	0.236
S2	3.3	0.014		2.685	2.226	0.108
S3	5.8	0.198		1.411	1.871	0.154
S4	7.8	0.812		6.358	0.473	0.623
yoy	60.0		0.469	2.699	2.617	0.073
1	85		7.0	2.633	1.386	0.250
2	199		97	1.166	0.740	0.477
3	290		311	0.501	0.200	0.819
4	341		513	0.302	0.200	0.819
5	376		694	0.199	0.200	0.819
6	401		848	0.129	0.200	0.819
7	418		964	0.088	0.200	0.819

Egg survival rate of 0.2 assumed.
S1 - S4 refer to larval stages. Estimated lengths, MRI unpublished.
Larval survival rates taken from Gibson(1993).
Larval weight estimated from length based on $L = 8.148\ W^{0.21}$ (Rose et al.1996).
Young-of-the-year weight estimated from length based on $L = 10.723\ W^{0.28}$ (Rose et al 1996).
Length estimate for age 1 fish was taken from Howell et al. 1992.
Length estimates for ages 2 through 7 taken from Witherell and Burnett 1993.
Weight for ages 1 through 7 based on $W = 9.25E\text{-}06\ L^{3.095188}$ (NEFSC 2000).

Table 4. Production foregone attributable to entrainment of each life stage at PNPS, 1980-1999.

	Stage 1	Stage 2	Stage 3	Stage 4	YOY	Total Production Foregone (kg)	Total Production Foregone (lb)
1980	236	1,465	7,802	0	0.35	9,504	20,909
1981	207	2204	3277	300	0.37	5,988	13,174
1982	74	775	12,351	2,942	0.56	16,143	35,514
1983	53	259	8060	1802	0.37	10,174	22,384
1984	5	0	175	109	0.07	289	636
1985	28	266	8,558	905	1.20	9,759	21,470
1986	147	666	4,227	533	1.06	5,574	12,263
1987	0	1	25	0	0.27	26	58
1988	54	191	16,080	3,538	0.30	51,379	113,033
1989	45	663	2,372	271	0.97	3,352	7,375
1990	18	133	7,301	228	0.48	7,680	16,897
1991	100	450	5532	261	2.00	6,345	13,959
1992	24	101	7,501	181	1.33	7,809	17,179
1993	43	408	5,262	613	1.90	6,329	13,924
1994	28	741	13,927	1,195	1.74	15,893	34,964
1995	44	325	9,412	2,602	2.16	12,385	27,248
1996	37	670	12081	6889	1.00	19,678	43,292
1997	61	1,099	44,236	14,720	1.25	60,116	132,255
1998	90	2337	62430	33953	2.43	98,812	217,387
1999	55	57	1,042	9	2.20	1,166	2,565
Kilograms:							
Mean	67	641	11,583	3,553	1	17,420	38,324
s.e.	14	151	3,408	1,776	0	5,518	12,140
Min	0	0	25	0	0	26	58
Max	236	2,337	62,430	33,953	2	98,812	217,387
Pounds:							
Mean	148	1,409	25,482	7,816	2	38,324	84,314
s.e.	31	332	7,497	3,908	0	12,140	26,708
Min	0	0	55	0	0	58	127
Max	520	5,141	137,346	74,697	5	217,387	478,252

Note: Lost biomass was calculated from the respective life stage to age 7.
Egg losses are grouped with stage 1 larvae.

Table 5. Biomass lost (pounds) between life stages for winter flounder entrained and impinged at PNPS, 1980 - 1999.

	S1 to S2	S2 to S3	S3 to S4	S4 to yoy	yoy to age 1	Age 1 to 2	Age 2 to 3	Age 3 to 4	Age 4 to 5	Age 5 to 6	Age 6 to 7	Total
1980	0.09	1.5	4	950	2,479	5,006	4,833	2,979	2,192	1,519	946	20,909
1981	0.08	2.1	3	598	1,562	3,154	3,045	1,877	1,381	957	596	13,174
1982	0.03	0.7	6	1,613	4,210	8,504	8,209	5,060	3,723	2,581	1,606	35,514
1983	0.02	0.3	4	1,017	2,654	5,360	5,174	3,189	2,347	1,626	1,012	22,383
1984	0.00	0.0	0	29	75	152	147	90	67	46	29	635
1985	0.01	0.3	4	975	2,545	5,140	4,963	3,059	2,251	1,560	972	21,470
1986	0.05	0.7	2	557	1,454	2,936	2,835	1,747	1,286	891	555	12,263
1987	0.00	0.0	0	3	7	14	13	8	6	4	3	57
1988	0.02	0.2	8	1,985	5,181	10,464	10,101	6,226	4,582	3,175	1,977	43,699
1989	0.00	0.6	1	332	863	2,935	4,287	4,461	3,481	2,328	1,620	20,307
1990	0.01	0.1	3	768	2,003	4,046	3,906	2,407	1,771	1,228	764	16,897
1991	0.04	0.5	3	634	1,655	3,343	3,227	1,989	1,463	1,014	631	13,959
1992	0.01	0.1	4	780	2,821	6,151	6,931	12,569	8,085	9,468	2,448	49,256
1993	0.02	0.4	3	632	1,651	3,334	3,219	1,984	1,459	1,011	630	13,924
1994	0.01	0.7	7	1,589	4,148	8,378	8,088	4,985	3,668	2,542	1,582	34,988
1995	0.02	0.3	5	1,238	3,231	6,525	6,299	3,883	2,856	1,980	1,228	27,243
1996	0.01	0.6	6	1,967	5,133	10,368	10,008	6,169	4,539	3,146	1,958	43,294
1997	0.03	1.0	21	6,010	15,685	31,681	30,582	18,850	13,871	9,614	5,984	132,299
1998	0.03	2.1	30	9,876	25,773	52,058	50,252	30,975	22,792	15,797	9,833	217,388
1999	0.02	0.1	1	117	306	619	598	368	270	187	117	2,584
Mean	0.02	0.6	6	1,584	4,172	8,508	8,336	5,644	4,105	3,034	1,724	
s.e.	0.0	0.1	2	522	1,360	2,740	2,636	1,660	1,209	892	515	
Minimum	0.00	0.00	0	3	7	14	13	8	6	4	3	
Maximum	0.09	2.14	30	9,876	25,773	52,058	50,252	30,975	22,792	15,797	9,833	

Table 6. Parameter values used to calculate eggs-per-recruit (EPR) in the absence of fishing mortality (EPRmax; top) and with fishing mortality at age estimated for 1998-1999.

Age	Fishing Mortality F	Natural Mortality M	Other Mortality P	Total Mortality Z	Cumulative Mortality Z	Cumulative Survival Sj	Mean Length	Mean Weight	Proportion Mature	Mean Fecundity	Egg Production
0											
1	0	0.2	0	0.2	0.20	1.0000	142	35	0	51,942	0
2	0	0.2	0	0.2	0.40	0.8187	194	91	0.03	143,828	3,533
3	0	0.2	0	0.2	0.60	0.6703	262	230	0.32	386,425	82,889
4	0	0.2	0	0.2	0.80	0.5488	326	450	0.86	790,240	372,976
5	0	0.2	0	0.2	1.00	0.4493	365	638	0.99	1,146,459	509,986
6	0	0.2	0	0.2	1.20	0.3679	395	813	1	1,484,450	546,099
7	0	0.2	0	0.2	1.40	0.3012	408	899	1	1,652,390	497,690
8	0	0.2	0	0.2	1.60	0.2466	420	983	1	1,817,451	448,178
9	0	0.2	0	0.2	1.80	0.2019	429	1052	1	1,953,739	394,453
10	0	0.2	0	0.2	2.00	0.1653	436	1105	1	2,058,827	340,322
11	0	0.2	0	0.2	2.20	0.1353	441	1145	1	2,138,360	289,396
12	0	0.2	0	0.2	2.40	0.1108	445	1175	1	2,198,130	243,560
										EPRmax =	3,729,081

Age	Fishing Mortality F	Natural Mortality M	Other Mortality P	Total Mortality Z	Cumulative Mortality Z	Cumulative Survival Sj	Mean Length	Mean Weight	Proportion Mature	Mean Fecundity	Egg Production
0											
1	0.018	0.2	0	0.218	0.22	1.0000	142	35	0	51,942	0
2	0.153	0.2	0	0.353	0.57	0.8041	194	91	0.03	143,828	3,470
3	0.252	0.2	0	0.452	1.02	0.5650	262	230	0.32	386,425	69,861
4	0.333	0.2	0	0.533	1.56	0.3595	326	450	0.86	790,240	244,329
5	0.279	0.2	0	0.479	2.04	0.2110	365	638	0.99	1,146,459	239,459
6	0.240	0.2	0	0.440	2.48	0.1307	395	813	1	1,484,450	193,989
7	0.240	0.2	0	0.440	2.92	0.0842	408	899	1	1,652,390	139,070
8	0.240	0.2	0	0.440	3.36	0.0542	420	983	1	1,817,451	98,513
9	0.240	0.2	0	0.440	3.80	0.0349	429	1052	1	1,953,739	68,204
10	0.240	0.2	0	0.440	4.24	0.0225	436	1105	1	2,058,827	46,288
11	0.240	0.2	0	0.440	4.68	0.0145	441	1145	1	2,138,360	30,963
12	0.240	0.2	0	0.440	5.12	0.0093	445	1175	1	2,198,130	20,499
										EPR =	1,154,644

Notes:
Mean length, weight, proportion mature and fecundity from Boreman et al. 1993.
Natural mortality and fishing mortality rates from NEFSC (1999) for 1997. In lower pane F for ages 1 through 5 were reduced by 10% to estimate 1998, 1999 fishing mortality rates.

Table 7. Parameter values used to calculate eggs-per-recruit (EPR) in the absence of fishing mortality (EPRmax; top) and with fishing mortality at age estimated for 1998-1999. Note higher fecundity estimates relative to Table 6.

Age	Fishing Mortality F	Natural Mortality M	Other Mortality P	Total Mortality Z	Cumulative Mortality Z	Cumulative Survival Sj	Mean Length	Mean Weight	Proportion Mature	Mean Fecundity	Egg Production
0											
1	0	0.2	0	0.2	0.20	1.0000	142	35	0	186,000	0
2	0	0.2	0	0.2	0.40	0.8187	194	91	0.03	529,000	12,993
3	0	0.2	0	0.2	0.60	0.6703	262	230	0.32	777,000	166,668
4	0	0.2	0	0.2	0.80	0.5488	326	450	0.86	1,064,000	502,185
5	0	0.2	0	0.2	1.00	0.4493	365	638	0.99	1,349,000	600,083
6	0	0.2	0	0.2	1.20	0.3679	395	813	1	1,676,000	616,566
7	0	0.2	0	0.2	1.40	0.3012	408	899	1	2,039,000	614,135
8	0	0.2	0	0.2	1.60	0.2466	420	983	1	2,430,000	599,231
9	0	0.2	0	0.2	1.80	0.2019	429	1052	1	2,785,000	562,282
10	0	0.2	0	0.2	2.00	0.1653	436	1105	1	3,095,000	511,600
11	0	0.2	0	0.2	2.20	0.1353	441	1145	1	3,357,000	454,321
12	0	0.2	0	0.2	2.40	0.1108	445	1175	1	3,576,000	396,232
										EPRmax =	5,036,296

Age	Fishing Mortality F	Natural Mortality M	Other Mortality P	Total Mortality Z	Cumulative Mortality Z	Cumulative Survival Sj	Mean Length	Mean Weight	Proportion Mature	Mean Fecundity	Egg Production
0											
1	0.018	0.2	0	0.218	0.22	1.0000	142	35	0	186,000	0
2	0.153	0.2	0	0.353	0.57	0.8041	194	91	0.03	529,000	12,761
3	0.252	0.2	0	0.452	1.02	0.5650	262	230	0.32	777,000	140,472
4	0.333	0.2	0	0.533	1.56	0.3595	326	450	0.86	1,064,000	328,970
5	0.279	0.2	0	0.479	2.04	0.2110	365	638	0.99	1,349,000	281,764
6	0.240	0.2	0	0.440	2.48	0.1307	395	813	1	1,676,000	219,020
7	0.240	0.2	0	0.440	2.92	0.0842	408	899	1	2,039,000	171,608
8	0.240	0.2	0	0.440	3.36	0.0542	420	983	1	2,430,000	131,716
9	0.240	0.2	0	0.440	3.80	0.0349	429	1052	1	2,785,000	97,223
10	0.240	0.2	0	0.440	4.24	0.0225	436	1105	1	3,095,000	69,585
11	0.240	0.2	0	0.440	4.68	0.0145	441	1145	1	3,357,000	48,609
12	0.240	0.2	0	0.440	5.12	0.0093	445	1175	1	3,576,000	33,348
										EPR =	1,535,076

Notes:
Mean length, weight, and proportion mature from Boreman et al. 1993.
Fecundity from Correia (1998).
Natural mortality and fishing mortality rates from NEFSC (1999) for 1997. In lower pane F for ages 1 through 5 were reduced by 10% to estimate 1998, 1999 fishing mortality rates.

Table 8. Eggs per recruit required to maintain a constant population size under the influence of conditional entrainment mortality rates ranging from 0 to 15%. Changes in instantaneous fishing mortality rates necessary to achieve the corresponding EPR values are shown along with changes in spawning stock biomass per recruit.

Conditional Mortality Rate	Eggs Per Recruit	Age 0 Survival Rate	Required Change In Fishing Mortality Rate	Spawning Stock Biomass Per Recruit (gms)
0.000	1,154,644	1.73214E-06	0	640
0.005	1,160,432	1.72350E-06	0.5013%	643
0.010	1,166,307	1.71481E-06	1.0101%	646
0.020	1,178,208	1.69749E-06	2.0408%	653
0.030	1,190,355	1.68017E-06	3.0928%	660
0.040	1,202,754	1.66285E-06	4.1667%	667
0.050	1,215,415	1.64553E-06	5.2632%	674
0.060	1,228,345	1.62821E-06	6.3830%	681
0.070	1,241,553	1.61089E-06	7.5269%	688
0.080	1,255,048	1.59356E-06	8.6957%	696
0.090	1,268,840	1.57624E-06	9.8901%	703
0.100	1,282,938	1.55892E-06	11.1111%	711
0.110	1,297,353	1.54160E-06	12.3596%	719
0.120	1,312,095	1.52428E-06	13.6364%	727
0.130	1,327,177	1.50696E-06	14.9425%	736
0.140	1,342,609	1.48964E-06	16.2791%	744
0.150	1,358,405	1.47232E-06	17.6471%	753

Literature Cited

Anderson, R.D. 2000. Impingement of organisms at Pilgrim Nuclear Power Station. In Marine Ecology Studies related to operation of Pilgrim Station. Semi-annual report No. 55, January-December 1999. Entergy Nuclear Generation Company.

Boreman, J. 1997. Methods for comparing the impacts of pollution and fishing on fish populations. Transactions of the American Fisheries Society 126:506-513.

Boreman, J., S.J. Correia, and D.B. Witherell. 1993. Effects of changes in age-0 survival and fishing mortality on egg production of winter flounder in Cape Cod Bay. American Fisheries Society Symposium 14:39-45.

Collings, W.S., C. Cooper-Sheehan, S.C. Hughes, and J.L. Buckley. 1981. The effects of power generation on some of the living marine resources of the Cape Cod Canal and approaches. Mass. Division of Marine Fisheries.

ENSR and Marine Research, Inc. (MRI). 2000. Study of winter flounder transport in coastal Cape Cod Bay and entrainment at Pilgrim Nuclear Power Station. Prepared for Entergy Nuclear Generation Company. Document Number 8734-188-300.

Gabriel, W.L., M.P. Sissenwine, and W.J. Overholtz. 1989. North American Journal of Fisheries Management 9:383-391.

Gibson, M.R. 1993. Population dynamics of winter flounder in Mount Hope Bay in relation to operations at the Brayton Point electric plant. Rhode Island Division Fish and Wildlife, West Kingston, R.I. Unpublished.

Goodyear, C.P. 1984. Analysis of potential yield per recruit for striped bass produced in Chesapeake Bay. North American Journal of Fisheries Management 4:488-496.

——. 1993. Spawning stock biomass per recruit in fisheries management: foundation and current use. Canadian Special Publication Fisheries and Aquatic Sciences 120.

Howell, P., A. Howe, M. Gibson, and S. Ayvazian. 1992. Fishery management plan for inshore stocks of winter flounder *Pleuronectes americanus*. Fisheries Management Report No. 21. Atlantic States Marine Fisheries Commission. 138p.

Laurence, G.C. 1975. Laboratory growth and metabolism of the winter flounder, *Pleuronectes americanus*, from hatching through metamorphosis at three temperatures. Marine Biology (Berlin) 32:223-229.

Entergy Nuclear Generation Company
Pilgrim Nuclear Power Station

Attachment #4

Response to Various Questions Relative to the §316 Demonstration Submittal

Responses to EPA Questions and Comments on Pilgrim 316 Demonstration

EPA Question: *On page 6-17 (Cost subsection of Section 6.1.6 – Variable Speed Pumps), should the value of 10% for reduction in power be 8.33% - equivalent to the reduction in entrainment impact?*

Response: The 10% value is correct. The 8.3% reduction in entrainment impact is an annualized value, based on the assumption that a reduction in entrainment is linearly related to a reduction if flow. It was calculated by dividing the 25% flow reduction over a 4-month period by 3 (because the four-month period is one-third of a year). The 10% reduction in power is an assumed value based on the expected loss in thermal efficiency of PNPS during the four-month flow reduction period. This value was used to calculate the $7.4M annual cost by multiplying 4 months x 10% loss/month x $18.5M (monthly power revenue).

EPA Question: *On page 6-87, Table 6.2-3, should the entrainment conditional mortality values for variable speed pumps and cooling water flow bypass be reversed?*

Response: Yes. The entrainment conditional mortality for variable speed pumps is 3.75% and the value for cooling water flow bypass is 4%. These values correspond to those in the text.

EPA Comment: *Please clarify whether all years of data or only the most recent years were used to determine the impingement impact, and explain the rationale for the selection.*

Response: Available data from the most recent 10-year period (1989 – 1998) were used to determine the entrainment conditional mortality for the Representative Important Species (RIS), as presented in Section 5.3. Recent data are believed to provide the most reliable and pertinent information for evaluating impingement impacts. A 10-year period was selected to provide a sufficient range of natural variability in the impingement data.

EPA Question: *Were entrained eggs included in the winter flounder adult equivalent analysis? If not, why not? What would be the effect if eggs were included?*

Response: Entrained eggs were not included in the winter flounder adult equivalent analysis. This is because winter flounder eggs are demersal and are not entrained in large numbers at PNPS. Also, since the natural survivability from the egg stage through the four larval life stages is relatively low, the contribution of eggs to adult equivalent numbers of fish is also low. Therefore, eggs were not included in the adult equivalent analysis because it was believed that their numbers do not substantially influence the adult equivalent values. Adult equivalents for the years 1980 – 1999 were recently recalculated with eggs included. The results, shown on the attached table, indicate that for full flow conditions, the difference in adult equivalent values with and without eggs included averages less than 0.5%. Therefore, inclusion of eggs would not substantially change the results or conclusions of the adult equivalent analysis.

EPA Question: *On page 6-41, it is stated that entrainment impacts of winter flounder larvae would be expected to increase with an offshore intake structure, and that the entrainment impact for the offshore intake scenario was assumed to be equivalent to that for the existing condition. Why would the entrainment impact not decrease with an offshore intake structure?*

Response: This discussion in the 316 Demonstration was based on the assumptions that (1) there would be no major difference in larval densities between nearshore and offshore locations, and (2) bottom larvae densities are generally greater than surface densities, resulting in increased entrainment for the submerged offshore intake. The results of the May 2000 winter flounder larvae study allow a reassessment of those assumptions. These results (see attached figures) indicate that for 2 of the 4 sampling events (May 8-9 and May 22-23) total larvae (Stages 1-4) densities were higher at Station A (nearest to the shoreline; representative of the existing intake location) than at Station B (approximately one mile offshore; representative of offshore intake location). For the other 2 sampling events (May 15-16 and May 30-31), total larvae densities at the two stations were essentially equivalent. The lower densities at the offshore station on one-half of the sampling dates could be interpreted as indicating that the offshore intake would have decreased impacts. However, because of the following it is believed that the assessment in the 316 demonstration is correct and entrainment impacts between the existing condition and the offshore intake scenario would be equivalent:

- The larvae study results show that total larvae densities were equivalent between Stations A and B for 2 of the 4 sampling events indicating that assumption 1 above is true approximately one-half of the time.

- The study results verify the assumption that larval densities in bottom waters are generally higher. At Station B, the bottom larval density was consistently the highest for every one of the 4 sampling events.

- The study results also show that Stage 4 larvae, which have the most significant impact on adult equivalent values, were found more frequently at the offshore stations.

- As discussed in the larvae study report, it is likely that Stage 4 larvae are present in bottom water at higher densities than sampled during the study. This is because they are located closer to the bottom than the bottom plankton sampling station. The expected relatively high Stage 4 density at the bottom makes this life stage susceptible to entrainment by a submerged offshore intake structure. Also, as discussed above, the impact of entrainment of Stage 4 larvae on adult equivalent values is greater than that of the other larval stages.

In summary, the potential for a higher Stage 4 entrainment rate, resulting in an increase in adult equivalents, likely offsets the incidents when total larvae densities are lower offshore. As a result, the entrainment impact for the offshore intake structure would be expected to be equivalent to that for the existing condition, and the conclusions in the 316 Demonstration continue to be valid.

EPA Question: What zone of influence was used in the impact assessment?

Response: Different zones of influence were assumed depending upon the specific circumstances of each impact analysis. Considerations for each analysis included the type of impact, behavior of the life stage of each species, and amount and type of available data. In several cases, a number of zones of influence were considered and one was selected based on data availability, an assessment of the ability of the data to accurately represent actual populations, and – where appropriate - the desire to use conservative predictions.

Impingement impacts on adult fish and lobsters were generally compared to estimated local populations. For these analyses, the zone of influence was dependent upon the location of the available data. For example, silverside and alewife populations were estimated from haul seine surveys directly adjacent to PNPS, and cunner populations were estimated from surveys at the PNPS breakwater. For these analyses, a very localized zone of influence was used. For winter flounder impingement, population data was obtained from trawling surveys of a defined region of western Cape Cod Bay in the vicinity of PNPS (see Figure 4.2-44 of the 316 Demonstration). This area defines the zone of influence for impingement of winter flounder.

Since eggs and larvae are transported to PNPS by currents determined by the regional circulatory structure of the bay, a more regional zone of influence is appropriate for the entrainment assessment. However, for several species, such as alewife and siversides, only local populations were available and a local zone of influence was used. For the cunner analysis, comparisons to both local and regional populations were attempted. The regional analysis was accepted as the most appropriate and therefore a regional zone of influence was assumed. Comparisons to both local and regional populations were also attempted for winter flounder. However, due to uncertainties over the actual zone of influence, a winter flounder larvae study was performed that does not require a zone of influence to be determined. This study – known as the larvae-to-larvae study – compares larval transport in Cape Cod Bay adjacent to PNPS with larvae numbers entrained by the station.

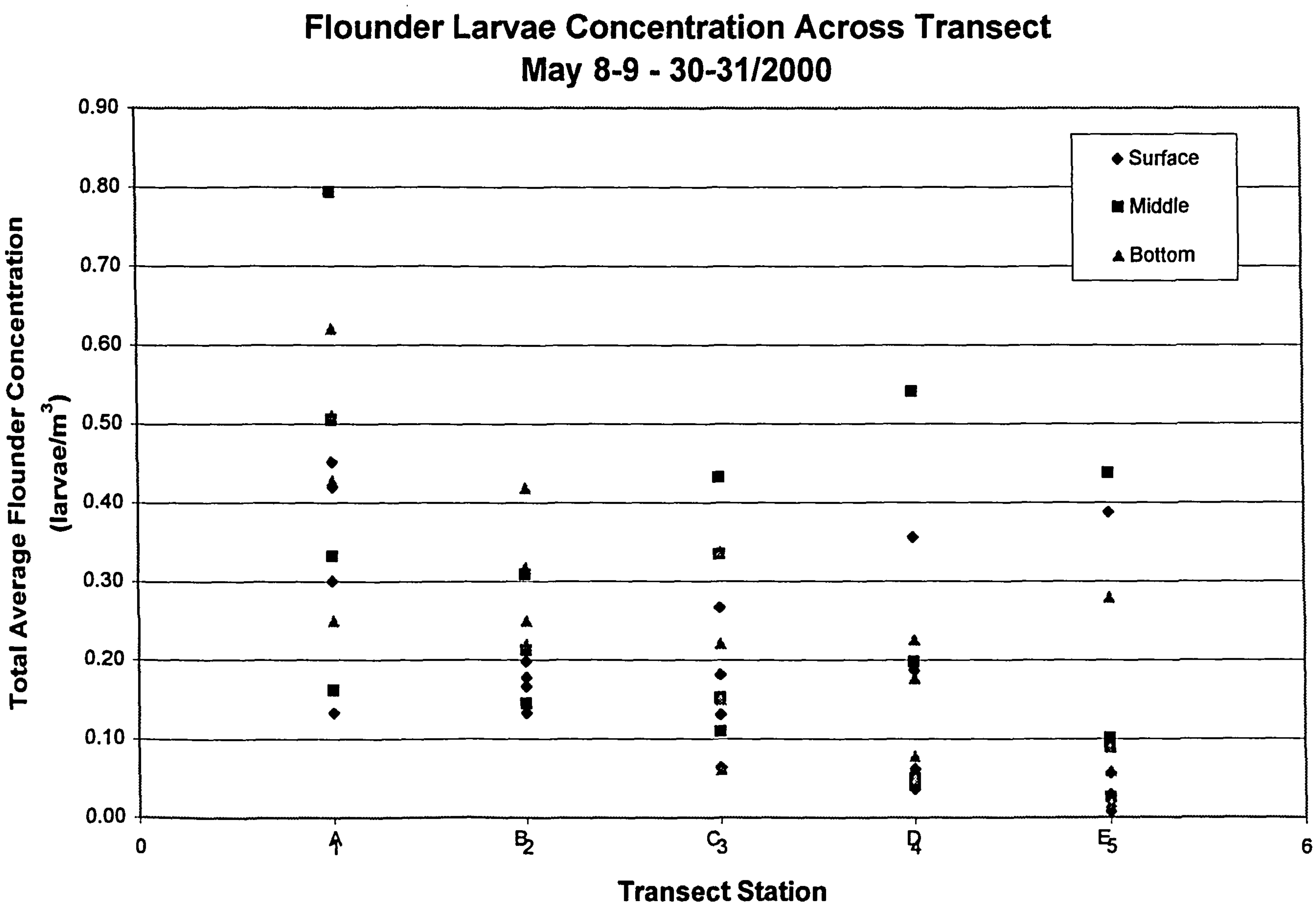
EPA Question: Why is the number of cunner in the impact predictions greater than the cunner population?

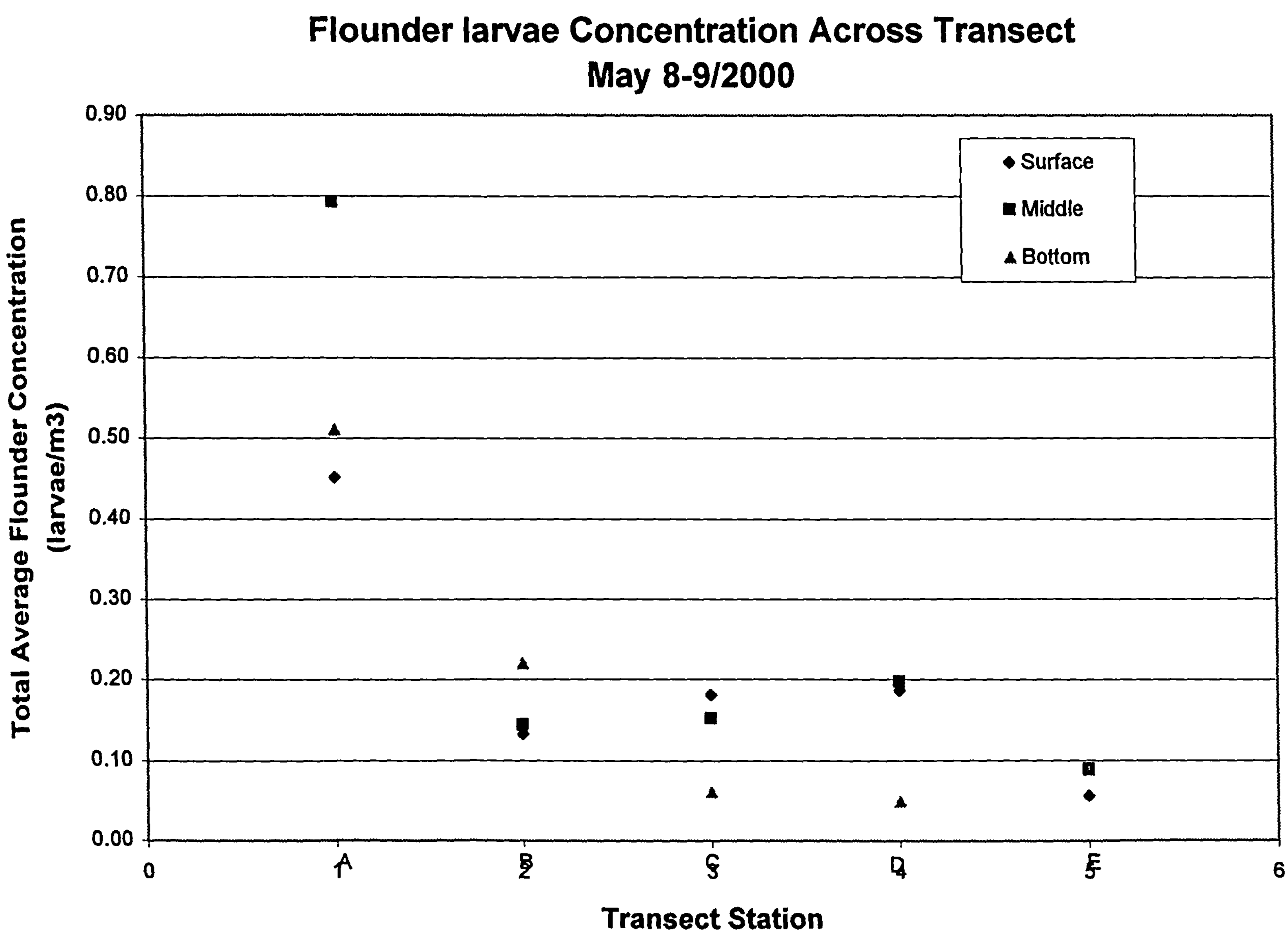
Response: The cunner population in the immediate vicinity of PNPS, along the intake breakwater, was estimated in 1992, 1994, and 1995 using tagging and recapture programs. These estimates are likely conservatively low primarily due to the difficulty of obtaining representative samples from the breakwater rock substrate. The number of cunner impinged was estimated to be 0.7% - 3% of the population. These estimates are likely high because of (1) the conservative underestimate of the population and (2) the assumption of 100% impingement mortality. Studies form 1989-1998 indicate an average survival rate of 43% for impinged cunner.

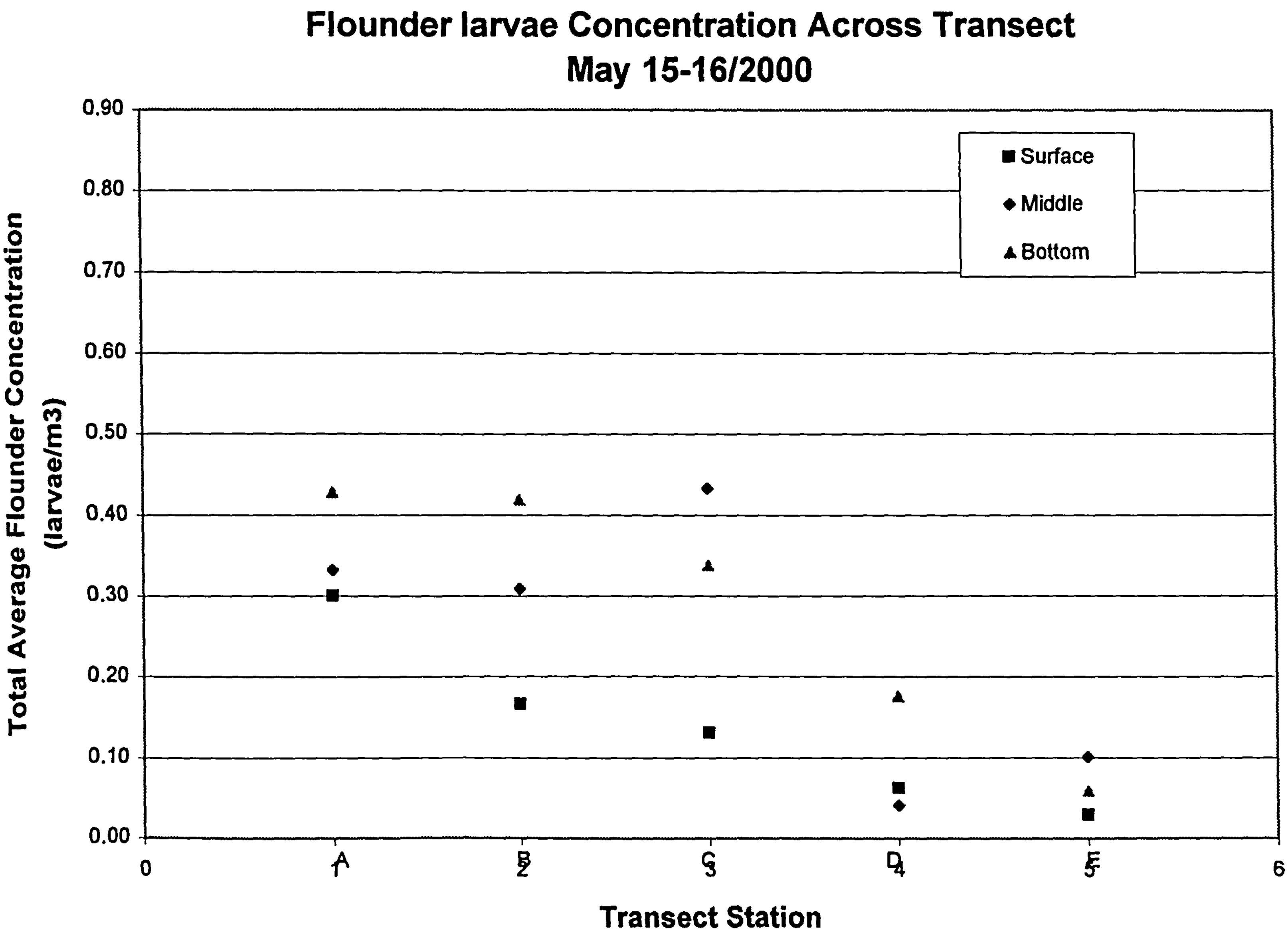
The calculated number of adult equivalents associated with cunner eggs and larvae entrained is higher than the estimated local population. A portion of the explanation for this is the conservatively low estimate of the local cunner population. However, it is likely that the most important reason is that (as discussed in the response above) cunner eggs and larvae are carried to PNPS by the bay-wide current pattern. This means that it is more appropriate to compare the adult equivalents associated with entrainment against a regional, rather than a local, population. This comparison indicates that the entrained adult equivalents represent less than 1% of the regional cunner population.

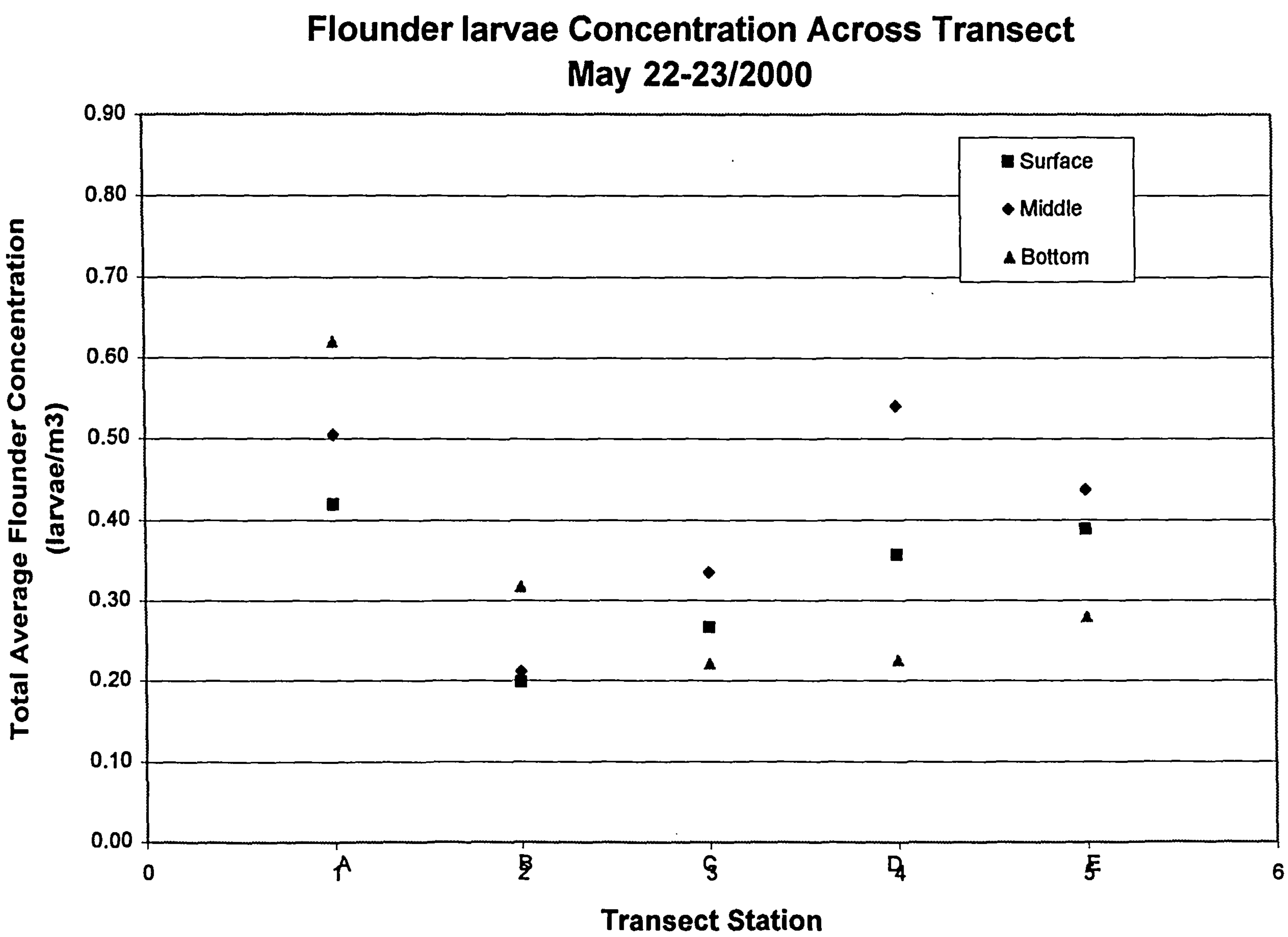
PNPS Winter Flounder
Equivalent Adult (EA) Assessment
With and without flounder eggs included
Numbers of Age 3 fish

Flow Conditions	Year	EA w/o Eggs	EA with Eggs	Difference	% difference
Full Flow	1980	7,443	7,458	15	0.20
Full Flow	1981	4,689	4,730	41	0.87
Full Flow	1982	12,643	12,673	30	0.24
Full Flow	1983	7,969	7,974	5	0.06
Full Flow	1984	9,128	9,130	2	0.02
Actual Flow	1984	226	227	1	0.44
Full Flow	1985	7,643	7,782	139	1.82
Full Flow	1986	4,365	4,387	22	0.50
Full Flow	1987	2,619	2,707	88	3.36
Actual Flow	1987	20	109	89	445.00
Full Flow	1988	15,558	15,573	15	0.10
Full Flow	1989	2,624	2,652	28	1.07
Full Flow	1990	6,016	6,016	0	0.00
Full Flow	1991	4,966	4,971	5	0.10
Full Flow	1992	6,114	6,132	18	0.29
Full Flow	1993	4,958	4,971	13	0.26
Full Flow	1994	12,446	12,457	11	0.09
Full Flow	1995	9,699	9,711	12	0.12
Full Flow	1996	15,395	15,416	21	0.14
Full Flow	1997	47,087	47,102	15	0.03
Full Flow	1998	77,393	77,397	4	0.01
Full Flow	1999	2,382	2,388	6	0.25
Actual Flow	1999	912	918	6	0.66
Average of Full Flow Only					0.48

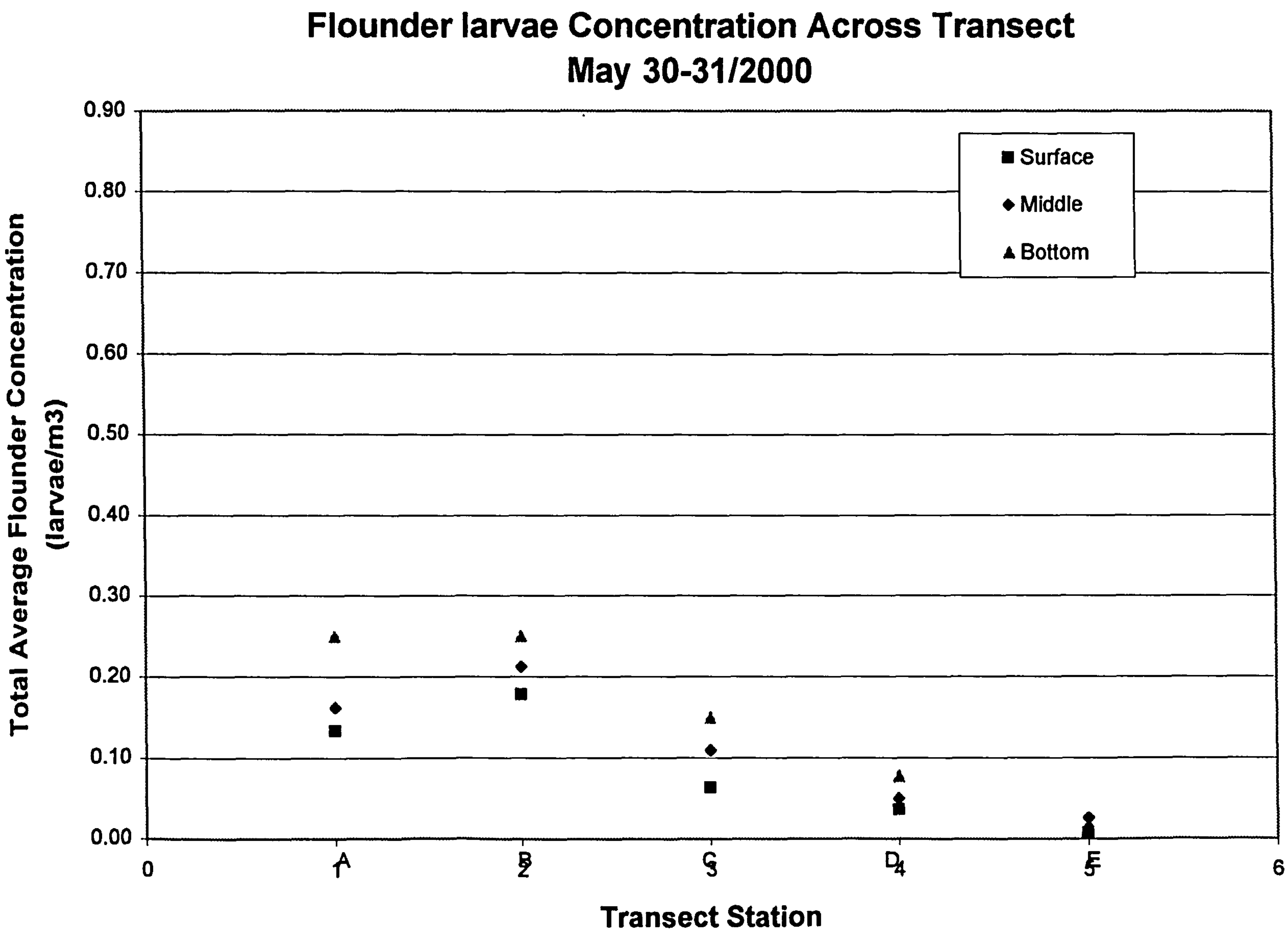

Flounder Larvae Concentration Across Transect
May 8-9 - 30-31/2000
Total Average Flounder Concentration (larvae/m3)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Surface
Middle
Bottom
0
A 1
B 2
C 3
D 4
E 5
6
Transect Station


Flounder larvae Concentration Across Transect
May 8-9/2000
Surface
Middle
Bottom
Total Average Flounder Concentration (larvae/m3)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
A
1
B
2
C
3
D
4
E
5
6
Transect Station


Flounder larvae Concentration Across Transect
May 15-16/2000
Total Average Flounder Concentration (larvae/m3)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Surface
Middle
Bottom
0
A 1
B 2
C 3
D 4
E 5
6
Transect Station



Flounder larvae Concentration Across Transect
May 22-23/2000
Total Average Flounder Concentration (larvae/m3)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Surface
Middle
Bottom
0
A
1
B
2
C
3
D
4
E
5
6
Transect Station



Flounder larvae Concentration Across Transect
May 30-31/2000
Surface
Middle
Bottom
Total Average Flounder Concentration (larvae/m3)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
A 1
B 2
C 3
D 4
E 5
6
Transect Station

	Surface	Middle	Bottom	May
1	0.45	0.79	0.51	8-9
1	0.30	0.33	0.43	15-16
1	0.42	0.51	0.62	22-23
1	0.13	0.16	0.25	30-31
2	0.13	0.14	0.22	8-9
2	0.17	0.31	0.42	15-16
2	0.20	0.21	0.32	22-23
2	0.18	0.21	0.25	30-31
3	0.18	0.15	0.06	8-9
3	0.13	0.43	0.34	15-16
3	0.27	0.33	0.22	22-23
3	0.06	0.11	0.15	30-31
4	0.19	0.20	0.05	8-9
4	0.06	0.04	0.18	15-16
4	0.36	0.54	0.23	22-23
4	0.04	0.05	0.08	30-31
5	0.06	0.09	0.09	8-9
5	0.03	0.10	0.06	15-16
5	0.39	0.44	0.28	22-23
5	0.01	0.03	0.02	30-31

GOODWIN | PROCTER

Robert H. Fitzgerald
617.570.1343
rfitzgerald@
goodwinprocter.com

Goodwin Procter LLP
Counsellors at Law
Exchange Place
Boston, MA 02109
T: 617.570.1000
F: 617.227.8591

March 11, 2002

By Hand

David M. Webster
Manager of the Massachusetts State Program Office
United States Environmental Protection Agency
Region 1
One Congress Street, Suite 1100 - CMA
Boston, MA 02114-2023

Re: Entergy Nuclear Generation Corporation: Redacted Version of Response to Comments

Dear Mr. Webster:

On behalf of Entergy Nuclear Generation Corp. ("ENGC"), and by way of follow up to our correspondence to you dated February 26, 2002, enclosed is a redacted version of ENSR's responses to the comments of TetraTech, Inc., dated February 9, 2001 and entitled "Draft Findings of Alternative Technology Assessment and Costing Review," on the § 316 Demonstration Report, dated August 24, 2000 and submitted on behalf of ENGC for the Pilgrim Nuclear Power Station.

As indicated in our prior correspondence, ENGC continues its request for confidentiality initiated with the § 316 Demonstration Report, particularly requesting that confidentiality apply to ENSR's responses to the full extent of the law, including 40 C.F.R. § 2.201-2.215, relative to business information. To that end, ENGC expressly requests that disclosure of confidential information not be made, except in compliance with applicable federal law. Consistent with this request, a redacted version of ENSR's responses is enclosed.

Should you have any questions or concerns regarding the enclosed or this matter, please do not hesitate to telephone Jay Scheffer (at (508) 830-8323) or me.

Best regards,

Robert H. Fitzgerald

Robert H. Fitzgerald

Enclosure

cc: Sharon Zaya, Environmental Protection Agency
Jacob Scheffer, Superintendent, Entergy Nuclear Generation Company ✓
John F. Alexander, Government Industry Liaison, Entergy Nuclear Generation Company
William J. Riggs, Director of Nuclear Assessment, Entergy Nuclear Generation Company
Jack Fulton, Esq., Entergy Nuclear Operations, Inc.

GOODWIN | PROCTER

Elise N. Zoli
617.570.1612
EZoli@
goodwinprocter.com

Goodwin Procter LLP
Counsellors at Law
Exchange Place
Boston, MA 02109
T: 617.570.1000
F: 617.227.8591

February 26, 2002

VIA HAND DELIVERY

David M. Webster
Manager of the Massachusetts State Program Office
United States Environmental Protection Agency
Region I
One Congress Street, Suite 1100 - CMA
Boston, MA 02114-2023

Re: Entergy Nuclear Generation Corporation: Responses to Comments

Dear Mr. Webster:

On behalf of Entergy Nuclear Generation Corp. ("ENGC"), ENSR has reviewed the comments of TetraTech, Inc. ("TetraTech"), dated February 9, 2001 and entitled "Draft Findings of Alternative Technology Assessment and Costing Review" (the "Draft Comments"), on the § 316 Demonstration Report, dated August 24, 2000 and submitted on behalf of ENGC for the Pilgrim Nuclear Power Station ("PNPS"). Since several of the Draft Comments were ambiguous, and that document was provided to ENGC and ENSR in *draft* form, ENSR sought clarification, through correspondence, dated June 6, 2001, of its questions. That request for clarification was the recommended approach of United States Environmental Protection Agency ("EPA" or the "Agency") staff, after discussion among EPA staff, ENSR, ENGC personnel and me on May 7, 2001.

EPA staff subsequently indicated, however, that TetraTech would not respond to ENGC's June 6, 2001 request for clarification. Accordingly, rather than allow TetraTech's Draft Comments to go unanswered, enclosed are responses prepared by ENSR on behalf of ENGC. As the responses indicate and consistent with the § 316 Demonstration Report, the weight of scientific evidence developed by ENSR and ENGC's professional consultants supports the conclusion that operations at PNPS have not created and are not likely to create an "adverse environmental impact" to the representative fish populations or the ecosystem, particularly to winter flounder, triggering consideration of the "best technology available" ("BTA"). To the extent TetraTech's Draft Comments suggest otherwise, ENGC does not concur, based upon the § 316 Demonstration Report, ENSR's the responses and otherwise.

Nonetheless, as EPA staff have requested, ENGC hypothetically has considered possible alternative technologies, as if a BTA determination were applicable. In particular, the § 316 Demonstration Report and ENSR's responses confirm that the use of variable speed pumps ("VSPs") will not have a measurable benefit on the representative fish populations, and that the costs of such equipment are in any event "wholly disproportionate" to any perceived potential environmental benefit to be gained. This cost analysis is supported by the actual costs of installation of VSPs at Indian Point 3, located in Buchanan, New York, a comparable nuclear facility, as more fully discussed in ENSR's responses. As it appears from TetraTech's Draft Comments that Indian Point is the example on which TetraTech relies in making its comment, ENSR's responses further discuss the relevant costs for Indian Point 3, a station owned by an affiliate of ENGC. As ENSR's responses confirm, TetraTech's analysis appears to be grounded in inaccurate data, which -- as we discussed in our meeting of May 7, 2001 -- TetraTech conceded it obtained through informal discussions with a former Indian Point 3 employee. In short, ENGC remains confident that EPA staff will review the enclosed responses, in conjunction with the § 316 Demonstration Report, and conclude, as ENSR has, that VSPs are not appropriately considered BTA, even within the context of a hypothetical BTA analysis.

In addition, ENGC reiterates its request that EPA fully consider: (1) the confirmation of ENSR's conclusions provided in additional biological monitoring, particularly the larval transport study performed in 2000, reported to EPA on December 8, 2000 and favorably received by EPA staff, and to be again performed and reported to EPA in autumn 2002, as it incorporates the suggestions of EPA staff and the PATC; and (2) also the highly favorable results of the winter flounder hatchery program, the report of which was submitted to the EPA via e-mail on January 30, 2002.

Please further note that, with this submission, ENGC continues its request for confidentiality initiated with the § 316(b) Demonstration Report, particularly requesting that confidentiality apply to ENSR's responses to the fullest extent of the law, including 40 C.F.R. §§ 2.201-2.215, relative to business information. To that end, ENGC expressly requests that disclosure of confidential information not be made, except in compliance with applicable federal law. Consistent with this request, a redacted version of ENSR's responses is enclosed, reflecting this request.

Finally, ENGC hereby must reserve its rights to supplement or modify ENSR's responses or the record for this matter, including without limitation if TetraTech responds to the June 6, 2001 request for clarification. This reservation of rights is necessary and appropriate, given that TetraTech's Draft Comments rely throughout on non-specific references to activities and control technologies at facilities, without disclosure of information essential to determining the relevance of the reference, *e.g.*, its location, the facility capacity or operating characteristics, which has impeded ENSR's ability to understand the Draft Comments, as well as to adequately and accurately respond. We further note that TetraTech's decision not to respond needlessly may impair full development of the record in this matter and, on that basis, has the potential to compromise EPA's decision making with respect to PNPS's NPDES permit-renewal application, including by failing to allow an informed technical discussion of issues of direct relevance to EPA's decision making.

As always, we continue to look forward to the prompt and satisfactory resolution of this matter. To that end, should you have any questions or concerns regarding the enclosed or this matter, please do not hesitate to telephone Jay Scheffer (at 508-830-8323), Bob Fitzgerald of this office (at 617-570-1343), or me.

Very truly yours,

Elise N. Zoli (CHF)

Elise N. Zoli

ENZ:amd
Enclosure
cc: Sharon Zaya, Environmental Protection Agency
Jacob Scheffer, Superintendent, Entergy Nuclear Generation Company (*via facsimile*)
John F. Alexander, Government Industry Liaison, Entergy Nuclear Generation Company
William J. Riggs, Director of Nuclear Assessment, Entergy Nuclear Generation Company ✓
Jack Fulton, Esq., Entergy Nuclear Operations, Inc. (*via facsimile*)

February 2002

On behalf of Entergy Nuclear Generation Corp. ("ENGC"), ENSR has reviewed and hereby responds to the comments of TetraTech, Inc. ("TetraTech"), dated February 9, 2001 and entitled "Draft Findings of Alternative Technology Assessment and Costing Review" (the "Draft Comments"), on the § 316 Demonstration Report submitted on behalf of ENGC for the Pilgrim Nuclear Power Station ("PNPS").

To simplify review of the responses, TetraTech's Draft Comment is provided first (in italics), followed by the ENSR response (in bold).

<u>TetraTech's Draft Comment</u>

1. ENSR Technology Recommendations/Conclusions

In its Draft Comments, TetraTech states: *"ENSR concluded that there was no adverse environmental impact being caused by the Pilgrim Station cooling water intake structure on the aquatic ecosystem of Cape Cod Bay. However, they reviewed 13 alternate technologies for reducing impingement and entrainment at the intake. Technologies evaluated included the following:*

Strobe Light System
Diversion Louver System
Submerged Off-shore Intake
Wedgewire Screens Outside Embayment
Fine-mesh Screen
Gunderboom System
Mechanical Draft Cooling Tower
Natural Draft Cooling Tower
Dry Cooling System
Variable Speed Pumps
Variable Speed Pumps With Condenser
Cooling Water Bypass
Cooling Water Bypass With Condenser

A summary of information provided by ENSR in the technology assessment is presented in ENSR Table 8.

In evaluating whether these technologies would constitute best technology available ("BTA") under Section 316(b), ENSR considered the following criteria:

- *Effectiveness – Effectiveness to reduce impingement and entrainment in general*
- *Biological Impacts to Species – Impacts and other effects for reducing station related impacts on the RIS*
- *Technical Feasibility and Reliability – Technical difficulties in constructing, operating, and maintaining technology*
- *Adverse Effects – Impacts other than to aquatic ecology*
- *Nuclear Safety Concerns – Technical issues that may compromise safety of the plant*
- *Cost."*

ENSR's Response

TetraTech's Draft Comment simply summarizes the procedure ENSR employed for the alternatives analysis and the conclusions in the § 316 Demonstration Report, without disputing ENSR's methodology or conclusions. Further, none of TetraTech's Draft Comments (each of which is identified and discussed below) supports a conclusion different from those in the § 316 Demonstration Report. Rather, TetraTech apparently concurs with the conclusions in the § 316 Demonstration Report, in which ENSR determined that the potential impacts of PNPS operations should not and cannot reasonably be interpreted to support the substantial costs and operational interruption of adding new technology. Rather, as indicated in the § 316 Demonstration Report, the weight of the scientific evidence supports the conclusion that PNPS's operations have not created and are not likely to create an adverse environmental impact to the Representative Important Species ("RIS") populations or the aquatic ecosystem, and therefore do not support the installation of the best technology available ("BTA"), particularly in light of the potential adverse environmental effects and costs of such equipment.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"The following section provides a discussion of all but the cost factors which will be discussed in Section 3.*

2. Review and Analysis of Technology Alternatives

Behavioral Barriers

Behavioral barriers evaluated in the ENSR report included technologies sometimes called avoidance systems. These technologies include any technology that is designed to induce fish to swim away from a cooling water intake structure. These technologies take advantage of the natural behavioral patterns of fish so that they do not enter an intake structure. Among the behavioral barriers that PNPS evaluated were sound barriers, light barriers, electrical barriers, air bubble barriers, and chain or cable barriers. These technologies are highly site-specific in their ability to repel fish, are not effective in reducing entrainment impacts, and would require extensive testing to determine their effectiveness. Because of this, we agree that these technologies would not be considered BTA for PNPS."

<u>ENSR's Response</u>

ENSR notes that TetraTech concurs with ENSR's conclusion that behavioral barriers do not represent the BTA for PNPS's operations and may not be appropriate even if an adverse environmental impact did exist.

<u>TetraTech's Draft Comment</u>

Diversion Devices

In its Draft Comments, TetraTech states: *"Diversion devices evaluated by ENSR included louvers and barrier nets. These are physical structures intended to use innate behavior to guide fish away from the intake structure. ENSR did not evaluate barrier nets except to dismiss them because of the risk from clogging, they do not protect eggs and larvae, and they have not been used in coastal setting. They also stated that there was a higher risk of greater impingement at velocities greater than 0.5 fps. Dismissing the technology based on this latter criteria was not consistent with statements made earlier that velocities at the opening of the embayment were 0.05 fps, well below that threshold."*

<u>ENSR's Response</u>

ENSR notes that TetraTech's technical assessment is apparently based on a misunderstanding. ENSR did not "dismiss" barrier nets because of the risk of greater impingement velocities. Rather, barrier nets received appropriately limited consideration in the § 316 Demonstration Report, because such nets are considered less effective and are subject to greater potential damage in coastal environments, making such devices unsuitable for the conditions present at PNPS. To the extent TetraTech has any information to the contrary, particularly relative to the demonstrated use of barrier nets in coastal facilities of comparable size and configuration to PNPS, ENSR requests the following information:

- **The identification of any such facilities (using such equipment), with appropriate contact persons able to discuss operation of the equipment, the costs, maintenance experience with equipment.**
- **The capacity, intake flows, locations, and source water bodies of these facilities.**
- **Available reports for these facilities that sufficient to demonstrate the efficacy, reliability and viability of the equipment.**

<u>TetraTech's Draft Comment</u>

In its Draft Comments, TetraTech states: *"Louver barriers were dismissed from consideration based on similar factors as the barrier nets. ENSR proposed to place the* *louver at the entrance to the embayment formed by the breakwaters. This configuration, they stated, would allow the coastal current to guide fish away from the intake embayment. This technology has been implemented at numerous hydroelectric facilities and typically is implemented with a fish bypass system. Another facility in California has a louver system that is placed just in front of their traveling screens which are angled to help guide the fish into the bypass system. If the louver installed at PNPS was implemented in this manner, there would be no risk of clogging and would not be an impediment to navigation. However, the technology is relatively untested at large power plants and would require extensive evaluation for efficacy at the Pilgrim Station. Therefore, we agree that this these technologies may not be considered BTA for PNPS."*

ENSR's Response

ENSR notes that TetraTech concurs with ENSR's conclusion that louvers may not be considered BTA at PNPS. TetraTech's conclusion apparently rests on its concession that louvers are "untested at large power plants," with the result that their efficacy, reliability and viability, among other factors, are appropriately suspect.

In addition, TetraTech's Draft Comment is of limited relevance, as the hydroelectric facilities mentioned in the Draft Comment are undoubtedly located in riverine, not coastal, environments, with the result that these examples are not comparable and should not guide EPA's decisionmaking for PNPS, even if an adverse environmental impact was present. While the location of and identifying information for the California facility TetraTech references in its Draft Comment is omitted, ENSR suspects that that facility also is located in a riverine setting, because louvers have not been proven effective in a coastal setting and, therefore, are not BTA. If ENSR's inference is correct, the California facility also is of limited relevance and again should not guide EPA's decisionmaking for PNPS.

TetraTech appears to agree that the louver technology would not be effective at PNPS; however, if TetraTech still believes that this technology might be effective, then ENSR specifically requests:

- **The identification of any facilities (using such equipment), with appropriate contact persons able to discuss equipment in question, the costs, and maintenance experience with equipment in question.**
- **The capacity, intake flows, locations, and source water bodies of these facilities.**
- **Available reports for these facilities that sufficient to demonstrate the efficacy, reliability and viability of the equipment.**

TetraTech's Draft Comment
Alternative Intake Systems

In its Draft Comments, TetraTech states: *"The alternative intake system that ENSR proposed was to locate the entrance to the intake structure approximately one mile away from the shore. The off-shore intake would include a mile-long tunnel, a 30-foot deep vertical shaft, and a velocity cap at the opening. ENSR dismissed this technology because of the cost and because they stated that it may entrain more winter flounder larvae than the existing technology since the later larval stage is likely to be concentrated at the bottom of the water column.*

This technology typically has many advantages and has been shown to be effective in numerous applications at both fossil and nuclear fueled power plants including the velocity caps. The major advantage is that a facility can locate the intake structure in an area that has limited biological activity thereby reducing both impingement and entrainment. In addition, colder water can be withdrawn which increases the efficiency of the facility and also helps with the temperature of the discharge. The velocity cap also reduces impingement of organisms because it changes the vector of the flow from vertical to horizontal which they can sense and will avoid. The reasons for dismissing this technology from a technical standpoint are unclear. Additional information should be evaluated to determine whether the opening to the intake structure could be placed in an area of the water body where winter flounder larvae would not occur (e.g., opening could be placed higher in the water column)."

ENSR's Response

As the § 316 Demonstration Report indicates, an off-shore intake structure is not recommended for PNPS, based on the potential for increased adverse environmental impacts to some species, navigational concerns and cost.

TetraTech apparently misunderstood ENSR's evaluation and subsequent removal of this technology from further discussion. For clarity, we address the potential for adverse environmental impacts in the following order; entrainment, impingement and thermal.

ENTRAINMENT: The existing PNPS intake of cooling water from Cape Cod Bay does not adversely impact RIS populations or the aquatic ecosystem as demonstrated, in addition to the analysis in the § 316 Demonstration Report, by the results of the May 2000 winter flounder larvae study (the "Study"). These results provide the basis for an assessment of potential entrainment impacts for the off-shore intake as suggested in the draft Tetra Tech comment. In particular, the results of this Study show:

- Total larvae densities were equivalent between the near shore station and an off-shore station located proximate to the potential off-shore intake site for 50% of the sampling events.

- Larval densities at the off-shore station were consistently higher in bottom waters than surface waters. Larvae densities in the middle of the water column were typically were similar to, but slightly less than, those at the bottom.

- Stage 4 larvae, which have the most significant impact on adult equivalent values, were found more frequently at the off-shore stations.

The potential for a higher Stage 4 entrainment rate results in an increase in potential impacts on adult equivalents. This impact for the off-shore structure offsets the incidents when total larvae densities are lower off shore. Based upon the Study, therefore, the potential entrainment impacts for the off-shore intake structure would be expected to approximate those for the existing intake structure.

IMPINGEMENT: The impingement rate for the existing intake system, as noted in the § 316 Demonstration Report, does not adversely impact the RIS populations or the aquatic ecosystem. Impingement, as a result of the installation of an off-shore intake structure, however, could increase for some species, such as flounder and lobster.

THERMAL: The existing thermal discharge from PNPS does not adversely impact the RIS populations or the aquatic ecosystem. As discussed in the § 316 Demonstration Report, even though the intake and discharge temperatures may be somewhat lower for the off-shore intake alternative, the thermal impacts on biota would be the same; i.e. there would be no adverse impact.

Furthermore, to minimize potential off-shore entrainment impacts to winter flounder, placement of the off-shore intake in the top 10 to 15 feet of the water column would be necessary. Such placement would require consideration of the requirements of Section 10 of the Rivers and Harbors Act with regards to the potential negative consequences to navigation and necessitate public involvement (i.e. notice, comment and hearings). In addition, the structural integrity of a vertical intake pipe whose top is in the surface layer would be compromised by the typical waves of a Nor'Easter characterized by a 100- year storm surge of 10 feet above NGVD (USACE, 1988) and a 20 year maximum observed wave height of 24.6 feet (USACE-WES, 1995). Thus the efficiency, reliability and viability of the technology are suspect.

Finally, TetraTech's statement about the purported "advantages" of off-shore intake structures is unsupported, particularly by a comparative analysis of off-shore and on-shore structures at the same facility. Without such support, TetraTech's statement is speculative, and fails to constitute the requisite scientific basis for reconsideration of the conclusions in the § 316 Demonstration Report.

TetraTech's Draft Comment
Alternative Intake Screen Systems

In its Draft Comments, TetraTech states: *"Three alternative screen systems were evaluated: fine-mesh, wedgewire, and gunderboom. For fine-mesh screens, ENSR proposed to use a one millimeter mesh. ENSR proposed to place the screens in front of the existing structure, but stated that the existing screen configuration would need to be increased from 4 to 12 screens to maintain the required flow and velocity in the intake structure. The screens would be operated continuously and a curtain wall and bypass system would be built to impede large debris. ENSR stated that they would need to increase the size of the screens in order to decrease the approach velocity to minimize impacts from impingement and clogging of the screen. ENSR also stated that fine-mesh screen have not been effective in substantially reducing winter flounder larvae entrainment and that survivability after impingement may be lowered. They stated that there is only a 6.5 percent survivability of winter flounder larvae after impingement at the Brayton Point Plant. However, the configuration of the Brayton Point Plant cooling water intake structure creates an approach velocity of approximately 1 fps (Lawler, Matusky & Skelly Engineers, 1987). Therefore, the fact that the velocity has been reduced to 0.5 feet per second may mean that less [sic] fish are impinged and that there is an increase in survivability of impinged organisms on the screens. In addition, low pressure spray washes and specially designed fish handling systems may increase survivability. ENSR dismissed fine-mesh screens as BTA due to the potential for clogging and associated nuclear safety concern, extensive maintenance requirements, and survivability.*

Fine-mesh screens have been successfully implemented at numerous facilities in the U.S. Use of 1 millimeter mesh or lower, however, is less common. Currently there are only five other plants in the U.S. using the finer mesh. Two of the plants have a design intake flow similar in magnitude to PNPS. However, one of those operates the screens only seasonally. These facilities do not have any problems with greater maintenance or clogging. However, it is our understanding that the risks of clogging the screens can be substantially reduced if the screens are rotated more frequently during periods of heavy loading. This technology appears to have some merit and should be evaluated further."

ENSR's Response

Irrespective of cost, fine-mesh screens are not recommended for PNPS, because information available to ENSR indicates that, in coastal environments and for comparable facilities, such screens are easily clogged, prone to maintenance problems, and not effective in reducing potential entrainment impacts. ENSR's professional judgment of the low effectiveness of fine-mesh screens is based on the low survivability of ichthyoplankton washed from fine-mesh screens installed at Brayton Point station, a 1600-megawatt, fossil-fuel-fired generating station located on Mt. Hope Bay. Test results from the 26-month survival study performed from March 1985 to December 1985 by LMS at Brayton Point Unit 4 (LMS, 1987) indicate that fine mesh (1.0 mm) screens installed at the intake were not effective in mitigating larval entrainment.

TetraTech's Draft Comment references "numerous facilities" at which TetraTech maintains fine-mesh screens have been "successfully implemented." ENSR again requests available information on these facilities and their fine-mesh screen implementation, including:

- **The identification of the facilities (including the five facilities that TetraTech states use 1 millimeter mesh screens and the two facilities that have a design intake flow similar in magnitude to PNPS), with appropriate contact persons.**
- **The capacity, intake flows, location, source water body, and screen rotation schedule used at these facilities.**
- **The technical basis for the determination of a successful implementation.**
- **Available reports for these facilities that discuss facility maintenance and demonstrate that clogging of the screens is not a maintenance, efficacy, or reliability concern.**
- **Survivability studies that have been performed at any of the above stations that demonstrate the level of survivability of ichthyoplankton, washed off fine-mesh screens and returned to the source water body.**

Without such information, TetraTech's Draft Comment is speculative, and fails to constitute the requisite scientific support required to support reconsideration of the conclusions in the § 316 Demonstration Report.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"For wedgewire screens, ENSR proposed to install a staggered array system of 15 tee-shaped cylindrical screens (each 84 inches in diameter and 23-feet long with 1 mm slots). The screens would be connected to the existing structure through a 1500-foot tunnel that extends out into the open water. Concerns that led ENSR to* *dismiss this technology as BTA were that the use of such a small slot size has not been proven and the possibility of clogging and biofouling. Larger slot sizes were not evaluated for their effectiveness in minimizing impingement and entrainment at the PNPS. Design criteria for wedgewire screens typically require an ambient cross current of approximately one feet per second to minimize clogging. It is not clear from the data provided whether that condition exists at PNPS. ENSR also stated that entrainment of eggs would not be affected by the screens, however, the 1 mm slot size should reduce entrainment of the majority of species."*

ENSR's Response

As the § 316 Demonstration Report indicates, wedgewire screens were not recommended for PNPS, because "the cost, navigational concerns, extensive maintenance requirements, nuclear-safety concerns, and potential for increased entrainment for some species outweigh the potential benefits of wedgewire screens."

In its Draft Comments, TetraTech focuses on a perceived correlation between slot size and clogging (or biofouling). TetraTech's observation is apparently based on a misconception. The potential for clogging is not attributable primarily to slot size, but to the coastal environment, particularly relative to the quantities of seaweed and other debris that tend to foul wedgewire screens, including screens with even larger mesh sizes. In the vicinity of PNPS, storms that mobilize quantities of seaweed and other fouling material occur regularly and are expected to create substantial maintenance problems. Further, ENSR is unaware of any other power facility of comparable intake flow to PNPS that uses wedgewire screens in the marine coastal environment.

Finally, and by way of response to the last sentence of TetraTech's Draft Comment, the analysis in the § 316 Demonstration Report did consider the reduction in entrainment of eggs for all RIS fish species, except for winter flounder and atlantic silversides, both of which have demersal eggs not subject to entrainment.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"Gunderbooms are filter curtains that extend the full depth of the water column. For the gunderboom technology, ENSR proposed to install a 1,500 foot long gunderboom at the entrance to the intake embayment. They dismissed this technology from consideration due to technical and nuclear safety concerns. To date, the gunderboom technology has been implemented at only one power plant in New York. This facility initially had problems with the anchoring systems and cleaning problems. However, since then they have redesigned the system and it has been extremely successful in* *minimizing ichthyoplankton entrainment. In light of what looks to be a successful deployment of the technology, another facility in California expects to implement the technology within the next couple of years. Unfortunately, neither of these facilities are located on open ocean waters. Therefore, the technology may not be considered a proven technology for this application and would require site-specific testing."*

ENSR's Response

ENSR notes that TetraTech concurs with ENSR's conclusions regarding Gunderbooms. In particular, as TetraTech concedes, Gunderboom technology is not currently available for facilities of comparable size and configuration to PNPS and therefore is not appropriately considered BTA. Neither the New York facility (presumptively, Lovett Station) located on the Hudson River, nor the potential deployment of the technology at an again unidentified California facility, although mentioned in TetraTech's Draft Comment, is identified as an open coastal marine environment. Without needlessly repeating the § 316 Demonstration Report, Gunderboom technology has yet to be proven in the coastal marine environment, and – in ENSR's professional judgment -- is generally incompatible with the intensity of storm-induced wave activity in the open coastal environment. TetraTech appears to agree that the Gunderboom technology would not be effective at PNPS; however, if TetraTech still believes that this technology might be effective then ENSR specifically requests:

- **The identification of any such facilities (using such equipment), with appropriate contact persons able to discuss the equipment in question.**
- **The capacity, intake flows, locations, and source water bodies of these facilities.**
- **Available reports for these facilities that discuss the capital costs, maintenance costs and experience with the equipment in question sufficient to demonstrate the efficacy, reliability and viability of the equipment.**

TetraTech's Draft Comment
Closed Cycle Systems

In its Draft Comments, TetraTech states: *"Closed cycle systems serve to reduce the flow that is withdrawn by the facility and in turn reduce the impingement and entrainment of organisms that are brought into the plant with the cooling water flow. Saltwater cooling towers require certain design features to combat the erosive properties of the cooling water. ENSR states that cooling towers at power plants on salt water are rarely used. However, there are numerous facilities that have implemented cooling towers on salt or brackish waters. ENSR evaluated two different wet cooling tower technologies and a dry cooling tower technology. The wet cooling towers they evaluated included a natural draft tower and a mechanical draft tower. Both of these structures will be constructed on concrete and include drift elimination systems. Flow using the wet cooling tower technologies would be* *reduced up to 93 percent from 321,000 gpm to 19,000 gpm. These systems are considered to be technically feasible and reliable and there are no safety concerns. ENSR rejected them based on the potential for fogging, icing and increased regional noise, visual impacts, and salt drift, as well as their cost. ENSR also evaluated dry cooling towers. These dry cooling towers would effectively reduce the amount of water withdrawn by the plant by 97 percent or to 10,000 gpm. However, there would be a 10 MW energy demand from the operation of the tower and a loss of thermal efficiency reducing the power production at the plant by 6 percent. This alternative was rejected by on the potential for noise and the cost."*

ENSR's Response

The comment simply summarizes a portion of the § 316 Demonstration. Further, TetraTech apparently agrees that closed cycle cooling is not BTA for PNPS.

TetraTech's Draft Comment
Variable Speed Pumps

In its Draft Comments, TetraTech states: *"The use of variable speed pumps (VSPs) at the intake would allow a reduction in cooling water flow during periods of peak entrainment and impingement (decrease in flow by 25 percent over a four month period each year). This technology would require the replacement of existing single speed drives with adjustable speed drives on each of the two circulating water pumps. An on-line condenser tube cleaning system would be included in this alternative to alleviate the predicted tube fouling. ENSR rejected this alternative because the reduction in flow through the condensers could cause operations difficulties (i.e., condenser tube fouling), result in decreased thermal efficiency in the turbines, require condenser replacement, and increase thermal plume effects. In addition, they stated that under full power production conditions using the existing PNPS condensers, the 25 percent reduction in flow could reduce the reliability of the entire system, and compromise the safety of the operation, as the condensers would be operating beyond their limits. Therefore they recommend replacement of the condenser to rectify potential instability in the system at a cost of $15 million (M). TetraTech would recommend that additional information be collected to evaluate the need for a new condenser and to determine the limitations of the existing system."*

ENSR's Response

TetraTech recommends further condenser analysis. PNPS already has conducted this analysis, which was submitted to EPA as memorialized correspondence in late January 2001. Results of that analysis indicate that a 25% reduction of flow to the condensers over a four-month period may not require condenser replacement. However, the disadvantages of the variable speed-pump (VSP) technology or flow reduction and the adverse effects on PNPS remain substantial. In addition to the costs to PNPS of VSPs and the reduction in power output, at a substantial social cost, there are a variety of serious adverse impacts on PNPS operations

attributable to VSPs or flow reductions. Without repeating the § 316 Demonstration Report, reductions in flow through the condensers could cause condenser-tube fouling, and therefore result in decreased thermal efficiency in the turbines and a commensurate increase in the discharge temperatures. More particularly, the analysis indicates that 25% reductions in flow in early June, when water temperatures exceed 65 degrees F, would yield condensate temperatures of 105 degrees F which would adversely affect overall plant performance including its generation capability. Among the most significant effects of this increased condensate temperature are: (1) degraded water purity in the reactor coolant, which results in increased corrosion in the reactor vessel, (2) reduced working life of the demineralizer resin, which causes increased consumption of demineralizer resin and an increase in radioactive waste production, and (3) greater likelihood of power reduction for condenser cleaning and power trimming to maintain acceptable operations, with a commensurate loss in production, affecting Massachusetts electric consumers.

TetraTech's Draft Comment
Cooling Water Bypass

In its Draft Comments, TetraTech states: *"With this alternative, PNPS would continue to withdraw the same flow, but during four months out of the year, they would divert approximately 25 percent of the flow from passing through the condenser and discharge it directly into the discharge canal. This alternative, ENSR states, would reduce the entrainment losses assuming that the mortality caused by only the temperatures in the discharge would be less than the mortality caused by passing through the entire plant. This alternative would not reduce impacts from impingement. ENSR states that this alternative would require replacement of the condensers if the existing power production is continued.*

We agree with ENSR that this would not be considered "best technology available." The facility would still entrain the same amount of organisms and subject them to adverse conditions in either the intake structure itself (at the screens), the condenser and the discharge canal. There is no data presented to support whether the ENSR claim of lower entrainment mortality would be realized in the actual implementation of this alternative."

ENSR's Response

TetraTech's Draft Comment echoes the § 316 Demonstration Report, in noting that this alternative should not be considered for PNPS. It should be noted, further, that ENSR assumed that there could be lower entrainment mortality in order to give every reasonable doubt in favor of the alternative during the evaluation. Despite this, the alternative could not be recommended.

<u>TetraTech's Draft Comment</u>
Mitigation Alternatives

In its Draft Comments, TetraTech states: *"Alternative non-BTA mitigation strategies were presented in the ENSR report. The alternatives included a smelt habitat and stocking effort, a winter flounder stocking and survival study, and scheduled outages during periods of highest larval density, when appropriate. These alternatives have not been considered BTA by EPA in the past and have not been considered in the content of this analysis. Typically mitigation alternatives have been implemented in addition to technologies determined to be BTA or when the cost of technologies have been determined to be "wholly disproportionate" to the benefits derived."*

<u>ENSR's Response</u>

In contrast to the policy outlined in TetraTech's comment, § 125.86 of EPA's Final Rule for Cooling Water Intake Structures for New Facilities provides for the use of voluntary restoration (or mitigation) measures including fish hatcheries. Regardless of whether they are considered "best technology available", we continue to believe that the mitigation alternatives considered in the § 316 Demonstration, such as the winter flounder hatchery, are preferred over any of the technology-based alternatives and are the recommended alternatives for PNPS. Furthermore, recent analyses show good survivability of winter flounder, which demonstrates that the fish hatchery is a successful mitigation method. Hatchery winter flounder and wild winter flounder were held in submerged pens in Plymouth Harbor and Duxbury Bay. The results of this experiment indicated that the hatchery fish clearly survive and, in fact, at a higher rate than wild fish stocked in the same pens (~40% vs. 25%).

<u>TetraTech's Draft Comment</u>
Review of ENSR Technology Cost Analysis

In its Draft Comments, TetraTech states: *"The objective of this review was to analyze the costs associated with the technologies selected for compliance with Clean Water Act Section 316(b) requirements, specifically to reduce impingement and entrainment. TetraTech, Inc. enlisted the assistance of Science Application International Corporation (SAIC) to perform a cursory review of the technology and cost sections of the PNPS § 316 Demonstration report. The nature of the review was defined, to a great extent, by the information provided in the report, and the issues discussed here are limited and are based on the (engineering and cost elements) details provided. The following section presents the result of SAIC's review of ENSR's costing of the technology alternatives presented in the report."*

General Comments on ENSR's Costing Methodology

"Generally, the basis of a budgetary or conceptual cost estimate should include as many details as possible on cost drivers. For example: general design criteria, space required and type of construction need to be included. In addition, any justification for unusual cost assumptions and above-the-national-average unit costs should be clearly stated. The scope of the review of ENSR costs included a cursory look into specific cost components, cost multipliers, and the methods used to annualize costs. The review approach followed generally recommended engineering practices for budgetary construction cost estimation. Additional information and sources of information that were used for comparison in reviewing some elements of the costing included:

- *Cost estimation tools developed specifically to estimate national compliance costs for the § 316(b) new source rule*
- *R.S. Means Company commercial cost reference publications*
- *Technical professionals at nuclear power facilities*

ENSR identified thirteen technological options to minimize adverse environmental impacts and provided cost estimates for these 13 options. Also, three non-technology-related mitigation proposals are presented and costed in the ENSR report. The review of the current § 316 Demonstration focused on the proposed technologies. The review compared costs presented by ENSR with "expected" costs. Without more detailed explanation regarding costing assumptions, this review of the ENSR analysis had to rely on typical costs to represent expected costs."

<u>ENSR's Response</u>

We believe that the information provided in the § 316 Demonstration is appropriate to the feasibility study level, order of magnitude cost estimates that were performed. Additional details would be appropriate for detailed engineering estimates of constructed costs. Based on our recent experience including Manchester Street Station in Providence, Rhode Island, PREPA Palo Seco and San Juan Stations in Puerto Rico, and our extensive historic experience, including with six Con Edison Power Stations in the New York City metropolitan area, in developing § 316 Demonstrations, we are not aware of any § 316 Demonstration that has ever included detailed engineering cost estimates or provided such detailed information.

<u>TetraTech's Draft Comment</u>

In its Draft Comments, TetraTech states: *"ENSR used several cost multipliers in the non-construction costs category that appeared to be unreasonable. For example, 30 percent of total direct costs was used for contingencies. Contingencies are used to cover the probability of overruns due to unforeseen events, intangibles, and unforeseen, highly unlikely* *occurrences of future events based on management decision to assume certain risks (for the occurrence of those events). The American Association of Costing Engineers (AACE International) study guide publication for the year 1996 states that contingencies should not be too high to create a "fat" estimate. A "fat" estimate occurs when the project management is not prepared (or technically incompetent) to accept risks and adds a "bias contingency). Generally contingency estimates range between 3 percent and 15 percent with 5 percent used as a typical percentage of construction costs. For sites with previous construction experience and well-known underground conditions and local conditions including labor and weather patterns, it is unreasonable to have a contingency estimate at 30 percent. A 10 percent allowance for contingency for a well known site in New England is considered a high percentage. Moreover, the non-uniform application of the contingency percentage multiplier by ENSR needs clarification. For example, ENSR applied the contingency factor to total component costs in alternative one (Strobe light system) and to the total direct cost (total component costs plus total non component costs) in alternative 3 (submerged off-shore intake). Also, the use of a single contingency factor for all types of construction and installation works proposed in the ENSR report needs justification. The risks associated with the execution of different types construction jobs are not the same and hence the contingency factor should not be the same."*

ENSR's Response

Based on standard cost engineering practice, 30% contingency is appropriate for this application, which consists of the development of feasibility level, order of magnitude cost estimates to evaluate a long list of alternative technologies based on conceptual designs. According to the EPA's Guide to Developing and Documenting Cost Estimating During the Feasibility Study (EPA, 2000), feasibility level, order of magnitude cost estimates should be accurate to within +50%/-30%. For a facility such as PNPS, a nuclear power plant located directly on a marine coast subject to a wide variety of storm conditions, a significant amount of uncertainty exists with regard to the site conditions and engineering constraints and problems that might be encountered during construction. Also, because it is difficult to estimate the degree of uncertainty between the various alternatives, our uniform application of the contingency factor is appropriate.

The accuracy and contingency values used in these cost estimates reflect the level of detail in the conceptual design. Contingency factors in the range suggested by TetraTech would be appropriate for a detailed evaluation. However, we are aware of no similar studies that have used contingency factors in the range suggested by TetraTech for a conceptual design as presented in a § 316 Demonstration.

The spreadsheet for the Strobe Light System, Alternative One, should be corrected so that the contingency is calculated as a percentage of the direct capital costs as it is done in all the spreadsheets.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"The calculation of annualized capital cost was flawed because it included amortized unrealized expected revenues due to claimed production losses during tie-in. It is unlikely that the power company would borrow these expected unrealized revenues at 9 percent for 30 years. More vexing in the cost analysis is that the tie-in shut down times are quite long. While these tie-ins shut down times might be reasonable under very special and unusual circumstances, many of these tie-ins should, or can, be done during scheduled outages."*

ENSR's Response

TetraTech's comment is unclear. Assuming that Tetratech is referring to the "Cost of Borrowed Capital," which was the capital cost expressed as an annual cost (from the present value at the former interest rate of 9%) multiplied by 30 years, this item has been removed from the cost estimates. Also, we believe that the tie-in shut down times used are reasonable, given that major modifications and tie in of new equipment to the cooling system of a nuclear power station are largely untried. More particularly, we are unaware of any such programs that have been completed during a typical scheduled outage period at comparable nuclear power plants. We would be interested in receiving information on any program where this has been accomplished. At Indian Point 3, the VSP installation in the mid to late 1980s took approximately 90 days. In order to provide for the uncertainty associated with the tie-in shut down times, we have included in a revised estimate (Attachment A) the costs for a range of durations from 5 to 15 days (or $[redacted]M to $[redacted]M) in excess of the typical scheduled outage period of approximately 30 days.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"The operation and maintenance (O&M) costs presented in the ENSR document claim assumed lost revenues due to lower plant efficiency as a result of a proposed technology. The cost attributed to the lower efficiency should be based on the added input (operation such as more fuel costs and maintenance) to produce the output that was generated before the installment of the new technology. Therefore, if the overall lost efficiency is 5 percent, it is reasonable to assume an equal amount of increase in the O&M costs or even a higher percentage value such as 10 percent because the relationship might not be a direct relationship. This assumes that the percentages claimed* *are reasonable. More details on the ENSR O&M cost basis is warranted for a better evaluation of these numbers."*

ENSR's Response

TetraTech's comment is unclear. The costs associated with lower efficiency are best presented as a social cost attributable to replacement of lost power. Further, TetraTech's proposed method may be appropriate for fossil-fuel powered facilities, where fuel input can be regulated; however, for a nuclear powered facility like PNPS, this method is difficult or impractical to execute as nuclear facilities run in a steady state.

The basis for the O&M cost estimate for the pertinent alternatives is included in the discussion of the specific comments below.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"ENSR claimed a loss efficiency between 5 and 10 percent that would result from installation of certain technologies but did not justify these losses. A nuclear power plant's net efficiency should be in the range of about 32 to 34 percent and their gross efficiency should run at about 34 to 36 percent. To claim, for example, that 10 percent of that efficiency will be lost because of bypassing some of the cooling water flow when the cooling water temperature is low is incomprehensible not only because of savings in pumping, but also because of an increase in the ΔT (i.e., energy savings for increase the water temperature in the condenser to produce steam)."*

ENSR's Response

TetraTech appears to be equating the power generation losses identified in the § 316 Demonstration Report with losses in the overall cycle efficiency. For this analysis, ENSR defined the generation losses as the sum of thermodynamic efficiency loss and generating capacity loss. These two components are explained below.

- **Thermodynamic Efficiency Loss: The function of a power station condenser is to condense steam on the exhaust side of a power turbine, resulting in a vacuum that increases the pressure differential across the turbine and increasing turbine efficiency. Anything that decreases the vacuum on the turbine exhaust side results in an increase in backpressure that decreases turbine efficiency. It is well known that an increase in cooling water temperature or delta T has just such an effect (Woodruff et al. 1998, pp 569 - 576; Baumeister et al. 1978, pp 9-38 – 9-64). This factor accounts for the generation losses associated with application of the cooling water bypass**

alternative and the cooling tower alternatives (i.e. mechanical draft, natural draft or dry cooling systems) of approximately 1 to 5%.

- **Generating Capacity Loss: For a given amount of cooling water, the allowable delta T (per the NPDES permit) puts an upper limit on the amount of steam that can be condensed. That is, as the cooling water flow rate is reduced, a point is reached where the reactor power will have to be reduced in order to reduce steam flow to keep the delta T of the cooling water below the maximum allowable. This factor dominates the generation losses associated with the variable speed pumps.**

Generation losses presented in the § 316 Demonstration were based on the available information at the time. Since then, a detailed analysis of the generation loss associated with the application of variable speed pumps at PNPS has been performed, as noted above, and determined that a reduction in flow of 25% during the spring (with a delta T below 32° F) would result in a generation loss of approximately 17%(see the more detailed discussion in the section on the specific evaluation of variable speed pumps below).

The revised range of generation losses for these technologies (i.e. variable speed pumps, cooling water bypass, mechanical draft and natural draft cooling towers, and dry cooling systems) is 1% to 17%.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"The ENSR O&M cost estimates took credit for the operation and maintenance of the new technology installed to comply with the rule. The O&M cost should account for the incremental increase or decrease in O&M cost as a result of installing the new technology. For example, assuming that the O&M cost of the existing pumps is $10M and that the O&M cost of the newly installed variable speed pumps is $12M, then the O&M cost attributable to § 316(b) is $2M, not $12M."*

ENSR's Response

TetraTech has misstated the methodology ENSR used for the cost estimate. O&M costs for the alternatives were presented as incremental increases over current O&M costs in the § 316 Demonstration Report.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"Finally, the ENSR presentation and calculation of costs was different than other conventional costing reports. For example, in the variable speed pumps alternative, the cost of borrowed money over 30 years was $16,676,634 (this* *was capital cost amortized over 30 years at a 9 percent discount rate and then the result multiplied by 30 years) and the present value of annual costs was $72,095,367 (this was O&M cost amortized over 30 years at a 9 percent discount rate and then the result multiplied by 30 years). In the next alternative (variable speed pumps with condenser), the cost of borrowed money over 30 years was $222,023,905 and the present value of annual costs was [sic] $3,929,673 (this was supposed to be the O&M cost [savings] amortized over 30 years at a 9 percent discount rate and then the result multiplied by 30 years). However, ENSR failed to indicate that these were savings rather than costs."*

ENSR's Response

As noted above, the "Cost of Borrowed Money" has been removed from the cost estimates. TetraTech's statement that the O&M cost was amortized over 30 years and then multiplied by 30 is incorrect. Please see our response to the next comment for details on how ENSR calculated the present value of the O&M. The present value of annual costs should have been a savings for Alternative 10B, Variable Speed Pumps with Condenser Replacement, as noted by TetraTech. Based on additional information provided to EPA, as mentioned previously, condenser replacement is not required for the use of variable speed pumps so Alternative 10B is eliminated from the evaluation and will not be discussed further.

TetraTech's Draft Comment

In its Draft Comments, TetraTech states: *"Moreover, amortizing O&M costs at a 9 percent discount rate is not a typical costing method. A review of available accounting and economic references did not support such a method. Inflating O&M costs can be achieved using an inflation factor, say 2 to 4 percent, over the life of the project. Such an accounting method would necessitate accounting for cash flow and expected increases in revenues due to inflation and profits due to market forces such as supply and demand."*

ENSR's Response

ENSR calculated the present value of the annual O&M costs according to standard engineering economics analysis (EPA, 2000). The Total Annual Cost (including O&M costs and the performance penalty) was multiplied by a uniform series factor of 10.2737 to convert the annual costs to present worth assuming an effective discount rate of 9% over the 30 year period. ENSR has adjusted the 9% discount rate to the OMB-recommended 7% rate (EPA, 1993). The effective rate did not include inflation in order to use constant value dollars for alternative comparison. This conservative assumption yields values lower than those adjusted for inflation.

TetraTech's Draft Comment
Specific Comments on ENSR Costs

In its Draft Comments, TetraTech states: *"The following provides specific examples of how the costs may be over estimated using the methodologies similar to ENSR. Table 9 provides the ENSR generated costs for each alternative. For comparison, the table also presents costs that have been adjusted with more reasonable assumptions including:*

- *10 percent contingency costs*
- *No tie-in production or efficiency losses*

The table also provides independently developed cost estimates for technologies where the costs could be obtained relatively quickly and efficiently."

ENSR's Response (to Comments in Table 9)

In general, the contention that the contingency costs are only 10 percent and that tie-in production and efficiency losses should be removed is not appropriate. The shutdowns associated with tie-in and the loss of efficiency due to increases in cooling water temperature (due to reduction in cooling water flow rate) are important factors in evaluating the cost impacts of each alternative. As shown in Table 9, the removal of these factors from the original cost estimate results in substantial, though incorrect, decreases in costs. The specific comments on Table 9 are discussed below.

Light Barrier: As noted in Table 9, the original cost estimate for the light barrier is four times larger than the reviewer's independent estimate. ENSR based its costs on information provided by specialty vendors as described in more detail below. The original cost estimate for the light barrier is more accurate than the reviewer's independent estimate because vendor sources are typically more accurate than RS Means particularly for specialty items like behavioral barriers.

Off-shore Intake: In Table 9, the reviewer claims that the original cost estimates for tunneling for the submerged intake structure may be "outdated and vastly overstated" based on cost data for construction of tunnels at the NH power station which is assumed to be Seabrook Station. However, as explained in more detail below, if the design flow rates for the Seabrook tunnels are used instead of the "normal" flow rates, the original cost estimate for total capital is within 4% of the revised estimate. Until more recent data is available on new tunneling technologies we believe our estimate is appropriate for a feasibility level, order of magnitude cost estimate.

<u>Wedgewire Screens</u>: **Because the basis for the reviewer's cost estimate for wedgewire screens is not included, we cannot explain why, as noted in Table 9, the reviewer's estimate is 90% lower than the original estimate. Without further explanation, we expect that the reviewer did not include many of the particular costs associated with installing and operating a wedgewire screen system at a nuclear power station located on an ocean coast.**

<u>Natural Draft Cooling Towers</u>: **Similarly the basis for the reviewer's cost estimate for the natural draft cooling tower is not included in Table 9 or the text so that we cannot comment on the difference in estimates. The tie-in times for construction of the cooling tower are expected to be two months. The breakdown of the potential schedule is:**

1. Excavate trenches to building, one week per line	**2 weeks**
2. Disconnect existing condenser lines from condenser	**2 days**
3. Install pipelines in trench	**2 weeks**
4. Connect to the condensers	**2 days**
5. Startup and test lines	**7 days**
	Total = 8 weeks (5 work days per week)

The inefficiency of power production using cooling towers relative to once-through cooling systems is well documented in literature. 5% is a typical power loss for a cooling tower.

<u>Variable Speed Pumps</u>: **As discussed in more detail below, concerns about the capacity of the existing condensers to handle a 25% reduction in flow considered for the Variable Speed Pump alternative have been addressed in the condenser performance analysis submitted to EPA in early 2001.**

<u>TetraTech's Draft Comment</u>
Specific Evaluation of Strobe Light System Costs

In its Draft Comments, TetraTech states: *"The ENSR report claimed a capital cost of $566,000 to install 63 mercury vapor lamps under water. Concerns associated with mercury vapor lamps included mercury released into the seawater in case of lamp breakage and emission of UV light that may cause deformation of genetic material in microscopic cells and macroscopic organisms and other living organisms. The cost included the installation of a steel frame that would support the lamps under water. Subtracting $75,000 for the steel frame support, the cost per lamp would be equal to $78,000 [($556,000-$75,000)/63]. The R.S. Means Heavy Construction Cost Data for 1998 provides costs for 1000 watt, mercury vapor underwater lamps at $950/lamp and costs for 1000 watt and mercury vapor floodlights including ballast and lamp at $365/unit. Therefore, assuming a diving team would cost $1,800/day installation [1 supervisor $600, 2 surface tenders @ $200/day, two divers @*

*$400/day] and support equipment at $600/day. The total cost for divers without mobilization/demobilization should equal about $2,400/day. Assuming $8,000 for mobilization/demobilization [airfare, accommodations, ground transport for the team and equipment], the labor costs for 10 days to anchor 5 lines of lamps in 45 feet deep waters (according to report schematic drawing) would equal approximately $32,000 [(2,400)*10 +8,000]. Assuming the costs of lamps, lines, power center and control are $120,000, the total capital cost should be approximately $152,000.*

ENSR annualized capital costs using a 9 percent discount rate and 30 years and the result was $55,100 per annum. A new estimate using more reasonable assumptions proved a new estimate of $14,800. An over estimation by a factor 3.71.

*The O&M costs for this technology also appeared excessive. The costs of 63 lamps/year were estimated by ENSR at $63,000/year. Assuming two diving trips to replace lamps at $1,800/day for the diving team [1 supervisor $600, 2 surface tenders @ $200/day, two divers @ $400/day] and support equipment at $600/day. The total divers cost without mobilization/demobilization would equal $2,400/day. Assuming $3,500 for mobilization/demobilization (airfare accommodations ground transport for the team and equipment, the total cost for two days would equal approximately $12,000/year [(2,400+3,500)*2]. The operator monitoring time of 10 hrs/week to monitor the underwater lamps is believed to be excessive. Therefore, assuming that the loaded hourly rate is $30/hr the annual-cost estimate would be equal to approximately $16,000/year [10*52*30]. Therefore, even at an excessive monitoring rate, total O&M cost should be $91,000 [63+16+12] versus ENSR's estimated $97,000."*

<u>ENSR's Response</u>

The capital and O&M costs for the strobe light system are based on quotes from reliable vendors with experience at comparable facilities. We believe these costs are more accurate than those from the Means Heavy Construction Cost Data for 1998. Ron Brown of Flash Technology located in Franklin, Tennessee provided the estimate for the capital and replacement costs. Derek McDonald of Marine Biocontrol Corporation, which provides divers for PNPS, provided the estimate of labor to perform annual maintenance.

Flash Technology estimated the cost for strobe light flashheads mounted on a steel support structure placed in front of the intake entrance. The system would include 20 tri-packs consisting of 60 flashheads, interconnect cable and a power center. The system would be operated in real time by computer to adjust flash rates, intensity, sequence of flash pattern, and review of operating status. The estimated uninstalled capital cost of this system is $330,000. The cost does not include the steel support structure or its installation on the intake structure.

ENSR estimated the cost of the steel support structure and installation to be $75,000.

Flash Technology recommended that the flashheads be replaced annually. The cost for 60 flashheads at $1050 each (provided by Flash Technology) would be $63,000. The cost for a team of divers composed of three union divers and one supervisor would be $284 per hour according to Marine Biocontrol. Marine Biocontrol estimated that the replacement/maintenance of the flashheads could be done in one 10-hour day for an annual cost of $2840 for labor. In addition, ENGC would provide an operator for 10 hours per week to operate and maintain the system at a cost of $60 per hour or $600 per week for 52 weeks a year. The total cost for a PNPS part-time operator would be $31,200 per year. The total annual O&M cost would therefore be $97,040.

As noted above, the contingency factor for this alternative was originally calculated as a percentage of the total component costs for a total of $122,500. In order to be consistent with the other alternative cost estimates, the contingency was recalculated based on Total Direct Costs for an amount of $133, 500. This change increases the Total Capital Cost from $566,500 to $578,500.

We do not agree with the estimating methods used by the reviewer for the strobe light system. RS Means is often inaccurate for cost estimates especially when compared to specialty vendor estimates. Furthermore, the reviewer supports ENSR's estimated O&M cost and contradicts the statement that the O&M costs appeared excessive. The reviewer estimate of $91,000 per year lies within 6.6% of the ENSR estimate of $97,040 per year.

The reviewer included disadvantages that ENSR did not include in the § 316(b) Demonstration Report. ENSR does not include in the report the contention that lamp breakage will release mercury to the aquatic environment or that the UV light in the lamps will cause deformation of genetic material in organisms in the water column. Consideration of this disadvantage would make it even less likely that this alternative would be selected.

TetraTech's Draft Comment
Specific Evaluation of Variable Speed Pumps

In its Draft Comments, TetraTech states: *"Costs for the "variable speed pumps (VSP)" option were verified using two methods. In the first method, cost elements included in the ENSR report were reviewed and used to fairly estimate the costs of this alternative. In the second method, a similar nuclear power facility was contacted to inquire about costs incurred and experience gained in using VSP for almost 10 years.*

In the VSP alternative, ENSR assumed the costs of variable speed drives at $605,000 and the costs of variable speed motor starters at $78,000. Adding all their multipliers except for the contingency factor (assumed 10% of total direct costs) and taking out the claims for lost generation, the total capital cost for this alternative was $1.34M. Amortized over a 30 year period at a discount rate of 9%, this would equate to an annualized capital cost of $0.13M and to an annual savings (using ENSR O&M numbers) of $0.25M. ENSR's annualized estimate for capital ($0.56M) and O&M ($7.01M) costs was $7.6M, well in excess of this estimate.

In the second verification method, experience at another power plant was used to get some idea of the costs that might be incurred. This facility was chosen because it has similar attributes to the Pilgrim facility. This other power plant had switched to variable speed pumps approximately 10 years ago when the facility bought 6 VSPs rated at 140,000 gpm each. The cost of speed controls, motors and drives were $2.6M. This implies a cost of $1.304M for units capable of handling a flow of 312,000 gpm. The costs were derived using a rounded construction cost index escalation factor of 1.35 and multiplying this escalation factor by the cost of $2.6M times the ratio of flows in both plants (840,000/312,000). Using ENSR claimed energy savings, this analysis shows a $0.25M savings per year.

The other facility's experience with VSPs shows that there may not be a need for an on-line condenser tube cleaning system. This facility uses brackish water that is biologically diverse and rich. To minimize fouling, once a week, one of the pumps is shut down for a very short period and water from the condenser is allowed to backflush. Moreover, the facility manually cleans the condenser once a year during the period of scheduled outages. This information points out the need for a better explanation of the VSP costs and the justification for the need for both a new condenser and a cleaning system. If silt or sedimentation is what ENSR wants to guard against, a more cost effective way is to run the VSPs for a short period at a higher speed to flush the condenser tubes.

It should be noted that the other facility recently experienced problems associated with the operation of their VSPs in that frequent pump breakdowns were occurring. It turned out that the breakdowns were caused because the operators were trying to avoid subcooling and ran the VSPs at a much lower rate (190 rpm) than the manufacturer's recommended rate (205 to 210 rpm). Operating the VSPs outside the specified rates caused the pumps to vibrate and required them to be checked, cleaned, and serviced more frequently. The facility has since returned to operating the pumps within the recommended range and has had no subsequent problems.

The claims that a new condenser will be needed if lower flows are used or that the efficiency will drop because of lower flows would also need explanation. With lower flows, the condenser operation should improve as it will take less energy to heat the water. To operate the condenser without sub-cooling the condensate is an operation problem that every power plant faces and tries to avoid. Implementation of VSPs is one way to avoid this problem."

ENSR's Response

The power plant described above in TetraTech's draft comment and our discussions with EPA appears to be Indian Point No. 3 (IP3) nuclear power station, which is currently owned by a subsidiary of ENGC. Actual costs of installing VSPs (including six cooling water pumps and an electrical building in addition to the six variable speed drives) at IP3 in the mid to late 1980s was $12.39M, excluding certain costs discussed in this section.

In order to further substantiate the VSP cost estimate ENSR has revised its cost estimate for PNPS based on the relevant actual costs incurred at IP3 for installation of VSPs. First ENSR selected the items from the IP3 capital expenditure records that were appropriate to PNPS. For example, ENSR did not include "modification of existing intake sump" or the "installation of new pumps" in the revised VSP estimate because these items were not required for the installation of VSPs at PNPS.

ENSR then adjusted each selected item in the IP3 records for the VSP installation to reflect the conditions at PNPS. The Component Costs were adjusted by multiplying the IP3 cost by a flow factor (the ratio of flows to the 6/10ths or 0.55) and a time factor (the Chemical Plant Engineering cost index ratio from 1989 to the present or 1.35).

The Non-Component Costs were adjusted by multiplying the IP3 cost by the percentage of Total Component Costs (TCC) (as calculated for actual IP3 costs). For example, the PNPS-estimated cost for installation of new drives and electrical equipment resulting from multiplying 7.2% (the actual IP3 cost of $350,000 divided by the actual IP3 total equipment cost of $4,830,000) by the estimated TCC for PNPS is $176,400. In a similar fashion, ENSR estimated the Non-Construction Costs for VSPs at PNPS based on the percentage of Total Direct Costs.

ENSR also estimated the incremental operation and maintenance costs for the new VSPs at PNPS by adjusting actual IP3 operation and maintenance costs for its existing VSPs. At IP3, the cost of the operation and maintenance of the VSPs alone is approximately $375,000 per year. ENSR multiplied the actual cost by a factor of 1/3 based on the number of pumps at each facility (6 at IP3 and 2 at PNPS).

As noted above, the revised cost estimate for VSPs at PNPS includes social costs for the tie-in shutdown period ranging from $[redacted]M for 5 days to $[redacted]M for 15 days. These "replacement power costs" (formerly called "lost generation during construction" and "performance penalty due to decreased thermal efficiency") reflect the fact that the lost power would have to be provided by other power providers during both the tie-in outage and reduced power operations due to loss of thermal efficiency. These "replacement power costs" are part of the social costs of power losses, but they understate the full social costs of reduced power at PNPS because they do not include the social costs for the increased emissions due to increased power output at other facilities, among other factors.

We disagree with the two methods of evaluating the cost estimates used by the reviewer. It is obvious as in the first method, that if one removes major cost items (e.g. the on-line cleaning system, the contingency based on 30% of the component costs, and the lost generation costs) the cost estimate for Total Capital Costs and Annual costs will decrease substantially (i.e. from $5.7M to $1.3 M). This evaluation reiterates the fact that the condenser operational costs and replacement power costs are important and real costs for this alternative. In addition, the subtraction of the newly estimated annualized capital cost of $0.13M from the total annual O&M costs of $0.38M for a net savings of $0.25M is not appropriate. The theoretical savings in operating the VSPs should be balanced with the legitimate costs of operating the VSPs (e.g. the replacement power costs and the on-line cleaning system).

As noted above, the condenser performance analysis submitted to EPA in early 2001, refines the decreased thermal efficiency from the estimated percentage of the original report, justifies installation of the on-line cleaning system and eliminates the potential requirement to replace the condensers. The condenser analysis determined that a reduction in flow of 25% during the spring would result in an efficiency loss of approximately 17%.

Furthermore, in late spring and early summer as water temperatures increase to 65 degrees F and above, the temperature of the steam condensate will increase to 105 degrees F at the 25% flow reduction, yielding potentially detrimental effects to the power station operation. One of the most significant effects of this increased condensate temperature is the greater likelihood of power reduction for condenser cleaning and power trimming to maintain acceptable operations. Therefore, this analysis confirms the need for an on-line cleaning system to implement this alternative.

The cost estimate for this alternative was revised to reflect the new information on thermal efficiency loss and to correct the amount of savings associated with running the pumps at 75% capacity. For the revised estimate, it was assumed that the thermal efficiency loss of approximately 17% associated with a cooling water temperature of 60 degrees F and a delta T of 32 degrees would be used. The revised estimate is attached as Attachment A.

<u>TetraTech's Draft Comment</u>

<u>Specific Evaluation of Submerged Off-shore Intake with Velocity Cap</u>

In its Draft Comments, TetraTech states: *"A facility in NH has an off-shore cooling water system with a "normal" flow rate of 469,000 gpm. The off-shore cooling system is comprised of two 19 foot diameter underground/underwater tunnels 3.2 miles long and 3.13 miles long. The tunnels were dug 200 feet below ground in solid bedrock. The off-shore intake construction included three intake structures that are 30 feet in diameter equipped with velocity caps and bars 4-5 inches apart to prevent entrapment of seals and seal pups and copper-nickel cladding to reduce biofouling at a cost of $150M (completed 1990). ENSR off-shore intake details are not available. However, the ENSR report assumed a tunnel (no dimensions) to convey 312,000 gpm and velocity caps at a capital investment of $80.9M with 30 days of tie-in losses in power production.*

Based on the NH facility costs and assuming an escalation factor of 1.35 (ignoring all the advances that occurred over the last ten years in underground tunneling techniques and that the tunneling might not be in bedrock and at a depth of 30 feet) the cost of a one mile off-shore intake will be $32M. Using ENSR report figures for O&M, the annual cost for this option (annualized capital at 9% for 30 years and O&M costs) should be 3.26M versus the ENSR cost of $8.02M.

ENSR estimated the cost for the tunnel, intake structure and the velocity cap to be $34.9M. Adding to that, ENSR claimed costs of $2.5M for tie-in, temporary dock, and marine equipment, $0.43M for electrical works, and other cost multipliers. Allowing 10% only for contingencies and excluding the monetary losses from the loss of power generation, the capital costs should be $52M. The annual cost should be (annualized capital at 9% for 30 years and O&M costs) $5.21M versus the ENSR cost of $8.02M."

<u>ENSR's Response</u>

The capital costs for the off-shore submerged intake structure are based on a similar structure evaluated by Northeast Utilities and Stone and Webster Engineering Corporation at Millstone Nuclear Power Station in 1993 (NU, 1993). The Millstone intake structure was designed for a flow rate of 958,000 gpm. It included a one-mile long tunnel (5000 lf, 24 foot diameter and lined), a vertical shaft 300 feet below mean sea level, a booster pump station and an off-shore inlet (15 feet high with velocity cap at 19.5 feet off sea floor). ENSR estimated the cost for this alternative using the 6/10ths rule and adjusted the 1993 costs to 1999 costs. Each item from the Millstone estimate was multiplied by the factor (300,000 gpm/958,000 gpm)*6/10 X the cost index factor, 1.21, to produce a detailed cost which resulted in a total of $34,900,000. The cost index factor is the ratio of the Chemical Plant Cost Indices (McGraw-Hill, 1999) for 1993 and 1999. The capital cost items included: a booster pump, gantry crane, discharge elbow,

mile-long tunnel, 30-foot vertical shaft, temporary cofferdam, transition structures, pump structure, forebay, dredging/foundation prep, and off-shore velocity cap.

In a similar fashion, the non-component costs were estimated based on Millstone's off-shore submerged intake structure. Each item, including tie-in, temp dock, marine equipment was multiplied by the 6/10ths-rule factor and cost index factor.

The cost of lost generation during construction included in the non-construction costs is based on an estimated 18-month construction period of which 1 month would be the actual tie-in of the off-shore submerged intake.

The O&M costs included the cost of ENGC administration (one operator 10 hours per week) and maintenance (one dive for six 10-hour days a year). The administrative cost was $31,200 per year at $60 per hour. The maintenance cost was based on a dive team similar to the one for the strobe light system (one supervisor and two divers at $284 per hour) for a total cost of $17,040 per year. The booster pump power demand is based on the assumption that the pumps would need to overcome the head losses in the tunnel (4 feet based on professional judgment). The power required to pump against that additional head at the flow rate of 311,000 gpm (assuming 75 % pump efficiency) would be 0.312 MW. The cost of 0.312 MW for 365 days per year, 24 hours per day at $[redacted] per hour would be $[redacted] per year rounded to $[redacted] per year.

We do not agree with the reviewer's analysis of the cost estimate. The NH facility to which the reviewer refers is likely to be the Seabrook Nuclear Power Station. According to other sources (NU, 1993), the Seabrook tunnel was designed based on a flow of 850,000 gpm at an average velocity of 6 feet per second (at a cost of $125M) rather than at a "normal" flow of 469,000 gpm (at a cost of $150M) as stated by the reviewer. As a result, the reviewer's independent estimate is incorrect. If the design flow rather than the "normal" flow is used to extrapolate the costs from the $125M using the 6/10ths rule and the 1.21 time cost index factor, then the resulting capital cost estimate is $84M instead of the $32M presented by the reviewer. As a result, the independent estimate based on the Seabrook tunnels confirms the relative accuracy of the ENSR estimate. As noted by the reviewer, these estimates may not reflect "all the advances that have occurred over the last ten years". We, like the reviewer, are not experts in tunneling technology and do not know what these advances are and what savings they may have produced in tunneling costs. Without this information, we believe that the costs as estimated are appropriate to the feasibility level, order of magnitude estimates that we sought to produce.

References

Baumeister T. et al. 1978. Marks' Standard Handbook for Mechanical Engineers. McGraw-Hill, New York, NY

Lindeberg, Michael R. 1992. Civil Engineering Reference Manual. Professional Publications, Inc., Belmont, CA

McGraw-Hill, eds. 1999. Economic Indicators. Chemical Engineering. December 1999, p. 134

EPA, 1993. Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit Cost Analysis.

EPA, 2000. A Guide to Developing and Documenting Cost Estimating During the Feasibility Study. Report No. EPA 540-R-00-002, OSWER 9355.0-7.5, July 2000

Northeast Utilities Service Co. (NU), January 1993, Berlin, Connecticut, "Feasibility Study of Cooling Water System Alternatives to Reduce Winter Flounder Larval Entrainment at Millstone Units 1, 2, and 3"

Lawler, Matusky & Skelly Engineers, October 1987. Brayton Point Station Unit No. 4 Angled Screen Intake Biological Evaluation Program, Volume I, Program Summary Report 1984-1986

USACE, 1988. Tidal Flood Profiles – New England Coastline. September 1988

USACE - WES, 1995. Hindcast Wave Information for the U.S. Atlantic Coast: Update 1976-1993 with Hurricanes. WIS Report 33. Waterways Experiment Station, Vicksburg, MS. June 1995.

Woodruff, E. B. et al. 1998. Steam Plant Operation. McGraw-Hill, New York, NY

ATTACHMENT A

		PNPS	IP3	IP3-Based				
IP3 Derived Cost Estimate for PNPS								
PNPS Intake Alternative Cost Estimate								
Alternative 10, Variable Speed Pumps	CW Flow	311000	840000	(driveand motor)	ratio	ratio[6/10]	cost index ratio	product of factors
Revised Feb 21, 2002	(gpm)							
Component Costs					0.37	0.55	1.35	0.74

Component	*IP3 Cost Brkdwn (1989 costs)*		**Base Cost**	
Two Variable Speed Drives	*$2,570,000*		$1,911,417	
Cooling water pumps	*$2,230,000*			
Cooling Fans for transformers in PCE building	*$30,000*		$22,312	
Total Equipment Cost for Phase 3 at IP3	*$4,830,000*			
On-Line Condenser Tube Cleaning System	*N/A*		$500,000	
Total of Component Costs (TCC)			$2,433,730	
Non-Component Costs		*% of TCC*		
Removal and Storage of existing pumps and motors, Phase 4a	*$300,000*	*6.2%*	*$75,582*	
Installation of new pumps and motors, Phase 4b	*$900,000*	*18.6%*	*$226,745*	
Installation of PCE building, Phase 4c	*$1,400,000*	*29.0%*	*$705,429*	
Installation of new drives and elect equipment, Phase 4d	*$350,000*	*7.2%*	*$176,357*	
Modification of existing intake sump, Phase 4e	*$900,000*	*18.6%*		
Removal and relocation of existing security trailers, Phase 4f	*$20,000*	*0.4%*		
Mobilization/demobilization, Phase 4h	*$160,000*	*3.3%*	*$80,620*	
Security modifications, Phase 4i	*$350,000*	*7.2%*		
Installation of cooling fans for PCE building, Phase 4k	*$150,000*	*3.1%*	*$75,582*	
Total	*$4,530,000*	*93.8%*		
Total of Non-Component Costs (TNCC)			*$1,340,315*	
Total Direct Costs (TCC + TNCC)			$3,774,045	
Non-Construction Costs		*% of TDC*		
Prelim Engineering, Phase 1	*$100,000*	*2.2%*	$83,312	
Engineering, Phase 2	*$855,000*	*18.9%*	$712,320	
Start up testing, cleaning, and flushing, Phase 4g	*$60,000*	*1.3%*	$49,987	
Construction Management, Phase 4j	*$300,000*	*6.6%*	$249,937	
Contingencies, Phase 4(l)	*$733,000*	*16.2%*	$610,679	
Direct/indirect charges, Phase 8	*$592,000*	*13.1%*	$493,208	
		58.3%	$2,199,443	
Replacement Power Cost* (5 to 15 days shutdown during construction**)			[redacted]	
Total of Non-Construction Costs				
Total Capital Costs (Total Direct + Total Non-Construction)	*$12,000,000*		[redacted]	
Annual Operation and Maintenance Costs				
Maintenance			$125,000	
Power Demand from Pumps			[redacted]	
Total of Operation and Maintenance Costs				
Annual Replacement Power Cost* (25% Decrease in Flow 4 months per year) (At delta T of 32° for a power loss of 17%)	0.17		[redacted]	
Total Annual Costs (At delta T of 32°)			$12,630,000	
Present Value of Annual Costs (30 years @ 7%* discount)** (Annual Costs x P/A factor of 12.4090) (At delta T of 32°)			$156,700,000	$15,600,000

Notes:
* The costs calculated for power losses understate the full social costs of reduced power at Pilgrim because they do not include the increased emissions due to increased power output at other facilities.
** The tie-in time is in addition to 30 days of scheduled outage time
*** The discount rate is from "Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit Cost Analysis" (EPA 1993)

$$P/A\ factor = \frac{(1+i)^n - 1}{i(1+i)^n}$$

where $i = 7\%$
P is present value,
A is annual amount,
and $n = 30$ years
Lindeberg, 1992