Seabrook Station

Long Term Environmental Monitoring Program

Proposal and Review

1996-1997

25931

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203-0001

CERTIFIED MAIL - RETURN RECEIPT REQUESTED

October 17, 1996

Mr. Bruce L. Drawbridge
Executive Director
Nuclear Station Safety and Oversight
North Atlantic Energy Service Corporation
P.O. Box 300
Seabrook, N.H. 03874

Re: Review of the Seven Working Documents that Evaluate Seabrook's Monitoring Program after Five Years of Plant Operation. NPDES Permit No. NH0020338.

Dear Mr. Drawbridge:

I have reviewed the above mentioned documents submitted with your letter dated August 29, 1996 and present the following suggestions, comments, concerns and questions.

o Your letter and various passages in the seven documents refer to the need to evaluate Seabrook's monitoring program after five years of post-operation data. The evaluation assesses the effectiveness of each monitoring program and requests certain program reductions and/or enhancements based upon the findings presented in the reports.

After reviewing these reports, the U.S. Environmental Protection Agency (EPA) believes Seabrook needs to present a scientific rationale justifying why five-years provides sufficient data to conclude findings of no change or no adverse impact to some members of the balanced indigenous biological community, especially since this facility will likely continue to operate for another 25 years. This rationale should be included in the documents.

Part of this rationale might include a discussion of the life cycle for each monitored species since different species can have vastly different life cycles. For example, if a species achieved multiple life cycles during a five year period with no apparent adverse effects noted, as compared to the control (farfield), that might justify the conclusion that sufficient data had been collected and reduced monitoring is appropriate. Another part of this rationale could be that the facility's operational pattern over the past five years is likely to continue substantively unchanged for the remaining life of the facility. However, is it reasonable to conclude that the operational pattern of the past five years will continue substantively unchanged in the future? Also, is it reasonable to conclude just because no environmental effects are apparent

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today that no environmental effects will be apparent 5, 10 or 25 years from now given the same or different levels of plant operation?

- EPA does not want to reduce any monitoring requirements that will curtail our real-time knowledge of the environment in any area affected or potentially affected by exposure to the thermal plume. These data are needed to adequately evaluate the effects of the facility's operation on the balanced indigenous biological community now and in the future.

- EPA would like to know if Seabrook believes the revised monitoring plan represents the long-term monitoring plan for this facility? After 20 years of pre-operation and 5 years of post-operation data collection, EPA believes that the proposed revisions should represent the long-term monitoring plan for this facility. If not, EPA would like an explanation of why the proposed revisions do not represent the long-term plan including how much additional data collection will be required to obtain that plan. Until the long-term plan is developed, the Agency has serious reservations about approving any revisions. The Agency views the long-term monitoring plan as a bottom-line level of monitoring for both biological and water-quality parameters that will remain relatively unchanged until the facility ceases to discharge heated water.

- Those areas of the present monitoring program that bear directly on Section 316 (a) and (b) Demonstrations should be noted as results from these monitorings are necessary for permit reissuances purposes. Each time a permit is reissued, the existing Section 316 (a) and (b) Demonstrations are reviewed. The permittee must certify any changes in: (1) the facility's discharge(s) characteristics, (2) waterway characteristics, and (3) resident or transient aquatic community. The permittee must then explain any differences identified, and their impact on the local balanced indigenous population. If any difference is noted, a new amended demonstration is then prepared on this incremental change in the environmental conditions at the facility based on recommendations of the Technical Advisory Committee. This demonstration, basically, finds that the permit's thermal discharge limits, for the area of concern, are protective of the balanced indigenous population of aquatic life including its propagation. In addition, the Agency also must conclude that the design of the intake structure(s) satisfies the best technology available requirements in that it minimize adverse environmental damage to aquatic organisms by impingement and/or entrainment. Impingement is the trapping and holding of large aquatic organisms such as fish and shellfish on intake structures and/or traveling screens and entrainment is the drawing in of small aquatic organisms such as fish eggs and larvae by the facility's circulating water system.

- The EPA believes that each white paper should contain the goals and objectives envisioned at the beginning of each monitoring program. That way any program revisions can be evaluated against the original objectives and goals as well as current concerns. For example, reading the introduction for Phytoplankton in the 1995 Environmental Studies Report it's quite clear what are the objectives of that monitoring program. However, in the Phytoplankton white paper I could not find such a description.

- EPA realizes these papers are working documents, but after comments are received from the Ecological Advisory Committee (EAC) and the Technical Advisory Committee (TAC) members, Seabrook needs to prepare a set of documents that represents Seabrook's final assessment including any responses to comments deemed appropriate by Seabrook. Then the EAC and TAC committees can make their final decisions on Seabrook's request for revision(s) to its monitoring program.

- EPA believes a discussion of how the nearfield and farfield stations were chosen should be included in these documents. This could be critical to resolving a concern arising from the following statement presented in the water-quality summary document. The authors conclude the following in reference to P5, "this station is over 1.5 km from the discharge, too far to be affected by power plant operation, and too far to even be considered a nearfield station." It appears this same statement could be applied to findings presented in the other papers regarding P5.

  It also appears that P2 might be located even further from the discharge diffusers than P5 which could lead to a similar conclusion regarding P2. To help resolve this problem, EPA would like to see the thermal discharge plume (to include the area within the 1 degree Fahrenheit isotherm) shown on the maps that include the sampling stations, Seabrook Power Station, Hampton Harbor and the intake and discharge structures. The Region also would like to see an arrow placed on these maps showing the direction of the longshore transport current.

  Based on the above discussion, it appears that P2's status as a nearfield station needs to be reevaluated. Noting the location of P2 as compared to the locations of the intake/-discharge ports and the areal extent of the associated thermal plume, EPA is concerned that P2 may be more representative of farfield than nearfield conditions. If this is true, the effects of the facility's thermal plume on the environment may not have been adequately accessed. Overlaying the thermal plume on the various maps should help clarify this situation. In fact, it may show that either the nearfield sampling point P2 should be moved closer to the plume or a new sampling

station should be established, possibly within the outer limits of the thermal plume, say 1 degree Fahrenheit isotherm, to adequately evaluate whether or not Seabrook's thermal plume has had any impacts on the environment.

- EPA wonders whether or not Seabrook has ever determined the number of viable eggs and larvae in the plume either just after emerging from the discharge diffusers or within the area bounded by the three degree Fahrenheit isotherm? These data could be subtracted from the number of viable eggs and larvae at the intake structure to determine the number killed due to entrainment. This number could then be translated into an estimate of how many adult organisms, such as finfish, lobster, etc. never reached maturity due to entrainment. This estimate would be the companion value to the estimate of various species lost to impingement which Seabrook presently reports. Also, has Seabrook performed any nutrient sampling in this part of the thermal plume to look for significant release of nutrients from the dead and dying organisms as compared to the intake area?

- EPA believes that the lobster larvae neuston sampling period should be cut back only two weeks on either end, thus the sampling period would run from June 1st to September 30th. Using the frequency distribution presented in the Epibenthic Crustacea document on page 17 as a point of reference, this sampling period would ensure that sufficient data are collected at both ends of the larvae period and show that data had been collected over the entire period when larvae were present in the water column.

- In the Mya Arenaria document, Seabrook proposes eliminating all sampling in the historically unproductive beds. However, if over time these beds become more productive how will this be known? EPA suggests, as a partial solution, continue stratified random sampling at one bed which is considered typical of the entire set of unproductive beds.

If you have any questions regarding my comments, please do not hesitate to call me at 617/565-3129. Jack Paar of EPA's EcoSystem Assessment group in Lexington, Massachusetts will be submitting his comments under separate cover.

Sincerely,

Frederick B. Gay

Frederick B. Gay
New Hampshire NPDES Permit Coordinator

CC: Jack Paar, EPA-EcoSystem Assessment Group
Jeffrey Andrews, NHDES, WD, SWQB
Robert Esterbrook, NHDES, Biology Bureau
Permit File

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Review of North Atlantic Energy Service Corporation
Seabrook Station
Long Term Biological Monitoring Program

Submitted 4/2/97
by
Jack Paar, III
Biologist, USEPA
Ecosystems Assessment
Lexington, MA

I have both general and specific comment regarding North Atlantic's Seabrook Station Long Term Biological Monitoring. During this evaluation I have examined and commented on the following program elements:

1) Epibenthic Crustacea
2) Marine Macrobenthos
3) Finfish
4) Water Quality
5) Zooplankton
6) Soft-Shelled Clam Mya arenaria
7) Phytoplankton & Chemical Nutrients

Though not actually part of the long term program I have also included comments on the following program:

8) Finfish Adult Equivalency

Introduction

In the past it has been assumed that monitoring programs would allow the prediction, characterization, prevention, and or mitigation of biological impacts from power plant operations. I suggest that this is no longer a responsible or an accurate assumption. I have four general areas of concern regarding monitoring programs: 1) the subjectivity of data analysis, 2) monitoring provides no protection for or conservation of natural resources (either in process or intent), 3) the focus of typical monitoring is too narrow, and 4) monitoring generally lacks sensitivity.

Monitoring Programs are Not Protective

In most instances monitoring is designed to demonstrate that Seabrook operations are not having any impact on the environment. This creates a potentially costly and vicious circle where regulators always require more monitoring and the permittee always propose less. The inability of traditional monitoring to predict, prevent, and or mitigate biological impacts provides little benefit to the environment either. Instead of focusing on prevention or mitigation monitoring hopes to demonstrate no significant or appreciable impact. Does North Atlantic know how it might mitigate, reduce, or prevent those impacts? Are mitigation opportunities being ignored because of the original monitoring design? Are there ways to enhance ecosystem health while meeting the monitoring demands of the CWA or are these two ideas incompatible? Are there ways North Atlantic with the assistance of the regulators might be encouraged to investigate resource conservation options rather than perpetually focusing its resources on trying to prove 'no impact'?

Monitoring Programs are Too Subjective

Typically, North Atlantic Energy Service Corporation, and their biological monitoring consultant, Normandeau Associates, affirm the ability of the current monitoring to detect station impacts

if they were to occur yet on several occasions in the last several years impacts "detected" by statistical analysis have been subjected to an additional, indefinite evaluation to determine the likelihood of Seabrook's ability to cause them (see # 2. **Macrobenthos** below*). Future regulatory review of this type of subjective appraisal will be much more rigorous than in the past. In light of this concern I have made several requests for additional information below.

Monitoring Programs are Too Focused

Monitoring programs focus on specific elements within the ecosystem and are unable to integrate individual species impacts with community or ecosystem health. By considering measurements in exclusion of one another, organisms in exclusion habitat for example, some of the more subtle yet important influences for change in ecosystems are being overlooked and we are limiting our ability to comprehend the broad consequences of human impacts.

Monitoring Programs Lack Necessary Sensitivity

Every monitoring program has a limited ability to detect change. This limitation is the result of an inability to accurately and practically characterize natural variations in the system being monitored. Whether comparing data between years or between nearfield and farfield stations most programs are incapable of detecting statistical differences between or among samples with the necessary levels of sensitivity to identify and mitigate stressors.

One way to ensure a common understanding of what these monitoring provides is to evaluate the statistical power of the various program elements. Power analysis of biological monitoring data and statistical methods calculates the program's ability to detect change. This has been done only on a limited basis with previous program elements for Seabrook Station monitoring. These evaluations revealed severe limitations; in most cases analysis could not detect change unless they were greater than 50% (some program elements may test higher or lower).

Regulators simply have no idea what's happening in these systems, with any certainty, unless the program specific threshold is exceeded. If changes are smaller than 50% they simply won't be considered statistically significant, while they may in fact be biologically significant. By the time monitoring detects such large change populations and/or communities may be in serious distress. Unfortunately, the criteria for improved sensitivity demands massive sampling efforts which are often too costly or impractical.

General

In many instances the best that monitoring can provide to the public is a vague sense of industry accountability, but due to the limits of these programs I believe it is generally a false sense of protection. At this time I am not convinced that the proposed changes will adequately or completely address these inherent difficulties and deficiencies. While I do believe

several modifications offer improvements, it should not be presumed that these improvements will address the serious limitations inherent in monitoring. My general recommendations follow:

1. Conduct a power analysis for each of the existing and proposed sampling programs to estimate the ability to detect change. Evaluate each estimated monitoring program power, with its associated sampling routine and statistical method, in light of alternative combinations of sampling and statistical methods.

2. In conjunction with step 1, establish a set of criteria for each program element (1-8) which will be used to identify and evaluate detected impacts. This criteria should be established and agreed upon before data collection and analysis begin.

3. Programs elements should each be based upon a clearly stated hypothesis. A program summaries should include a null hypothesis testing strategy and a concise statement of the focus of that program. Program focus should, for example:
   a) predict or measure population/community effects (measure ecosystem health)
   b) quantify direct impacts from impingement, entrainment, and discharge, or
   c) accomplish both a and b.

4. Conduct an evaluation of program data application to 316 (a) & (b) assessment. How will this data be used in future demonstrations (e.g. permit applications)?

5. Establish well delineated assessment endpoints (impacted organisms, populations, marine community, habitat, and or the ecosystem) for each of the program elements so that all parties agree on what is actually being measured, why it's being measured, and how it's being measured. The tables associated with the different draft Evaluation of Seabrook Station Marine Macrobenthos Program after Five Years reports might be a good format for communicating such information.

6. Establish sampling and analysis regimes and SOPs including QA/QC procedures. The TAC and EAC should meet in the near future to establish SOP requirements, sampling, and data handling/analysis protocols.

7. Regulators must have complete and timely access to all the raw data.

8. A detailed explanation of all metrics, equations, and calculations used in preparation of all tables, charts,

graphs, etc. should be included in SOPs and annual reports.

9. Dendrograms used in displaying data in reports are cryptic. Another method should be used to display this information or North Atlantic should include detailed explanations for there interpretation.

Specific Comments Pertaining to Program Elements

1. **Epibenthic Crustacea**

I do not recommend the elimination of sampling stations and the restriction the sampling period at this time. While it seems clear that changes in the CPUE of lobster and crabs were significantly different only at the farfield station in the past, there is no guarantee that this will remain true in the future. Plant influences at P2 and P5 are potentially different (intake and discharge respectively) and it is still possible that impacts may occur in the future at the discharge station and not at the intake.

It should also be pointed out that a decrease in CPUE at the nearfield station begs the question of whether or not this is a decrease relative to the nearfield station. Has the CPUE increased at the nearfield station? Disturbances in community structures might alter relationships and provided more favorable conditions for one particular species. An increase is an alteration and as much of a change in the "balanced indigenous population" as a population decrease.

I disagree that sparse catches at the beginning and end of the larvae sampling season "contribute only variability without adding to the description of annual abundance", it is important to the variability in larval densities. Correlations between seasonal water temperatures, station operations, or other environmental triggers should be further investigated. I recommend that sampling continue from May through October and that analysis of abundance trends be conducted for the shorter period, mid-June through September. I concur with the proposal to reduce the number of Cancer spp. larval collections from three to one per sampling date per station.

2. **Marine Macrobenthos**

a. **General Comments**

Evidence of impacts have been detected by this program element. I recommend a complete review of the existing data and the metrics employed to date. In addition, in order to determine the best use of the data, that review should include an examination of alternative metrics which might be employed in future analysis of macrobenthic and macrofaunal data.

*I am troubled by the phrases on page 7 of the draft Evaluation of Seabrook Station Marine Macrobenthos Program after Five Years that states in paragraph 3, "Significant interaction terms based on ANOVA were noted for six of the seventeen community and selected taxa parameters monitored for mid-depth and deep communities. However, ...,further examination and analysis revealed that most of the observed differences responsible for significant interaction terms were not consistent with plant impact." On what basis was the significance judged "not consistent with plant impact." In response to this I suggest a detailed explanation of the determinations of no station impacts in the analysis of macroalgae and macrofauna. Particular attention should be given to a review of all Laminaria digitata data, collection, and analysis.

b. **Destructive Sampling**

I recommend that all intertidal (B1MLW, B5MLW) and mid-depth (B19, B31) stations be included in destructive sampling. I agree with New Hampshire that Spirorbid data collection frequency could be reduced, but not yet dropped. Since it has only been collected once per year I also recommend that deep station data collection and analysis continue at the previous frequency and locations. (6 stations x 5 replicates x 3 times a year = 60 samples per year).

c. **Non Destructive Sampling**

I recommend that stations B17, B35, (shallow subtidal) B19 and B31(mid-depth) stations be sampled as proposed. (4 stations x 6 transects x 3 times per year=72 samples per year).

d. **General Algae**

North Atlantic should maintain intertidal sampling at stations B17, B35. The proposal to sample stations B17, B35 (shallow subtidal) and B19, B31 (mid-depth) should be approved. (6 stations x 3 times per year= 18 samples). The percent similarity clustering dendrograms are cryptic. A different method should be employed or they should be explained in greater detail. This cannot be the best metric for evaluation of similarity. If it is I would like to see some papers (Boesch 1977?) in support of that assertion as well as an explanation of the criteria used by North Atlantic to "classify the station-year collections into clusters.

e. **Bottom Panels**

The proposal to continue evaluating bottom panels should include the deep stations B04 and B34 at least once per year. This element would then include stations B19, B31 (mid-depth) and the deep stations. Mid-depth stations would be subsampled three times each year for a total of four subsamples per station.

3. **Finfish**

a. **General**

Evidence of impacts have been detected by this monitoring program element. I suggest a complete review of these impacts, the data, and the metrics employed to date. In addition, in order to determine the best use of the data, I request an examination of other metrics which might be employed in future analysis of finfish studies. The dendrograms used in the finfish section of the annual reports are cryptic. Another method should be used to display this information or North Atlantic should explain their interpretation and give examples of how different patterns might be interpreted.

b. **Ickthyoplankton**

Why were only nine species selected for ANOVA between the two nearfield stations? Were these the dominant taxa? Were other species sampled? Why weren't other species data used in the ANOVA? Is there a guarantee that the nearfield stations will always remain similar in the future?

Off shore ichthyoplankton sampling isn't very useful. They may be use in comparisons with intake densities, but this is not their intended purpose. Comparisons between nearfield and farfield stations is essentially a futile exercise. Attention should be focused on establishing accurate ichthyoplankton densities by species for use in estimating entrainment impacts. This element should be considered for elimination.

c. **Ichthyoplankton Entrainment**

This element need further attention though, the proposed improvements in ichthyoplankton entrainment sampling appear to be addressing some of the inadequacies of past programs. The EAC and the TAC should give top priority to this program element. There is a good amount of old (+10 years) research conducted on entrainment sampling. Has anything been done more recently?

Streaming nets in the intake will always present problems. Sampling errors have been addressed in a number of papers (e.g. Hudson River), these should be examined and a best options approach should be presented to the TAC. Are larval and egg densities uniformly distributed both spatially an temporally in the intake? Has this been tested? Small inaccuracies in these measurements could have serious consequences on the validity of the entrainment estimates as well as adult equivalency estimates.

d. **Mid-water and Surface/Near Bottom Gill Netting**

These program elements, while suspended at the time of this writing, should be eliminated as proposed by North Atlantic.

. **Otter Trawl and Beach Seine**

Otter trawling as proposed should be approved. It would be helpful to see SOPs for trawling and seining, data handling, and analysis to confirm uniform sampling efforts and the appropriateness of the chosen techniques and metrics. I would like to know more about how CPUE, length, and abundance are calculated and compared.

f. **Impingement**

This is another element that in the past has had serious flaws that until recently were not known to the regulators. The proposed changes to sampling are inadequate. Daily changes in abundance of fish impinged will almost surely be missed even with the proposed changes. Holding the screens for one 24 hour period each week is better than the old method, but still may not pick up changes occurring throughout the week. This program needs some serious investigation.

Investigations should examine the literature available in this area and develop clear understanding of sampling reliability and precision. Mark Mattson seems to have been on the right track in his 1988 AFS Monograph, Reliability of Impingement Sampling Design: An Example from the Indian Point Station (4:161-169). His approach would take some time to pursue. For the time being I would propose a program which measures fish on the screens in the following two ways :

1) A daily program which counts (with taxonomic identification) the fish for one hour each shift, each day could be used to calculated a 24 hour impingement "rate".

2) Three eight hour counts (with taxonomic identification) could be made each week, during the morning, afternoon, and night of separate days and an impingement "rate" could be calculated for the week.

We also need to better define the limits for reporting impingement events to the regulators. What triggers a report? What is Seabrook Station protocol for operating the rotating screens? We need to review these protocols.

g. **Sex Ratios**

I would like to suggest that fish sex ratios be measured and tracked from year to year. This seems to be a fairly sensitive measure of population stability. The TAC and EAC should discuss this issue.

4. **Water Quality**

Nutrient sampling as conducted currently should be eliminated. I do however, think there is a possibility that Seabrook Station alters the nutrient "mix" in the discharge area as well as potentially impacting benthic communities. While total nutrient values clearly enter and exit the Seabrook Station in the cooling water system relatively unchanged, there is arguably a conversion of the zooplankton biomass, from living organisms to dissolved nutrients, as they are killed or damaged during entrainment. This conversion of biomass may be "invisible" because of the great amount of flushing, mixing, and plankton densities occurring in the offshore waters, but some evaluation of this process needs to be made at

some future date so this issue can either be put to rest or investigated further. I suggest that the EAC look into this matter and pass on some options to the TAC before the end of the year.

5. **Zooplankton**

a. **Microzooplankton**

Microzooplankton sampling could be useful in investigating food chain impacts and potential alterations of prey/predator relationships, but this seems impractical at this time. It should be noted however that microzooplankton serve a function in this system and that the quantity entrained by Seabrook Station may not be, as assumed, insignificant. This is one of the areas where monitoring is both too focused and lacks the sensitivity to investigate these subtleties.

b. **Macrozooplankton**

The proposed sampling changes should be approved.

c. **Bivalve**

Bivalve sampling should continue. I agree that station P5 may be dropped.

While Mya accounts for less than 1% of all bivalve larvae entrained I know that total annual entrainment is quite large. Because this species is of regional importance the bivalve larvae entrainment sampling should not be eliminated as requested, but should continue as previously conducted.

6. **Mya arenaria**

All clam flat counts should continue at this time. I am not convinced that a truly random survey is possible given the limited areas available for sampling. A parallel study might be useful in demonstrating this. The nearfield, and green crab sampling should continue as proposed.

Is there some better way to survey clam digger impacts more precisely than simply counting the licenses or the number of diggers per flat? Isn't there a way to estimate CPUE for clamming?

7. **Phytoplankton and Chemical Nutrients**

I agree that this element be eliminated as long as North Atlantic commits resources to investigating the biomass conversion/nutrient enrichment issue described in 4. above.

8. **Adult Equivalence Estimates**

Serious flaws have been identified in the fish entrainment enumeration program design and methodology. Monitoring data was used to calculate adult equivalence (AE) for winter flounder and hake. The accuracy of that exercise must now be critically questioned. Estimates must be developed to predict a range of potential error in the existing data set and a correction factors developed and the AE report should then be repeated;

North Atlantic should recalculate all estimates of AE for winter flounder and hake as well as for all ichthyoplankton species sampled. These calculations should include AE losses due to ichthyoplankton entrainment. Ichthyoplankton entrainment counts should be adjusted with correction factors because of the errors introduced by exclusive daytime sampling as well as the use of .505 mm mesh plankton net. A report of corrected AE should be made to the regulatory agencies as soon as possible.

no adjustment!

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
One Blackburn Drive
Gloucester, MA 01930-2298

OCT 17 1996

Mr. Fredrick Gay
New Hampshire NPDES Program Unit
Environmental Protection Agency
John F. Kennedy Building
Boston, MA 02203

RE: Comments on Seabrook Station 1995 Environmental Studies Report and Proposed Long-Term Program

Dear Mr. Gay:

We have completed our review of the proposed long-term Seabrook Station Environmental Monitoring Program and the 1995 annual Environmental Studies Report. Both of these items were presented and discussed at the September 10, 1996 Technical Advisory Meeting (TAC). Other than a few outstanding issues, the National Marine Fisheries Service (NMFS) generally concurs with the conclusions and recommendations presented in the reports. We support the efforts of Seabrook Station to re-focus the monitoring program after five years of data collection and analysis. Proposed changes will result in reducing program redundancies, but will also increase monitoring efforts where more detailed information is necessary. In particular, parts of the monitoring which need to be improved involve seal and fish impingements, entrainment monitoring and the need for conducting future adult equivalency estimates for species of commercial and recreational importance. Please consider the following comments, observations and recommendations during the development of a final long-term Environmental Program.

Seal Impingements

Records since 1993 indicate that Seabrook Station has on occasion mortally impinged harbor seals in the station's seawater cooling system. In 1993, one seal was reported; 1994, three seals; 1995, six seals; and 1996, nine seals, thus far. This unfortunate problem is not likely to go away on its own, and unchecked this situation might worsen due an estimated 8.7% annual rate of population increase for this species in Maine Coastal waters (Kenny and Gilbert, 1994).

For unknown reasons seals enter the seawater intake pipes which are located about one mile offshore in approximately 60 feet of water. Designed to keep large debris from entering, vertical steel bars are spaced 22 inches apart on the intake openings. Apparently smaller and medium sized seals have little problem passing between the bars. Water entering the three intake pipes takes about forty minutes to travel the three mile distance to the enormous forebays beneath the station. Traveling screens within the pumping station are operated about once a week to extract debris. Whole seals and deteriorated body parts have been collected during routine debris collection from the screens. Apparently, some seals sink in the forebay, and as they decay, parts of their bodies are found in the screen washing trays. Some seals have been observed floating in

the forebays and are manually removed with great difficulty due to limited human access to this area.

All whole and partial seal carcasses have been turned over to the New England Aquarium for necropsies. It seems that the seals drown in the three mile pipeline somewhere between the intakes and the forebay. Perhaps the seals enter the intakes and become disoriented and cannot find a way out. No significant correlation between fish impingements and seal takes can be drawn. Due to the design of the forebays and intake system, one can never be sure how much time has elapsed from when a seal dies until it is discovered.

Seabrook Station is cooperatively working with NMFS to find a resolution to this ongoing problem. On August 20, we met with Seabrook's Environmental Sciences Supervisor, Mr. Ron Sher, to discuss the problem. As in the past, we advised Mr. Sher that the Marine Mammal Protection Act (MMPA) prohibits the taking of a marine mammal without an exemption. We also provided him copies of the latest regulations regarding small take exemptions, along with pertinent excerpts from the MMPA and the Stock Assessment Report.

To obtain a small take exemption for lethal takes of seals, Seabrook would have to petition NMFS for rule making under MMPA §101(a)(5)(A) [50 CFR 216.101-106]. A number of deterrence and prevention measures were discussed at our meeting, including additional grating on the intakes to reduce the 22" openings, and sonic devices to scare seals or fish (if the seals are pursuing prey when they enter the intakes, a fish scarer may remove the bait). The practicability and cost effectiveness of the measures will be evaluated by Station staff. Other options may arise as efforts to respond to this problem continue.

Fish Impingement

Achieving accurate monitoring of fish impingement has been a long-term problem, and continues to be a problem at Seabrook Station. During the first four years of operation, small fish were not removed from impingement debris by plant personnel, resulting in potentially gross underestimates of impinged fish. Actions were taken to rectify this problem in the fall of 1994, and impingement estimates were believed to be more accurate since that time. However, during NMFSs' August site visit, which included a demonstration of the impingement screen sampling procedures, additional problems were identified which continue to underestimate fish mortalities. We recommended at that time that the modifications described below, in addition to those already proposed by the Station, be incorporated into the long-term monitoring program to alleviate these deficiencies.

The problem which we identified involves the mesh size of the sampling basket used to collect the debris from the traveling screens. The mesh size of the traveling screens is .375 square inches and is designed to collect all debris greater than this size. However, as observed during our site visit, these screens clog up and allow smaller pieces to get caught in the screen. A clogged, non-functioning screen can allow small fish to squeeze through the screen. During routine cleaning of the screens, which typically occurs once a week, the debris from these screens travels down a chute in the fore-bay pump house and lands in a large metal basket constructed of

floor grating material with openings approximately 1.0" x 2.0". At this point, much of the small debris and organisms collected by the .375" traveling screens falls through the sampling basket and does not get included in the monitoring count. We witnessed many pounds of shell debris and small fish in the pile which accumulated underneath the sampling basket. We recommend that the simplest way to rectify this deficiency is to install a new sampling basket constructed with a mesh size that corresponds to no larger than the mesh size of the traveling screens.

NMFS supports the proposal by Seabrook Station to conduct a special year-long study to determine if small fish are being lost due to decay or other reasons during the current week-long interval between impingements samples. Evidence would seem to support this hypothesis. Many fish presently come up very decomposed and it is likely that some fish are falling apart and pieces are pulled through the screens. Predation occurring at the screens may also be a factor which would reduce the estimate of fish takes resulting from the intake water system. The proposed study would test the hypothesis by conducting an additional screen washing each week. One washing would occur after a full six days and an additional washing would occur after only one day to minimize the potential for biomass loss from the sample.

Fish Entrainment

NMFS is concerned about current methods to estimate the number of fish eggs and larvae entrained through the condenser cooling water system, and fully supports the proposal by Seabrook Station to increase the level of entrainment sampling. The existing sampling program only collects samples during daylight hours utilizing a 505-μm mesh. It is scientifically well established that many zooplankton and fish larvae undergo some degree of vertical migration between day and night. As a result of this phenomenon, it is likely that day time only sampling is missing a significant amount of species diversification. Seabrook Station's proposal to begin collecting samples over a full 24 hour period should alleviate this problem.

The second proposed entrainment program modification involves sampling with a 333 μm mesh net in addition to the current 505 μm net. Studies which have shown fish larvae between 2 and 5 mm can be extruded through a 505 μm mesh justify this change. Larvae form most of the commercially important fish species, including yellowtail and winter flounder, pollock and cod, all fall within this size range when hatched (Fahay, 1983). Eggs are even smaller, usually less than 1.0 mm. The possibility exists that the current entrainment sampling program has underestimated the take of fish larvae and eggs. NMFS supports the addition of the smaller net and is interested in reviewing the results of further studies.

Adult Fish Equivalency Estimate

In light of the above comments and proposed modifications to both the entrainment and impingement monitoring programs, NMFS recommends that after a full year of additional data collection, Seabrook repeat the equivalent-adult estimate study which was first conducted in 1995 (Saila). This earlier study concluded that takes of pollock, winter flounder and hakes were ecologically insignificant. Application of the modified sampling techniques may discover a significant increase in fish mortality. New adult-equivalency estimates are necessary to fully

assess Seabrook Station's impacts on local fishery resources.

Conclusion

NMFS commends Seabrook Station for taking a proactive approach to increasing the accuracy of its monitoring program. We feel that many of the proposed changes and incorporation of our recommendations will lead to a long-term monitoring program that will be more sensitive than the existing program at detecting ecological impacts posed by the station. Our agency will continue to work with Seabrook Station to resolve the seal mortality issues. If you have any questions pertaining to this letter, please contact Eric W. Hutchins at (508) 281-9313.

Sincerely,

Christopher Mantzaris
Chief, Habitat and
Protected Resources Division

Literature Cited:

Fahay, M.P. 1983. Guide to the early stages of marine fishes occurring in the western North Atlantic Ocean, Cape Hatteras to the southern Scotian Shelf. J. Northwest Atlantic Fisheries Science 4;

Kenny, M.K. and J.R. Gilbert. 1994. Increase in harbor seal and gray seal populations in Maine. Dept. of Commerce, NOAA-NMFS Contract Rep. 50-EANF-2-00064, 19 pp.

Saila, S.B. and W.H. Howell. 1995. Equivalent-adult estimates for three species of groundfish impinged and entrained at Seabrook Station. Prepared for North Atlantic Energy Service Corporation, P.O. Box 300, Seabrook Station, Seabrook, New Hampshire.

cc: Technical Advisory Committee
Seabrook Ecological Advisory Committee
Normandeau Associates
Seabrook Station, Ron Sher
F/NEO2, Doug Beach

File: 1503-02 NH NPDES
Seabrook, N.H.
Seabrook Station NPDES/TAC

STATE OF NEW HAMPSHIRE
INTER-DEPARTMENT COMMUNICATION

RHE

FROM Robert H. Estabrook, Administrator
Biology Bureau

Date September 30, 1996

SUBJECT Seabrook Station: Status of Long-Term Environmental Studies Program Proposals

AT(OFFICE)
Dept. of Environmental Services
Water Division

TO File

The Technical Advisory Committee (TAC) for the Seabrook Station environmental studies program met in Seabrook on September 5, 1996. The purpose of the meeting was to listen to and discuss North Atlantic's (NA) proposal for the long-term environmental studies program at Seabrook Station. With five years of post-operational data evaluated, NA is proposing significant changes to the existing monitoring program, based on information learned during those five years. The idea is to have a more focused program that will continue for the foreseeable future.

My understanding of the outcome of the above meeting and the current status of the proposals is as follows.

1. In 1995 NA proposed some changes, including (1) discarding old contingency samples, (2) deleting surface panels program, and (3) switching from a fixed to mixed effects ANOVA. These proposed changes were never acted on. At the end of the meeting it was decided that NA will send a letter to the state and EPA with the outstanding requests and a sign off by the Seabrook Ecological Advisory Committee (EAC), which consists of regional university professors with expertise in marine ecology.
   At this time I have not seen the above letter.

2. The 1996 proposed changes for the long-term monitoring program have been reviewed by both the NH Fish and Game Department (John Nelson) and the NH Department of Environmental Services (Bob Estabrook). Preliminary agreement was reached between the two on the areas where they agreed, disagreed or agreed with modifications to the proposed changes.

   At the TAC meeting it was requested that each member of the EAC sign a statement that they are in agreement with the proposed changes and that the changes will not affect our ability to detect impacts from plant operation. Upon receiving these written statements (and any modifications that EAC members may require), NA will formally submit the proposed changes to the EPA Regional Administrator and DES' Water Division Director.

Messrs. Nelson and Estabrook are prepared to make their recommendations to the full TAC as soon as the formal submittal is received.

cc: E. Schmidt, P.E., Ph.D., Director, WD, DES
J. Andrews, P.E., DES
J. Nelson, NHF&G
J. Parr, EPA
F. Gay, EPA

State of New Hampshire
DEPARTMENT OF ENVIRONMENTAL SERVICES
6 Hazen Drive, P.O. Box 95, Concord, NH 03302-0095
603-271-3503 FAX 603-271-2867
TDD Access: Relay NH 1-800-735-2964

November 1, 1996

Frederick Gay
N.H. State Program Unit-NPDES Coordinator
U.S. Environmental Protection Agency
J.F. Kennedy Federal Building
Boston, MA 02203

Dear Mr. Gay:

This letter conveys preliminary comments from New Hampshire for the long-term environmental studies program proposal for Seabrook station. The proposals were presented to the TAC on September 5, 1996. The comments represent a coordinated response of the Department of Environmental Services (DES) and the Fish and Game Department (F&G).

DES and F&G have two concerns relative to the process of providing comments on the proposals to North Atlantic (NA). First of all, it was our understanding at the end of the September TAC meeting that the proposed sampling program was to be submitted to the EAC, and that each EAC member would provide a signed statement that he agrees with the proposal and that the proposed changes would not impair our ability to detect impacts from plant operation. We have not seen such agreements and there is some question if any comments should be provided to NA until such agreements are received.

The second concern relates to the process by which comments are provided to NA. We feel that one coordinated response, representing the concerns of NH, EPA and the National Marine Fisheries Service (NMFS), should be provided, as was done historically. Several uncoordinated responses give NA both the dilemma of deciding how to respond to conflicting opinions and the opportunity to pit one group's opinions against another's.

I have talked to Jack Paar about this issue. He agrees that a coordinated response should be provided but, at this time, his work load prevents him from participating in a coordinated response with New Hampshire. By way of this letter we are providing a copy of our comments to Jack. We request these comments not be forwarded to NA until Jack has had an opportunity to at least comment on our comments. I understand that you and NMFS have already responded directly to NA. However, the above scenario will at least result in a coordinated response from NH and EPA biologists.

The comments are provided below. They are specific comments to the specific proposals, listed program by program. We consider these comments to be preliminary at this time and reserve the right to make changes based on input from the EAC and other TAC members. As you know, final approval from New Hampshire to approve NPDES permit modifications can only be given by the Director of the Water Division of DES.

1. Water Quality (chemical nutrients)

   We agree with the proposed modifications. Nutrient sampling will be dropped and station P5 will be dropped for temperature, salinity and dissolved oxygen measurements.

2. Phytoplankton

   We agree with the proposal to completely drop the phytoplankton sampling program.

3. Zooplankton

   We agree with the proposal to drop the microzooplankton program. We do not agree with the proposal to drop bivalve larvae sampling, although we will agree that station P5 can be dropped. We also do not agree with the dropping of the bivalve larvae entrainment program. We accept the proposed changes to the macrozooplankton program (drop station P5 and drop replicates) although, without the replicate contingency samples, it is incumbent on North Atlantic to re-sample immediately if a sample is lost.

4. Finfish

   We generally support the proposed changes to the finfish program but remain concerned about the reduction in replicates. Again, it will be NA's responsibility to not have any data gaps due to the loss of a sample and the lack of any contingency samples. We support proposals to:

   - drop station P5 for ichthyoplankton sampling
   - enhance ichthyoplankton entrainment to include night sampling and compare net sizes
   - drop gill net sampling
   - make no changes to the trawl sampling program
   - make no changes to seine sampling program
   - increase sampling frequency for impingement assessments.

5. Marine Macrobenthos

   a. destructive sampling: We are comfortable with the dropping of B04, B13, B34 (deep) and B16 (mid-depth) stations. However, the intertidal stations (B1MLW, B5MLW) should continue to be assessed. These stations were

established primarily to evaluate impacts from backflushing. As long as backflushing remains a possibility for biofouling control, these stations should continue to be monitored at some frequency.

We agree that Spirorbid counts, length/reproductive status of dominant fauna and colonial abundance measurements can be reduced (perhaps once every three years), but they should not be dropped completely.

b. non-destructive sampling: As above (5a), we agree with the proposed changes except that the intertidal stations should be continued.

c. general algae: Again, we believe that the intertidal stations should be continued.

In addition, the available data demonstrates a decline in *Laminaria* abundance in the post operational period. We would like to see a proposed study modification to more closely look at this apparent decline.

d. bottom panels: We agree with the proposals to drop the deep stations (B04, B34), drop the annual panels, add the subsampling of the triannual mid-depth panels to estimate variability, and add wooden panels to monitor woodborers (*Teredo* spp.).

6. Epibenthic Crustacea

a. adult lobster/crab: No change proposed; we suggest data also be collected on V-notch, eggs, and shell condition (i.e., molt stage). F&G should be consulted as to the methods used to collect this additional data.

b. lobster/crab larvae: We agree with dropping station P5 for both lobster and crab larvae, shortening the sampling period for lobster larvae neuston, and reducing the replicates for the crab larvae. As with other reductions in replicate and contingency samples, it is expected that NA will ensure sufficient sample numbers for all scheduled sampling trips. Data gaps are not acceptable.

7. Soft-shell Clam (*Mya*)

a. *Mya* adults & spats: We do not support dropping flats 3 and 5.

b. Clam digger counts: We are open to proposals for streamlining clam digger counts. Reliance on clam license sales only, however, is not acceptable.

c. As stated above under zooplankton (#3), we do not agree to any reduction in *Mya* larvae sampling. It is important that all stages of this valuable resource continue to be assessed.

In summary, with the exception of the *Mya* (adult and larvae) programs and other minor changes, we are generally supportive of the proposed changes for the long-term environmental studies program. We particularly commend North Atlantic for taking a proactive approach to enhance the accuracy of its fish impingement and ichthyoplankton entrainment programs. We continue to be concerned about possible data gaps from the lack of contingency samples, and would like to see a proposal to look in more detail at the apparent decline in *Laminaria* since plant operation.

We have reviewed the comments from NMFS dated October 17, 1996, and fully support the comments on seal and fish impingement, fish entrainment, and the request to repeat the adult fish equivalency estimate study after sufficient valid data is collected.

It is also our understanding that the final agreed to sampling program will be the sampling program for many years to come. With the exception of special studies (e.g., the 24-hour entrainment study) or minor changes, we would not expect to see North Atlantic propose changes to the long-term program for many years.

Very truly yours,

Robert H. Estabrook

Robert H. Estabrook
Administrator, Biology Bureau

RHE/baw
cc: E. Schmidt, P.E., Ph.D., DES
J. Andrews, P.E., DES
J. Nelson, F&G
J. Parr, EPA
E. Hutchins, NMFS

THE CITY COLLEGE
CITY UNIVERSITY OF NEW YORK
Convent Avenue at 138th Street
New York, New York 10031

Dr. John H. Tietjen
Department of Biology

Telephone: (212) 650-8519
FAX: (212) 650-8585
E-Mail: jhtcc@cunyvm.cuny.edu

30 October 1996

Mr. Frederick B. Gay
United States Environmental Protection Agency
Office of Ecosystems Protection
New Hampshire State Programs Unit
Mail Code cnh
John F. Kennedy Federal Building
Boston, MA 02203-2211

Dear Mr. Gay,

Enclosed please find my letter of endorsement of the biological monitoring program for Seabrook Station. I believe that the program presented by NAESCO will adequately assess the impact of Seabrook Station operation on the "balanced indigenous populations of fish, shellfish and wildlife" of the receiving waters adjacent to the Station.

I have instructed the other members of the Seabrook Ecological Advisory Committee to mail their comments regarding the seven major monitoring programs directly to you. Dr. Robert Wilce will be out of the country for two months; thus you will not be receiving comments from him until considerably later.

Please feel free to call me should you have any questions.

Sincerely,

John H Tietjen

John H. Tietjen
Professor of Biology
Seabrook Ecological Advisory Committee

THE CITY COLLEGE
CITY UNIVERSITY OF NEW YORK
Convent Avenue at 138th Street
New York, New York 10031

Dr. John H. Tietjen
Department of Biology

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30 October 1996

Mr. Frederick B. Gay
United States Environmental Protection Agency
Office of Ecosystems Protection
New Hampshire State Programs Unit
Mail Code cnh
John F. Kennedy Federal Building
Boston, MA 02203-2211

Dear Mr. Gay,

In late summer of this year drafts of the seven major biological monitoring programs at Seabrook Station were prepared for NAESCO by the Aquatic Services Branch of Northeast Utilities Company and submitted to the Seabrook Ecological Advisory Committee and Normandeau Associates, Inc. for review. For each program a comprehensive summary of the results to date and recommendations for future work were prepared. I have reviewed the proposed biological monitoring programs for Seabrook Station and am of the opinion that the proposed monitoring programs will adequately assess the effect of station operation on the "balanced indigenous populations of fish, shellfish and wildlife" in the coastal waters adjacent to the station.

Therefore, I fully endorse the programs of study proposed by NAESCO for the following programs:

1. Water Quality

2. Phytoplankton and Chemical Nutrients

3. Zooplankton

4. Epibenthic Crustacea

5. Marine Macrobenthos

With respect to the program planned for *Mya arenaria*, I agree that the program should become an Abundance Survey program. I also believe that NAESCO has adequately justified deletion of Flats 3 and 5 from the survey. However, given the importance of *Mya arenaria* in the local area I recommend continued monitoring of the clam populations at these sites for at least another two years. At the end of that time should the recent population trends seen at Flats 3 and 5 continue I would be inclined to approve the discontinuance of monitoring these flats.

With respect to the Finfish Monitoring Program, I am in agreement with the proposal submitted by NAESCO. However, I strongly endorse the recommendation for the fish impingement program made by NMFS and noted in its letter to you (17 October 1996). Installation of a sampling basket with a mesh size no greater than that of the traveling screens (or some other engineering device to ensure capture of small fish) is absolutely necessary to obtain good estimates of finfish impingement. Since impingement and entrainment are the two major means by which Seabrook Station may impact finfish it is imperative that estimates of these effects be as accurate as possible. I believe that the proposed entrainment and impingement monitoring programs will improve our knowledge of these effects.

Should you have any questions do not hesitate to contact me.

Sincerely,

John H Tietjen

John H. Tietjen
Professor of Biology
Seabrook Ecological Advisory Committee

cc: Seabrook Technical Advisory Committee
Seabrook Station, R. Sher
Northeast Utilities, M. Keser

HC 61 Box 109
Round Pond, Maine 04564
6 November 1996

Mr. Frederick B. Gay
United States Environmental Protection Agency
Office of Ecosystems Protection
New Hampshire State Programs Unit
Mail Code cnh
John F. Kennedy Federal Building
Boston, Massachusetts 02203-2211

RECEIVED
NOV 13 1996
NH STATE PROGRAM UNIT

Dear Mr. Gay:

During the summer of 1996 the Seabrook Ecological Advisory Committee and Normandeau Associates, Inc. exhaustively reviewed draft proposals for seven major biological monitoring programs at Seabrook Station, prepared by Northeast Utilities Co. (Aquatic Services Branch) for NAESCO. The goal of the monitoring programs is to assess the effects of plant operation on the "balanced indigenous populations" in nearby coastal waters. I believe the proposed programs will do this, and fully endorse the revisions suggested for

1) Water quality;
2) Zooplankton, including elimination of the microzooplankton program;
3) Epibenthic crustacea;
4) Marine macrobenthos;
5) Fish, with modifications proposed by Mr. Christopher Mantzaris (NMFS) in his letter to you of 17 October 1996; the elimination of
6) Phytoplankton and Chemical nutrients; and
7) *Mya arenaria.*

With respect to 7 above, a recent letter from Dr. John Tietjen, EAC Chairman, notes that the New Hampshire Department of Fish and Game wishes to have historic sampling continued at all current sampling flats. This is an unobjectionable public service which I can easily endorse also.

Please do not hesitate to contact me if you have questions.

Sincerely yours,

Bernard J. McAlice
Professor Emeritus, Oceanography
University of Maine

UNIVERSITY OF NEW HAMPSHIRE

Department of Zoology
Rudman Hall
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(603) 862-2100 FAX (603) 862-3784

RECEIVED
NOV 13 1996
NH STATE PROGRAM UNIT

Mr. Frederick Gay
New Hampshire NPDES Program Unit
Environmental Protection Agency
John F. Kennedy Bldg.
Boston, MA 02203

Nov. 6, 1995

Dear Mr. Gay:

As a member of the Seabrook Ecological Advisory Committee, I've had the opportunity to review the results of the current biological monitoring programs. I have also been involved with discussions relating to proposed changes in the monitoring program at Seabrook station, and reviewed the documents that relate to these recommendations. After careful consideration, I wish to convey that I fully endorse the proposed recommended changes in the monitoring programs associated with Water Quality, Phytoplankton and Chemical Nutrients, Zooplankton, Epibenthic Crustacea, and Marine Macrobenthos.

With respect to the program planned for *Mya arenaria*, I agree that the program should be limited to an abundance survey. I also agree that the elimination of flats 3 and 5 is justified, but because this species supports an important recreational fishery, I suggest that all flats , including 3 and 5, be surveyed for another two years. These data will provide valuable information to the New Hampshire Dept. of Fish and Game.

With respect to the finfish monitoring program, I am in agreement with the changes recommended by NAESCO. I do however, support the recommendation that the sampling of impinged fish be improved by reducing the mesh size in the basket used to collect fish from the traveling screen. This should reduce or eliminate the loss of small, impinged fish, and make any subsequent equivalent adult analyses more accurate.

Should you have any questions, please do not hesitate to contact me.

Sincerely,

Hunt Howell
Professor of Zoology

cc: Dr. John Tietjen

November 13,1996
317 Switch Road
Hope Valley, R. I. 02832

Mr. Fred rick B. Gay
United States Environmental Protection Agency
Office of Ecosystems Protection
New Hampshire State Programs Unit
Mail Code cnh
John F. Kennedy Federal Bldg.
Boston,MA 02203-2211

Dear Sir:

Reference is made to the seven major biological monitoring programs at Seabroook Station which were prepared for NAESCO by the Aquatic Services Branch of Northeast Utilities Company and reviewed by the Seabrook Ecological Advisory Committee and by Normandeau Associates, Inc.. I have participated in reviews of the proposed programs and I endorse the entire program of study prepared for NAESCO which involves the following specific components:

1. Water Quality
2. Phytoplankton and Chemical Nutrients
3. Zooplankton
4. Epibenthic Crustacea
5. Marine Macrobenthos
6. Fish Monitoring
7. Soft Clam (Mya arenaria) Studies

In addition I endorse the NMFS recommendations regarding more adequate fish impingement monitoring.

Yours truly.

Saul B. Saila
Member, Ecological Advisory Committee

cc: J. H. Tietjen

November 3, 1997

To: Fred Gay, EPA
From: John Hart

Subj: TAC Meeting

Here is the info that you requested on the number of promary samples that were collected but which will not be worked up if the program proposals on the table are approved. It does not include contingency samples because they would be processed only if one of the primary samples were lost.

Phytoplankton		126
Microzooplankton		252
Macrozooplankton		168
Bivalve larvae		56
Ichthyoplankton		48
Benthos		
	Destructive sampling	20
	General algae	22
	Bottom panels	4
TOTAL		**696**

Also attached, as discussed, is the form I plan to use to record the votes. I have a form for each of the mods on the table. I have discussed the concept of a private TAC deliberation followed by a vote with Hutchins, Lewis,, Smith and Jack Paar and all seem to support approach.

Please give me a call if you have any questions at (603) 773 7762. Otherwise I'll see you on Thurs. Coffee and.. at 0830. Meeting starts at 9.

Regards

John

cc: Ron Sher

25938

North Atlantic

North Atlantic Energy Service Corporation
P.O. Box 300
Seabrook, NH 03874
(603) 474-9521

The Northeast Utilities System

November 20, 1997

NPDES Permit No. NH0020338
NYE-97035

AR #97027946

Mr. Carl DeLoi
New Hampshire State Program Unit
U. S. Environmental Protection Agency
John F. Kennedy Building
Boston, MA 02203

Dr. Edward Schmidt
NH Dept. of Environmental Services
Water Supply & Pollution Control Division
6 Hazen Drive
Concord, NH 03302

RECEIVED
NOV 26 1997
NH STATE PROGRAM UNIT

Seabrook Station
Revised Long-Term Environmental Monitoring Program

The purpose of this letter is to request final EPA and NHDES approval for the North Atlantic Energy Service Corporation (North Atlantic) revised Long-Term Environmental Monitoring Program (the Program) for Seabrook Station. The Program consists of the following components, which in turn consist of various Program elements.

1. Water Quality
2. Phytoplankton
3. Zooplankton
4. Finfish
5. Marine Macrobenthos
6. Epibenthic Crustacea
7. Softshell Clam (*Mya arenaria*)

North Atlantic submitted proposed revisions to the Program components and elements to the Seabrook Station Technical Advisory Committee in a letter dated September 25, 1997.[1] The TAC approved the proposed revisions at a November 6, 1997 meeting with the exception of the following three program elements which are being held for further review as described below.

[1] North Atlantic letter NYE-97027 dated September 25, 1997, "Final Long-Term Environmental Monitoring Proposal," John B. Hart to EPA

4.a.2 Finfish-Ichthyoplankton-Entrainment - The TAC withheld final approval of this Program element pending their review of the revised Entrainment procedure which North Atlantic expects to submit to them in early December. Since this is a program enhancement, as agreed at the TAC meeting, North Atlantic will go forward and implement the revised Entrainment program as soon as possible and will adjust it later, if necessary, on the basis of the TAC's review.

4.e Finfish-Impingement - The TAC withheld final approval of this Program element pending their review of the revised Impingement procedure which North Atlantic expects to submit to them in early December. Since this is a program enhancement, as agreed at the TAC meeting, North Atlantic will go forward and implement the revised Impingement program as soon as possible and will adjust it later, if necessary, on the basis of the TAC's review.

5.c Marine Macrobenthos - The TAC withheld final approval of this program element pending final receipt of the Kelp Study and a commitment on the part of North Atlantic to implement the follow-up recommendations presented to them at the TAC meeting. In addition, as agreed at the TAC meeting, North Atlantic will drop the mean sea level stations but maintain the tidepool stations in the revised program.

Summaries of the current (labeled Past Program) and the Revised Program (per the November 6 TAC Meeting) for each Program component are provided in the seven tables comprising Enclosure 1. These tables detail North Atlantic's sampling and analysis obligations per the TAC's revisions of November 6, 1997, including our interim approaches for those three Program elements which are subject to further review by the TAC. North Atlantic also agrees to evaluate the existing 1997 backlogged samples associated with Program components and elements that are being revised.

Section I.A.11.d of Seabrook Station's NPDES Permit requires that, after acceptance by the TAC, final approvals of Program revisions are required from the EPA Regional Administrator and the Director of the New Hampshire Water Supply and Pollution Control Division or their designees. North Atlantic would like to implement the revised Program as described in the Enclosure 1 tables by January 1, 1998 and, therefore, respectfully requests these approvals as soon as possible.

The original sign-off sheets documenting the TAC's decision on each Program element were collected at the November 6 TAC meeting by TAC Chairman, Frederick B. Gay of your staff, and will be retained by the EPA as part of the record of the meeting. Copies of these sign-off sheets are enclosed (Enclosure 2).

If you have additional questions, please contact me at (603) 773-7762.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

cc (with attachments)

TECHNICAL ADVISORY COMMITTEE:

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NH Dept. of Environmental Services
Water Supply & Pollution Control Division
6 Hazen Drive
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Mr. Robert Estabrook
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ENCLOSURE 1 TO NYE-97035

1. WATER QUALITY

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
1) Offshore Temperature Profiles, Salinity & Dissolved Oxygen Measurement	
• **Stations/Sampling frequency:** P2, P7/4 times per month (concurrent with ichthyoplankton sampling)	• **Stations/Sampling frequency:** P2 (intake), P5 (discharge), P7 (farfield)/4 times per month
• **Methodology:** all parameters measured surface and bottom with field probe; additional temperature readings will be made every 2 meters to the bottom	• **Methodology:** S-C-T probe at 2m depth intervals for temperature (~10 readings/profile); water samples taken near surface and near bottom (2 reps for DO) and analyzed in lab (S-C-T probe for salinity, Winkler titration for DO)
• **Total samples/year:** 96 profiles (48 trips x 2 sta.)	• **Total samples/year:** 144 profiles (48 trips x 3 sta.)
2) Estuarine Water Quality (Temperature and Salinity)	
No change from past program.	• **Station/Sampling frequency:** HH (Hampton Harbor)/recorded weekly at high and low slack tides
	• **Total samples/year:** 104/parameter (52 wks x 2 tidal stages)
3) Continuous Temperature Monitoring	
No change from past program.	• **Stations:** DS (discharge) and T7 (farfield; both stations sampled for 316/NPDES compliance)
4) Nutrients	
This program element deleted.	• **Stations/Sampling frequency:** P2, P5, P7/once per month in Jan., Feb., Dec., twice per month Mar. through Nov.
	• **Total samples/year:** 63 for each nutrient
	• **Data collected:** whole near-surface water concentrations of total phosphorus, orthophosphate, nitrate, nitrite, ammonia

2. PHYTOPLANKTON

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
Phytoplankton This program deleted.	• **Stations/sampling frequency:** Stations P2, P5 and P7 sampled once monthly in January, February and December and twice monthly March through November. • **Replicates:** 2 • **Total samples/year:** 126 • **Data collected:** Density per liter

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3. ZOOPLANKTON

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
3.a. Microzooplankton	
• This program element deleted.	• **Stations/Sampling frequency:** Stations P2, P5, and P7 - surface and bottom samples - monthly December through February and twice a month March through November • **Replicates:** 4 collected; 2 processed • **Total samples/year:** 504 collected; 252 processed • **Data collected:** Density per m^3
3.b. Macrozooplankton	
• **Stations/Sampling frequency:** Stations P2 and P7 sampled twice per month • **Replicates:** 2 collected; 1 processed • **Total samples/year:** 96 collected; 48 processed • **Data collected:** Density per $1000m^3$	• **Stations/Sampling frequency:** Stations P2, P5 and P7 sampled twice per month • **Replicates:** 2 collected; 1 processed • **Total samples/year:** 144 collected; 72 processed • **Data collected:** Density per $1000m^3$
3.c. Bivalve larvae **Offshore:**	
• **Stations/Sampling frequency:** Stations P1, P2, and P7 sampled weekly from mid-April through October • **Replicates:** 2 replicates • **Total samples/year:** 168 **Data collected:** Density per m^3	• **Stations/Sampling frequency:** Stations P1, P2, P5, and P7 sampled weekly from mid-April through October • **Replicates:** 2 replicates • **Total samples/year:** 224 • **Data collected:** Density per m^3

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3. ZOOPLANKTON (continued)

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
3.c <u>Bivalve larvae (cont'd)</u> **Entrainment:**	
• **Stations/sampling frequency:** Sampled weekly[1] from mid-April through October at the Seabrook Station screenhouse.	• **Stations/sampling frequency:** Sampled 4 times a month from mid-April through October at the Seabrook Station screenhouse.
• **Replicates:** 3 replicates	• **Replicates:** 3 replicates
• **Total samples/year:** 84	• **Total samples/year:** 84
• **Data collected:** Density per m^3	• **Data collected:** Density per m^3

[1] Note: The September 25, 1997 letter from North Atlantic to EPA indicated, under the "Proposed Program" column, that these samples would be taken four times per month. This has been changed conservatively to once per week to reflect the fact that some months will have more than four weeks.

4. FINFISH

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
4.a.1. <u>Ichthyoplankton -- Offshore</u>	
• **Stations/Sampling frequency:** P2 and P7 sampled four times a month	• **Stations/Sampling frequency:** P2, P5, and, P7 sampled four times a month
• **Replicates:** 2 collected; 1 processed	• **Replicates:** 2 collected; 1 processed
• **Total samples/year:** 192 collected; 96 processed	• **Total samples/year:** 288 collected; 144 processed
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae
4.a.2. <u>Ichthyoplankton -- Entrainment</u>	
• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month over a period up to 24 h encompassing both day and night. In addition, 16 comparisons between day and night catches on the same day as a special study to be performed over the course of a year and then reassessed.	• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month during the day
• **Replicates:** 1 (~24-h composite sample, which represents a sample volume greater than the past methodology)	• **Replicates:** 3 taken sequentially
• **Total samples/year:** 96 for at least 1 year of operation, with two samples to be collected simultaneously, one with 0.505-mm mesh and one with 0.333-mm mesh; entrainment sampling to be re-assessed following this study.	• **Total samples/year:** 144
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae

4. FINFISH (continued)

REVISED ROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
4.b. Mid-water gill net	
• This program element deleted. Interim approval to delete this program granted by EPA per 3/21/97 letter, following a harbor porpoise taking in gill nets deployed as part of program.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly in February, June, and October • **Replicates:** 2 24-h sets • **Total samples/year:** 18 • **Data collected:** species abundance, length measurements
4.b. Surface/near-bottom gill net	
• This program element deleted. Interim approval to delete this program granted by EPA per 3/21/97 letter, following a harbor porpoise taking in gill nets deployed as part of program.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly • **Replicates:** 2 24-h sets • **Total samples/year:** 144 • **Data collected:** species abundance, length measurements
4.c. Otter Trawl	
• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly • **Replicates:** 2 • **Total samples/year:** 144 (likely not always achievable due to lobster pots at T2) • **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly • **Replicates:** 2 • **Total samples/year:** 144 (not always achieved due to lobster pots at T2) • **Data collected:** species abundance; length measurements to nearest 2 cm

4. FINFISH (continued)

REVISED ROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
4.d. Beach Seine	
• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November	• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November
• **Replicates:** 2	• **Replicates:** 2
• **Total samples/year:** 48	• **Total samples/year:** 48
• **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Data collected:** species abundance; length measurements to nearest 2 cm
4.e. Impingement	
• **Stations/Sampling frequency:** Sampling frequency of twice a week for at least for 1 year of operation in a special study to assess the effectiveness of sampling: one ~24-h sample would be compared to a 6-day sample collected during the remainder of the week to determine if there is appreciable decay or loss of small fish on screens; impingement sampling schedule to be re-assessed following this study	• **Stations/Sampling frequency:** Sampled weekly when plant was operating
• **Replicates:** N/A	• **Replicates:** N/A
• **Total samples/year:** minimum of 104 (subsamples may be taken during storm events)	• **Total samples/year:** minimum of 52 (subsamples may be taken during storm events)
• **Data collected:** species abundance, representative length measurements to nearest 1.0 mm; debris load (seaweed/shell)	• **Data collected:** species abundance; representative length measurements to nearest 1.0 cm; debris load (seaweed/shell)

5. MARINE MACROBENTHOS

REVISED PROGRAM PER 11/6/97 MEETING	PAST PROGRAM
5.a. Destructive Sampling	
• **Stations/Sampling frequency:** B1MLW/B5MLW (Intertidal), B17/B35 (Shallow subtidal), B19/B31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW (Intertidal), B17/B35 (Shallow subtidal), B19/B31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth) sampled 1X per year
• **Replicates:** 5	• **Replicates:** 5
• **Total samples/year:** 90	• **Total samples/year:** 110
• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa	• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa, Spirorbid counts, length and/or reproductive status of some dominant fauna, colonial abundance
5.b. Non-Destructive Sampling	
No change from past program.	• **Stations/Sampling frequency:** B1MSL/B5MSL (intertidal quads and transects), B17/B35 and B19/31 (Shallow subtidal and mid-depth) 3X per year
	• **Replicates:** Intertidal quads-6 (2 each in 3 zones), Intertidal transects-3, Subtidal transects-6
	• **Total samples/year:** 126
	• **Data collected:** % frequency/cover of intertidal dominants; % frequency of understory subtidal reds, kelp, urchin and *Modiolus* counts

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5. MARINE MACROBENTHOS (continued)

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
5.c. General Algae	
• **Stations/sampling frequency:** B1MLW/B5MLW tidepools, B1MSL/B5MSL tidepools, B1MLW/B5MLW (intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW tidepools, B1MSL/B5MSL tidepools, B1MLW/B5MLW, B1MSL/B5MSL (Intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth intake) sampled 1X per year
• **Replicates:** 1	• **Replicates:** 1
• **Total samples/year:** 30	• **Total samples/year:** 40
• **Data collected:** presence/absence of algal taxa	• **Data collected:** presence/absence of algal taxa
5.d. Bottom Panels	
• **Stations/Sampling frequency:** B19/31 (Mid-depth) triannual panels 3X/year	• **Stations/Sampling frequency:** B19/31 (Mid-depth), B04/B34(Deep); triannual panels 3X/year, annual panels 1X per year
• **Replicates:** 1 panel (4 subsamples)	• **Replicates:** 1panel
• **Total samples/year:** 24 subsamples	• **Total samples/year:** 28
• **Data collected:** counts of selected dominant taxa, *Teredo* sp. counts in attached wooden panel	• **Data collected:** counts of selected dominant taxa

6. EPIBENTHIC CRUSTACEA

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
6.a. Adult Lobster/Rock Crab	
• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.	• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.
• **Replicates:** 1 (30 traps)	• **Replicates:** 1 (30 traps)
• **Total samples/year:** 156	• **Total samples/year:** 156
• **Data collected:** Lobster/crab abundance, carapace length, determination of sex, molt stage, and presence of V-notch	• **Data collected:** Lobster/crab abundance, carapace length, sex determination
6. b. Lobster Larvae Neuston	
No change from past program.	• **Stations/Sampling frequency:** P2, P5 and P7; 1X per week from mid-May to mid-Oct.
	• **Replicates:** 1
	• **Total samples/year:** 63
	• **Data collected:** lobster larvae density
6. c. *Cancer* spp. larvae (macrozooplankton sampling)	
• **Stations/Sampling frequency:** Station P2 and P7 sampled twice per month	• **Stations/Sampling frequency:** Stations P2, P5, and P7 sampled twice per month
• **Replicates:** 2 collected, 1 processed	• **Replicates:** 2 collected; 1 processed
• **Total samples/year:** 96 collected, 48 processed	• **Total samples/year:** 144 collected; 72 processed
• **Data collected:** Density per $1000m^3$	• **Data collected:** Density per $1000m^3$

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7. *MYA ARENARIA*

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
7.a. <u>Random survey - Hampton Harbor</u>	
No changes to past program.	• **Stations/Sampling frequency:** *Mya* adults - flats 1,2,4 / *Mya* spat - flats 1-5; once per year in the fall. • **Replicates:** varies • **Data collected:** Density and length to nearest mm
7.b. <u>Nearfield/Farfield Study</u>	
No changes to past program.	• **Stations/Sampling frequency:** 10 stations each in Hampton Harbor and Plum Island Sound, once per year in the fall. • **Replicates:** 3 • **Total samples/year:** 60 • **Data collected:** Seed clam (1-12 mm) density

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7. *MYA ARENARIA (continued)*

REVISED PROGRAM PER 11/6/97 TAC MEETING	PAST PROGRAM
7.c. <u>Predator Surveys</u>	
1. Clam digger counts • **Investigate other options to estimate annual exploitation rate.** • **Stations/Sampling frequency:** Stations 1,2,3,4 and 5; once per week except from June through August • **Replicates:** 1 • **Total observations/year:** 190 • **Data collected:** Number of diggers per flat.	**a) Clam digger counts** • **Stations/Sampling frequency:** Stations 1,2,3,4 and 5: once per week except from June through August • **Replicates:** 1 • **Total observations/year:** 190 • **Data collected:** Number of diggers per flat.
2. Green Crabs No change from past program.	**b) Green Crabs** • **Stations/Sampling frequency:** Stations 1-4 within *Mya* Flat 2 in Hampton Harbor; twice monthly except Feb. and Mar. • **Replicates:** 2 • **Total samples/year:** 160 • **Data collected:** Monthly CPUE

7.d. <u>Bivalve Larvae:</u> discussed with zooplankton evaluation

ENCLOSURE 2 TO NYE-97035

Program Element 1

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Program Element	Proposed Modification
Table 1 Program Element	**September 25, 1997 Final Proposal**
1. Water Quality	Eliminate nutrient sampling and Station P5 for temperature, salinity and dissolved oxygen.

Additional TAC Revisions or Conditions

No additional comments.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 2

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
2. Phytoplankton	Eliminate this program

We agree to eliminate this program subject to satisfactory completion and evaluation of existing backlogged samples and presentation of White Paper on Biomass conversion to TAC. Program may be reinstituted to address TAC concerns after evaluation of the backlogged data.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 3.a

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
3.a Zooplankton-Microzooplankton	Eliminate this program

We agree to eliminate this program subject to satisfactory completion and evaluation of existing backlogged samples. Program may be reinstituted to address TAC concerns after evaluation of the backlogged data.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 3.b

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
3.b Macrozooplankton	Elimination Station P5 and reduced sample replicates from 3 to 1.

We agree to proposed modifications subject to satisfactory completion and evaluation of existing backlogged P5 samples. Program may be reinstituted to address TAC concerns after evaluation of the backlogged data.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 3.c

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
3.c Zooplankton-Bivalve larvae (including entrainment)	Drop Station P5

The program will be maintained with the exception of the elimination of Station P5 subject to the evaluation of the backlogged samples.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 4.a.1

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Program Elements	Proposed Modifications
Table 1 Program Element	**September 25, 1997 Final Proposal**
4.a.1 Finfish-Ichthyoplankton--Offshore	Drop Station P5

Additional TAC Revisions or Conditions

The program will be maintained with the exception of the elimination of Station P5 subject to the evaluation of the backlogged samples.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 4.a.2

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
4.a.2 Finfish-Ichthyoplankton--Entrainment	Improve program by investigating day/night and mesh effects

Hold for further review.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☐ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 4.b

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
4.b Finfish-Gillnet sampling	Eliminate this program (NOTE: Interim approval already granted as a result of harbor porpoise take)

Additional TAC Revisions or Conditions

No revisions. It was eliminated per a letter from the EPA dated March 21, 1997 and suspended as of that date.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 4.c

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
4.c. Finfish–Trawl Sampling	No changes except increase precision of length measurements.

Additional TAC Revisions or Conditions

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce W. Smith

Bruce Smith
NH Fish and Game Department

Program Element 4.d

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
4.d. Finfish--Seine Sampling	No changes except increase precision of length measurements.

Additional TAC Revisions or Conditions

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Program Element	Proposed Modification
Table 1 Program Element	**September 25, 1997 Final Proposal**
4.e Finfish--Impingement	Investigate fish decay issue; conduct 1-year study comparing 1-day vs. 6-day screenwashes

Additional TAC Revisions or Conditions:

Hold for review.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 5.a

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
5.a Marine macrobenthos--Destructive sampling	Eliminate deep and intake stations

Additional TAC Revisions or Conditions

We agree to changes subject to satisfactory completion and evaluation of existing backlogged samples.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 5.b

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
5.b. Marine macrobenthos--Non Destructive	No changes, keep all intertidal sampling.

Additional TAC Revisions or Conditions

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce W. Smith

Bruce Smith
NH Fish and Game Department

Program Element 5.c

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
5.c Marine macrobenthos--General algae	Drop tide pools and mean sea level stations

Additional TAC Revisions or Conditions:

Hold for review.

Add sampling stations B1MLW/5BMLW tidepools and B1MSL/B5MSL tidepools. Review backlogged data.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☒ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
5.d Marine macrobenthos--Bottom panels	Eliminate deep stations and annual panels; subsample mid-depth triannual panels and all wooden panels.

We agree to proposed changes subject to satisfactory completion and evaluation of existing backlogged samples. Program may be reinstituted to address TAC concerns after evaluation of the backlogged data.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 6

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Table 1 Program Element	September 25, 1997 Final Proposal
6. Epibenthic crustacae	No changes to lobster program. P5 dropped from crab program. Reduction in crab replicates from 4 to 1.

Additional TAC Revisions and Conditions

We agree to proposed changes subject to satisfactory completion and evaluation of existing backlogged samples.

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

Program Element 7

A meeting of the Seabrook Technical Advisory Committee was held on November 6, 1997 to discuss modifications to the Seabrook Station Long-Term Environmental Monitoring Program as described in North Atlantic Energy Service Corporation's letter to the EPA dated September 25, 1997. Those modifications are summarized in Table 1 attached to that letter and described more fully in the enclosure to that letter. The undersigned members of the Seabrook Station Technical Advisory Committee hereby render the following decisions on the modifications. Where additional revisions or conditions have been made by the TAC, they are so indicated.

Program Elements	Proposed Modifications
Table 1 Program Element	**September 25, 1997 Final Proposal**
7. Softshell Clams	No changes to existing program.

Additional TAC Revisions or Conditions

☑ Approve ☐ Disapprove

Robert Estabrook
NH Dept. Of Environmental Services
Water Division

☑ Approve ☐ Disapprove

Eric Hutchins
National Marine Fisheries Service

☑ Approve ☐ Disapprove

Jack Paar
Environmental Protection Agency

☑ Approve ☐ Disapprove

Bruce Smith
NH Fish and Game Department

25933

North Atlantic

North Atlantic Energy Service Corporation
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The Northeast Utilities System

October 21, 1997

NYE-97033

RECEIVED
OCT 24 1997
NH STATE PROGRAM UNIT

Mr. Frederick Gay
NPDES Permit Coordinator
New Hampshire State Program Unit
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Seabrook Station
Technical Advisory Committee Meeting--November 6, 1997

A meeting of the Seabrook Station Technical Advisory Committee (TAC) has been scheduled for Thursday, November 6, 1997 at 9 a.m. The meeting will be held in the Seabrook Station Science & Nature Center. The TAC members have been contacted and all members plan to attend the meeting. Enclosed please find agenda for the meeting. The primary objective of this meeting is to obtain final TAC approval on the modifications to the Long-Term Environmental Monitoring Program[1] so that they can be implemented on January 1, 1998.

Also please find enclosed, a brief paper by Dr. Saul Saila, Seabrook Station Ecological Advisory Committee. This paper was inadvertently omitted from our September 25, 1997 submittal and concludes that determining changes in the sex ratio of fish is not an effective method of determining Station impacts.

If you have additional questions, please contact me at (603) 773-7762, or Ron Sher, Senior Scientist at (603) 773-7729.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

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[1] North Atlantic Letter NYE-97027, dated September 25, 1997, "Final Long-Term Environmental Monitoring Program Proposal," J. Hart (North Atlantic) to Environmental Protection Agency.

cc (with Enclosure)

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Seabrook Station
Technical Advisory Committee Meeting

Thursday, November 6, 1997

Agenda

9:00 a.m. Introduction/Meeting Overview--John Hart

9:15 a.m. Review of Final Monitoring Program Proposals--Ron Sher

- Water Quality
- Phytoplankton
- Zooplankton
- Finfish/Impingement and Entrainment
- Macrobenthos
- Epibenthic Crustecea
- Softshell Clam

11:30 a.m. Marine Mammal Protection Project--John Hart

12:00 a.m. NPDES Permit Renewal--John Hart

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Some Comments and Suggestions Related to Sex Ratio Estimation in Fishes as a Response to Regulatory Concerns for Seabrook Monitoring Program Modification

S.B. Saila

Background—

A search was made of Aquatic Sciences and Fisheries Abstracts from 1971-1996, as well as of the entire National Sea Grant holdings. Relatively little information was found on sex ratio changes in fishes. A summary of some of the relevant documents follows.

- Conover and Fleisher (1986) demonstrated a temperature sensitive period for development in the Atlantic silverside by measuring sex ratio changes in larvae between low and high temperature treatments. They found the sensitive period of sex determination to be fixed at 15 mm in length at higher temperatures for male production. A specific development period was found for temperature dependent sex differentiation.
- Lewis and Sower (1982) found that dietary testosterone induced a significantly higher production of male fish compared to controls in feeding studies.
- Coleman et al. (1996) have demonstrated that some grouper species, which are protogynous hermaphrodites, are influenced by high fishing intensities with skewing of sex ratios in favor of females.
- Tate (1984) has suggested that effective breeding numbers can be increased by altering the sex ratio in controlled breeding populations in order to minimize genetic drift.
- Kvarnemo et al. (1995) demonstrated effects of sex ratio changes on breeding behavior of small laboratory populations of the sand goby.

Comments—

Determination of the sex of larval and juvenile fish is difficult in the sense that microscopic examination of the gonads is usually required, and a substantial amount of skill is also needed for sex differentiation. There is a very small region in the vicinity of the diffuser ports of Seabrook with a temperature increase of 3°C above ambient. A temperature range of 6°C above ambient for periods of tens of days was required to induce sex changes in the work described by Conover and Fleisher. The probability of larvae or juveniles of silversides remaining in the vicinity of the Seabrook diffusers long enough to be significantly influenced for sex ratio changes is believed to be extremely low.

No records of the effects of sex ratio changes were found for regionally important commercial species in the Seabrook area. It is concluded that determination of sex ratios with a view toward detecting power plant effects in this case is not cost effective, and its implementation is not recommended.

References

Conover, D.B. and M.H. Fleisher. 1986. Temperature-sensitive period of sex determination in the Atlantic silverside, *Menidia menidia*. Canadian Journal of Fisheries and Aquatic Sciences 43(3):514-520.

Coleman, F.C., C.C. Koenig, and L.A. Collins. 1996. Reproductive styles of shallow water groupers (*Pisces: Serranidae*) in the eastern Gulf of Mexico and the consequences of fishing spawning aggregation. Environmental Biology of Fishes 47:129-141.

Lewis, K.M. and S.A. Sower. 1994. Effects of dietary testosterone on growth and sex ratio of juvenile Atlantic salmon (*Salmo salar*). Fish Physiology and Biochemistry, Vol. 9, No. 5/6:513-517.

Tate, D. 1984. Effective breeding efficiency: An index to justify the effects that different breeding programs and sex ratios have on breeding and genetic drift. The Progressive Fish Culturist 46:292-298.

Kvarnemo, C., E. Forggren, and C. Magnhagen. 1995. Effects of sex ratio in intra- and inter-sexual behavior in sand gobies. Animal Behavior, London, Vol. 50(6):1,455-1,461.

OCT 0 8 1997

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The Northeast Utilities System

September 25, 1997

NPDES Permit No. NH0020338
NYE-97027
AR# 97015983

U. S. Environmental Protection Agency
NPDES Permit Operation Section
P.O. Box 8127
Boston, MA 02114

Seabrook Station
Final Long-Term Environmental Monitoring Program Proposal

North Atlantic Energy Service Corporation (North Atlantic) submits herein the Final Seabrook Station Long-Term Environmental Monitoring Program Proposal for review by the Seabrook Station Technical Advisory Committee (TAC) pursuant to Part I.A.11.d of the referenced NPDES Permit[1]. The enclosed final proposal incorporates Seabrook Station TAC member comments on the initial Long-Term Monitoring Program Proposal submitted in August 1996[2] and reviewed at the annual TAC meeting on September 5, 1996. It should be emphasized that no program reductions or eliminations are in this proposal that have not received full consensus of the TAC.

North Atlantic requests that the program proposal be approved during the fall of 1997 in order to implement the Long-Term Environmental Monitoring Program in 1998. It is expected that when this proposal is approved, the program reductions or eliminations will be effective immediately. Therefore, samples already collected in 1997 will not be analyzed and results will not be reported in the 1997 Environmental Monitoring Report.

North Atlantic is currently contacting TAC members in order to schedule the annual TAC meeting, currently anticipated to be in October 1997. The purpose of this meeting is to discuss the Final Seabrook Station Long-Term Monitoring Program Proposal and related Seabrook Station Environmental Monitoring Program issues.

If you have additional questions, please contact me at (603) 773-7762.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

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1 Seabrook Station's NPDES Permit Part I.A.11.d, states that "Annually, after the effective date of this permit, the permittee may propose changes to the approved biological, hydrological and chlorination programs to the Regional Administrator (of the EPA) and the Director (NHDES). After TAC acceptance and upon approval of the Regional Administrator and Director, the proposed program will become an enforceable element of this permit.

2 North Atlantic letter NYE-96021, dated August 29, 1996, Seabrook Station—Long-Term Environmental Studies Program Proposals," B. Drawbridge (North Atlantic) to C. DeLoi (EPA)

cc (with attachment)

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Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The initial draft-proposal of the Seabrook Station Long-Term Environmental Monitoring Program was prepared in 1996 by North Atlantic with support from the Northeast Utilities Environmental Lab (NUEL) and Normandeau Associates Inc. (NAI) in consultation with the Seabrook Ecological Advisory Committee (SEAC). The draft proposal was endorsed by the SEAC and formally submitted to the Seabrook Station Technical Advisory Committee (TAC) in August 1996. Proposals were made for each of the seven major Monitoring Program components. Following the receipt of TAC comments on the draft proposal, North Atlantic held several meetings and consultations with individual TAC members as well as the SEAC to address TAC questions and resolve issues.

Table 1 summarizes the responses of the TAC Agencies to each of the seven original draft program proposals. The TAC agreed that the Phytoplankton Monitoring Program should be terminated. The other six program components, with some adjustments and improvements, have emerged as the consensus Seabrook Station Long-Term Monitoring Program and are listed below.

- Water Quality Monitoring
- Zooplankton
- Finfish / Entrainment and Impingement
- Marine Macrobenthos
- Epibenthic Crustacea
- Softshell Clam (*Mya arenaria*)

Following Table 1 are seven narrative summaries for each of the components of the Environmental Monitoring Program Proposal. They represent the TAC, SEAC and North Atlantic consensus for the Long-Term Environmental Monitoring Program. Although Entrainment and Impingement Monitoring are part of the Finfish Program, they are described separately, because of their importance. Each summary includes a map with the location of the sampling stations in the new program, and a two-column table comparing the new and previous components as to sampling design, frequency, and number of samples collected in each case.

Issues or questions on the proposed monitoring program raised by the TAC which required further discussion were addressed at several meetings with individual TAC agencies during the review of the initial proposal. Meetings were held with the following TAC members: Mr. Bruce Smith (NHF&G) on December 27, 1997; Mr. Jeff Andrews and Mr. Robert Estabrook (NHDES) on January 31, 1997 and Mr. Jack Paar (EPA) on May 16, 1997.

Responses to TAC questions and the status of pending commitments are described below:

- **Enhanced Entrainment and Impingement Monitoring Program** Procedures are currently being drafted by Seabrook Station's Environmental Monitoring Program Contractor, Normandeau Associates, who will also implement these monitoring programs at Seabrook Station. These procedures will be available prior to the upcoming TAC meeting.

- **Biomass Matter Conversion** The conversion of entrained plankton into nutrients, which could result in a nutrient enrichment in the plant's discharge area, was raised by the EPA. Although the dilution of the discharge water into the surrounding seawater is too large for the above effect to be significant, North Atlantic will submit a white paper on this subject prepared by Dr. McAlice (SEAC).

- **Statistical Power of the ANOVA Statistical Model** A question regarding the power of this model and other statistical tests conducted to assess impacts of plant operation, was raised by the EPA. It was agreed that Dr. Saila (SEAC) and Dr. Lorda (NUEL), in consultation with Jack Paar, would investigate availability of software to conduct a power analyses and will report the results to the TAC. No off-the-shelf software capable of analyzing the power of multiway nested ANOVA models has been found to-date. Changes/additions to the program "PowerPack" developed at the University of Iowa are a possibility now being explored. The need for clear and consistent criteria to decide when an impact has occurred, was another issue related to the power of the tests. These criteria will be selected in consultation with the SEAC, but not before the power analysis issue is resolved.

- **Abundance of Kelps** A question from NHDES/NHF&G about an apparent decrease in the abundance of kelps (Laminaria spp.) in the plant's discharge area will be addressed in a technical paper to be prepared by NUEL.

- **Lobster Study Data** A request from NHF&G to include additional lobster data (molt stage and the reporting of V-notches) in the annual monitoring reports is being pursued with Normandeau Associates and the contracted lobsterman who performs this element of the program.

- **Rationale for a Five-Year Operational Period to Evaluate Monitoring Program** The EPA asked what the rationale was for establishing five years of operational data as sufficient to evaluate the monitoring programs and propose changes. The rational was based on the following:

  1) There is no reason to expect that, on the average, the next 25 years of plant operation will be different from the first 5 years in terms of cooling water usage, thermal discharge, etc.;

  2) Except for fish, lobster, crabs and softshell clams and some benthic organisms with life spans of more than one year, most other organisms being monitored have very short life spans ranging from days and weeks for phytoplankton and microzooplankton to up to a year for some benthic organisms; since no reductions and only minor program adjustments were proposed for organisms with turnover rates longer than one year, it was reasonable to assume that additional years of monitoring at present levels of effort would not change the conclusions reached in the 5-yr evaluation; and

  3) The 5-year period was agreed to by the TAC during the December 1994 meeting in Seabrook.

- **Real-Time Monitoring Data** Response to EPA: Continuous monitoring of surface water temperature will continue at a site adjacent to the discharge, providing real-time data on the thermal plume and ensuring compliance with the NPDES permit

- **Definition of Long-Term Monitoring Program** Response to EPA: The proposed long-term monitoring program is not the final monitoring program, but simply a major revision based on what has been learned after five years of plant operation. As stated above, five years of operational data is sufficient to evaluate potential impacts on many of the organisms and communities currently monitored, based on life cycles. It is likely that as the monitoring program continues and more data are accumulated, it may be necessary to make minor program changes to better assess abundance and distribution of local species. Changes may be proposed as long as they are supported by valid data and sound scientific reasoning. Knowledge about marine populations and the established methodology for monitoring them has changed substantially since the inception of the program, it is advantageous to all stakeholders advantage that the ability to adjust and refocus the program be retained. The ability to propose changes to the program is specified in Seabrook Station's NPDES Permit Part I.A.11.d.

- **Basis for the Location of Nearfield and Farfield Stations** Response to EPA: The current location of Station P5, the nearfield biological station closest to the discharge, was selected on the basis of modeling results for predominant currents, winds and tide conditions for the purpose of documenting discharge plume effects on the balanced indigenous populations. The model validation study conducted in 1990 during plant operation revealed that, for the cases tested, the thermal plume does not reach the Station P5 buoy, which is almost 1 km from the discharge. On occasion, Station P5 is within the 1 ^{o}F surface isotherm, with no plume effects at the bottom. Station P5 was not designed to examine thermal plume effects in any direct way, but rather to monitor nearfield effects on the planktonic population, which is continually changing. Station P2, the nearfield station, which is used to monitor intake effects, is located close to the intakes (less than 300 feet, with tows encircling the intake marker buoy). Direct intake effects are also monitored by the impingement and entrainment programs. Because the entire monitoring program is based on the Before-After, Control Impact (BACI) sampling design, the usability of the current database depends on the maintenance of Stations P2 and P7 (farfield/control station) at their present locations. Maps that show the location of Stations P2 and P5 relative to the predicted/observed extent of the thermal plume are enclosed as Attachment 1.

- **Clustering Methods** Use of clustering methods to summarize samples of assemblages of larval fish and other organisms, has been difficult to interpret according to the EPA. It was agreed that Dr. Saila (SEAC) would look into other alternatives and would recommend best currently available multivariate methods to the TAC. Written comments by Dr. Saila on this matter are enclosed as Attachment 2. These comments will be discussed at the upcoming TAC Meeting.

- **Viability of Entrained Eggs and Larvae** Response to EPA: North Atlantic has always conservatively assumed that no entrained ichthyoplankton survives. Estimating actual survival by sampling the discharge area (i.e., the region bounded by the 3 ^{o}F isotherm) is not feasible because of the rapid mixing and tremendous dilution ratio of the discharged water together with a relatively small number or organisms entrained per unit volume of cooling water.

# # #

Table 1. SUMMARY OF RESPONSES TO TECHNICAL ADVISORY COMMITTEE AGENCY COMMENTS ON THE PROPOSED SEABROOK STATION LONG-TERM ENVIRONMENTAL MONITORING PROGRAM.

Monitoring Program Elements	Original Proposed Changes	Agency Responses to Proposal			Final Proposal
		EPA Region 1	NOAA NMFS	NH State DES and F&G	
1. Water Quality	Eliminate nutrient sampling and Station P5 for temperature, salinity and dissolved oxygen.	Agree.	Agree.	Agree.	No changes to proposal to eliminate program elements.
2. Phytoplankton	Eliminate this program.	Agree. Biomass conversion issue presented to TAC.	Agree.	Agree.	White paper on biomass conversion to be presented to TAC.
3. Zooplankton					
a. Microzooplankton	Eliminate this program.	Agree. Food chain impacts still possible, impractical to assess.	Agree.	Agree.	No changes to proposal to eliminate program.
b. Macrozooplankton	Reduce sample replicates from 3 to 1, drop Station P5.	Agree.	Agree.	Agree.	Already approved.
c. Bivalve larvae (including entrainment)	Eliminate this program.	Disagree with elimination, but agrees to drop Station P5.	Agree.	Disagree with elimination, but agrees to drop Station P5.	Drop Station P5. Otherwise program will be maintained.
4. Finfish					No changes to program as proposed.
a. Ichthyoplankton					
a.1. Offshore	Drop Station P5.	Agrees. Suggests entire program element could be eliminated.	Agree.	Agree.	
a.2. Entrainment	Improve program by investigating day/night and mesh size effects.	Agree.	Agree.	Agree.	
b. Gill-net sampling	Eliminate this program.	Agree.	Agree.	Agree.	Interim approval granted due to porpoise taking.
c. Trawl sampling	No changes, increase precision of length measurements.	Agree.	Agree.	Agree.	
d. Seine sampling	Same as for trawl above.	Agree.	Agree.	Agree.	
e. Impingement	Improve program. Investigate fish decay issue; conduct 1-year study comparing 1-day vs. 6-day screenwashes.	Agree.	Agree.	Agree.	

Table 1. (Continued)

Monitoring Program Elements	Original Proposed Changes	Agency Responses to Proposal			Final Proposal
		EPA Region 1	NOAA NMFS	NH State DES and F&G	
5. Marine macrobenthos					
a. Destructive sampl.	Eliminate intertidal (3X/yr), deep and intake stations (1X/yr) and some incidental params. (e.g., spirorbids). Keep shallow subt. and mid-depth (3X/yr)	Agree to drop deep stations but keep intertidal.	Agree	Partially agree. Keep intertidal sampling	Keep all intertidal stations, but eliminate deep and intake stations.
b. Nondestruct. sampl.	Eliminate intertidal stations	Agree	Agree	Disagree. Keep intertidal sampling	Keep all intertidal sampling.
c. General algae	Eliminate intertidal ((3X/yr), deep and intake stations (1X/yr). Keep shallow subt. and mid-depth (3X/yr)	Partially agree. Keep intertidal.	Agree	Partially agree. Keep intertidal.	Keep intertidal mean low water stations, drop tide pools and mean sea level stations.
b. Bottom Panels	Eliminate deep stations and annual panels; subsample mid-depth triannual panels and add wooden panels	Agree	Agree	Agree	No changes to proposal.
6. Epibenthic crustacea	Drop Station P5 and shorten the sampling season of lobster larvae	Disagree with lobster larvae changes, agrees to reduce crab larvae from 3 to 1 rep. (thru macro-zooplankton prog.).	Agree	Agree	Leave lobster larvae sampling as is. Reduction in macrozooplankton replicate samples already approved by the TAC.
7. Softshell clam	Drop flats 3&5, reallocate same effort; reduce clam digger counts	Disagree	Disagree	Disagree	Program will maintained.

WATER QUALITY

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objectives of the water quality program are to collect environmental data to aid in interpreting information obtained from the environmental monitoring program and to determine whether the operation of Seabrook Station Circulating Water System has had a measurable effect on the physical and chemical characteristics of the water column. The proposed long-term program focuses on areas that are most likely to detect potential power plant effects and will provide data to explain biological variability.

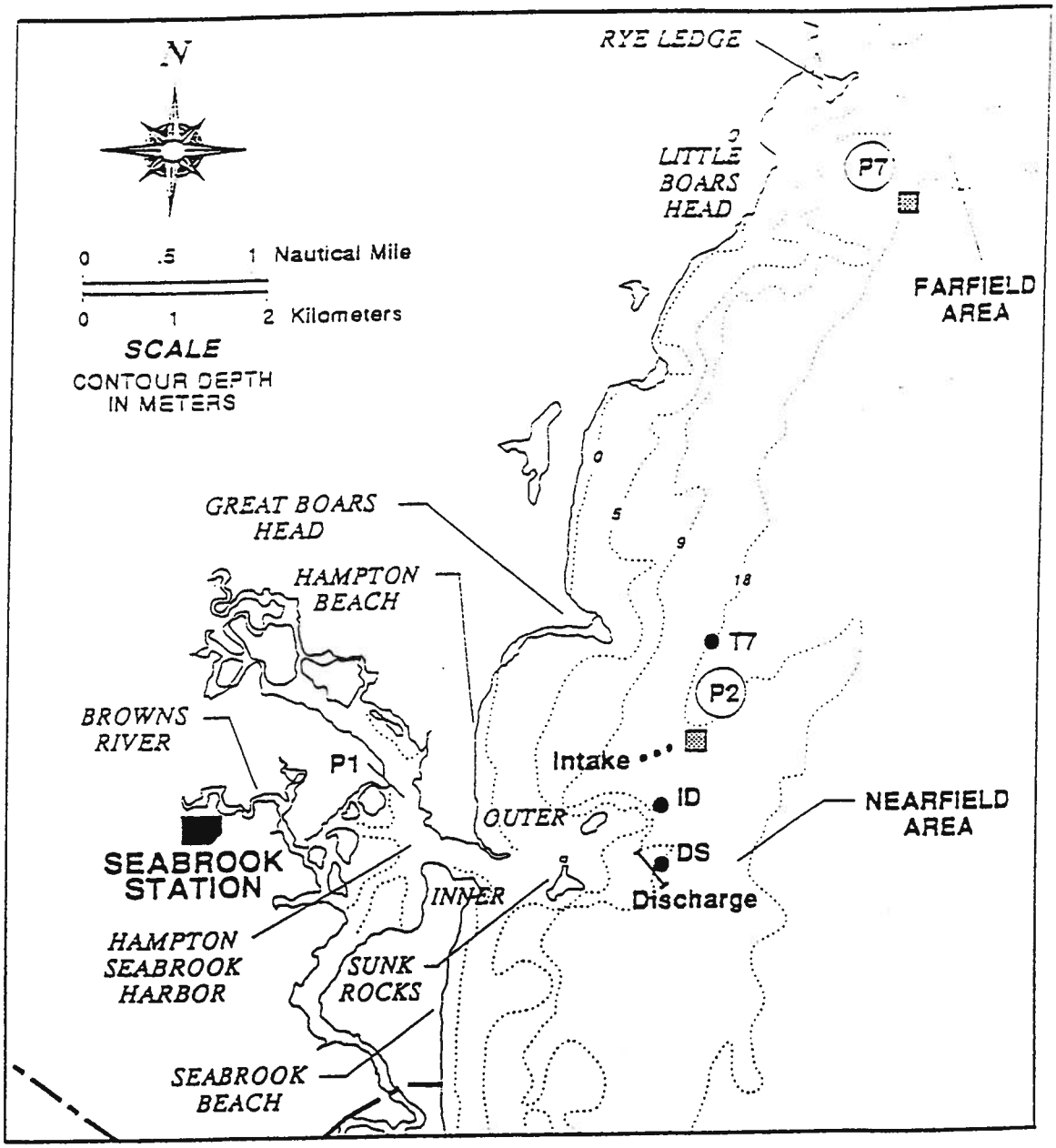
1. Water temperature, salinity and dissolved oxygen are biologically important parameters that influence the distribution of fish, plankton and benthic organisms. Measurement of these parameters should be accomplished with dependable field instruments, utilizing current analytical technology, and minimizing difficulties associated with handling and storage of glass bottles, and generation and disposal of hazardous wastes from Winkler titrations.

2. Comparisons of recent data to the historical database will allow determination of whether changes have occurred since Seabrook Station began operation; comparisons between the nearfield (P2) and farfield (P7) stations will distinguish between localized (i.e., potentially power plant-related) and regional changes. Stations P2 and P7 have the longest time-series of concurrent data collection.

3. Modifications to past programs will have minimal effect on ability to detect power plant impact, should it occur:

    - suspension of nutrient sampling - no impacts shown to date (see Phytoplankton evaluation); inherently high variability make it unlikely that this sampling could ever show impact. Questions raised by EPA regarding entrained plankton biomass conversion to dissolved nutrients are being reviewed by the Seabrook Ecological Advisory Committee. A report summarizing the outcome of this review will be presented to the Technical Advisory Committee.

    - deletion of sampling station P5 (discharge) - this station is actually over 1 km from the discharge, too far to be affected by power plant operation, and too far to even be considered a nearfield station. Discharge effects will continue to be assessed by the continuous temperature monitoring program.



LEGEND

▩ = water quality stations

● = continuous temperature monitoring stations

Water quality sampling stations for proposed Long-Term Biological Monitoring Program for Seabrook Station.

WATER QUALITY

PROPOSED PROGRAM	PAST PROGRAM
1) Offshore Temperature Profiles, Salinity & Dissolved Oxygen Measurement	
• **Stations/Sampling frequency:** P2, P7/4 times per month (concurrent with ichthyoplankton sampling)	• **Stations/Sampling frequency:** P2 (intake), P5 (discharge), P7 (farfield)/4 times per month
• **Methodology:** all parameters measured surface and bottom with field probe; additional temperature readings will be made every 2 meters to the bottom	• **Methodology:** S-C-T probe at 2m depth intervals for temperature (~10 readings/profile); water samples taken near surface and near bottom (2 reps for DO) and analyzed in lab (S-C-T probe for salinity, Winkler titration for DO)
• **Total samples/year:** 96 profiles (48 trips x 2 sta.)	• **Total samples/year:** 144 profiles (48 trips x 3 sta.)
2) Estuarine Water Quality (Temperature and Salinity)	
• no change from past program	• **Station/Sampling frequency:** HH (Hampton Harbor)/recorded weekly at high and low slack tides
	• **Total samples/year:** 104/parameter (52 wks x 2 tidal stages)
3) Continuous Temperature Monitoring	
• no change from past program	• **Stations:** DS (discharge) and T7 (farfield; both stations sampled for 316/NPDES compliance)
4) Nutrients	
none - no impact shown to date; inherently high variability and lack of mechanism for impact make it unlikely that they ever could show impact.	• **Stations/Sampling frequency:** P2, P5, P7/once per month in Jan., Feb., Dec., twice per month Mar. through Nov.
	• **Total samples/year:** 63 for each nutrient
	• **Data collected:** whole near-surface water concentrations of total phosphorus, orthophosphate, nitrate, nitrite, ammonia

ZOOPLANKTON

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The proposed zooplankton monitoring program will focus on larger zooplankton, which based on life history information have greater potential for plant impact, and bivalve larvae that support commercially and recreationally important populations.

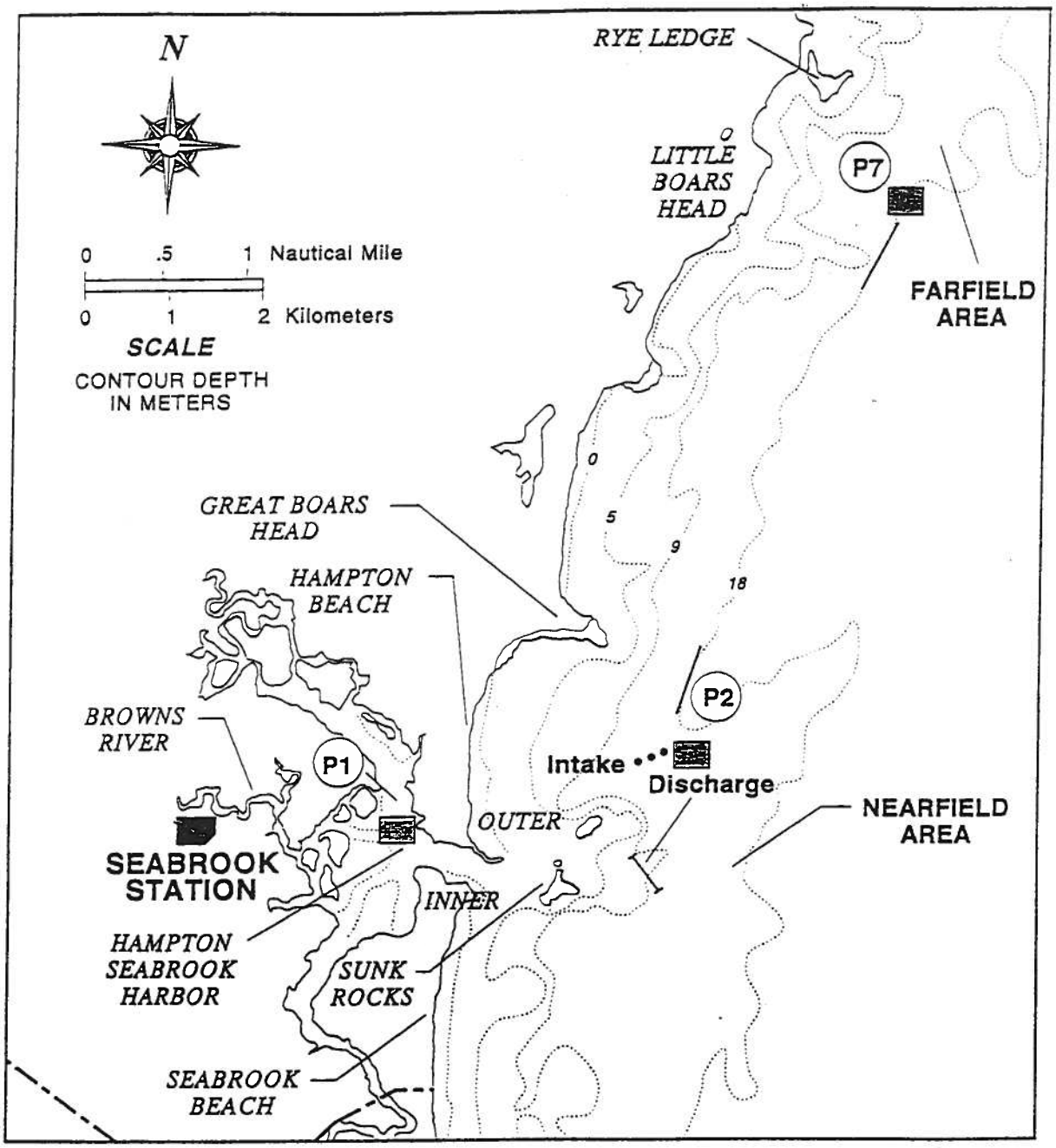
1. **Macrozooplankton sampling program** sampling design was based on the results of analyses of data collected through 1995. Macrozooplankton collections will consist of one sample per sampling date at stations P2 and P7. Station P5 will no longer be sampled.

    - Results from ANOVAs for each selected species, using the proposed sampling design, indicated that there would be minimal loss in sensitivity to detect a potential plant operational impact. The estimated variances for the critical interaction and error terms were similar with either one sample at two stations (proposed) or with three replicates at three stations (current), suggesting that current sample replication is redundant.

    - The sampling of only one of the two nearfield stations will not reduce the ability of the program to detect potential plant operational impacts using the BACI ANOVA model, nor affect additional analyses (i.e., numerical classification and MANOVA).

2. **Bivalve larvae sampling program** has provided abundance information and analyses for bivalve species, which indicated no significant effect of Seabrook Station operation after 5 years. However, this program will continue, with samples taken weekly from mid-April through October at stations P1, P2, and P7.

    - No differences were detected with ANOVA between the two nearfield bivalve larvae stations (P2 and P5). Further, based on the length of the preoperational database, which starts in 1975 for P2 and P7, but only in 1986 for P5, sampling will be discontinued at station P5. Stations P1, P2, and P7 will continue to be sampled, which will maintain the BACI design for future impact assessment. Finally, sampling at stations P2 and P7 will allow the bivalve larvae sampling to conform with the macrozooplankton and ichthyoplankton sampling programs, which have retained these two offshore stations.



LEGEND

——— = zooplankton stations

▓ = bivalve larvae stations

Macrozooplankton (P2 and P7) and larval bivalve (P1, P2, and P7) sampling stations.

ZOOPLANKTON

PROPOSED PROGRAM	PAST PROGRAM
1) Macrozooplankton	
• **Stations/Sampling frequency:** Stations P2 and P7 sampled twice per month	• **Stations/Sampling frequency:** Stations P2, P5 and P7 sampled twice per month
• **Replicates:** 1 sample	• **Replicates:** 4 replicates collected; 3 replicates processed
• **Total samples/year:** 48	• **Total samples/year:** 288 collected; 216 processed
• **Data collected:** Density per $1000m^3$	• **Data collected:** Density per $1000m^3$
2) Bivalve larvae	
• **Stations/Sampling frequency:** Stations P1, P2, and P7 sampled weekly from mid-April through October	• **Stations/Sampling frequency:** Stations P1, P2, P5, and P7 sampled weekly from mid-April through October
• **Replicates:** 2 replicates	• **Replicates:** 2 replicates
• **Total samples/year**: 168	• **Total samples/year**: 224
• **Data collected:** Density per m^3	• **Data collected:** Density per m^3
Microzooplankton	
• This program element deleted.	• **Stations/Sampling frequency**: Stations P2, P5, and P7 - surface and bottom samples - monthly December through February and twice a month March through November
	• **Replicates:** 4 collected; 2 processed
	• **Total samples/year:** 504 collected; 252 processed
	• **Data collected:** Density per m^3

FINFISH

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objectives of the finfish program are to provide information needed to assess losses to fish populations from entrainment and impingement due to Seabrook Station operation. While no impacts have been observed to-date, continued or enhanced monitoring is warranted in most instances, given the ecological and economic importance of many local finfishes.

1. **Ichthyoplankton sampling program** sampling design was based on the results of analyses of data collected through 1995. Ichthyoplankton data will be collected at stations P2 and P7 four times a month (see attached).

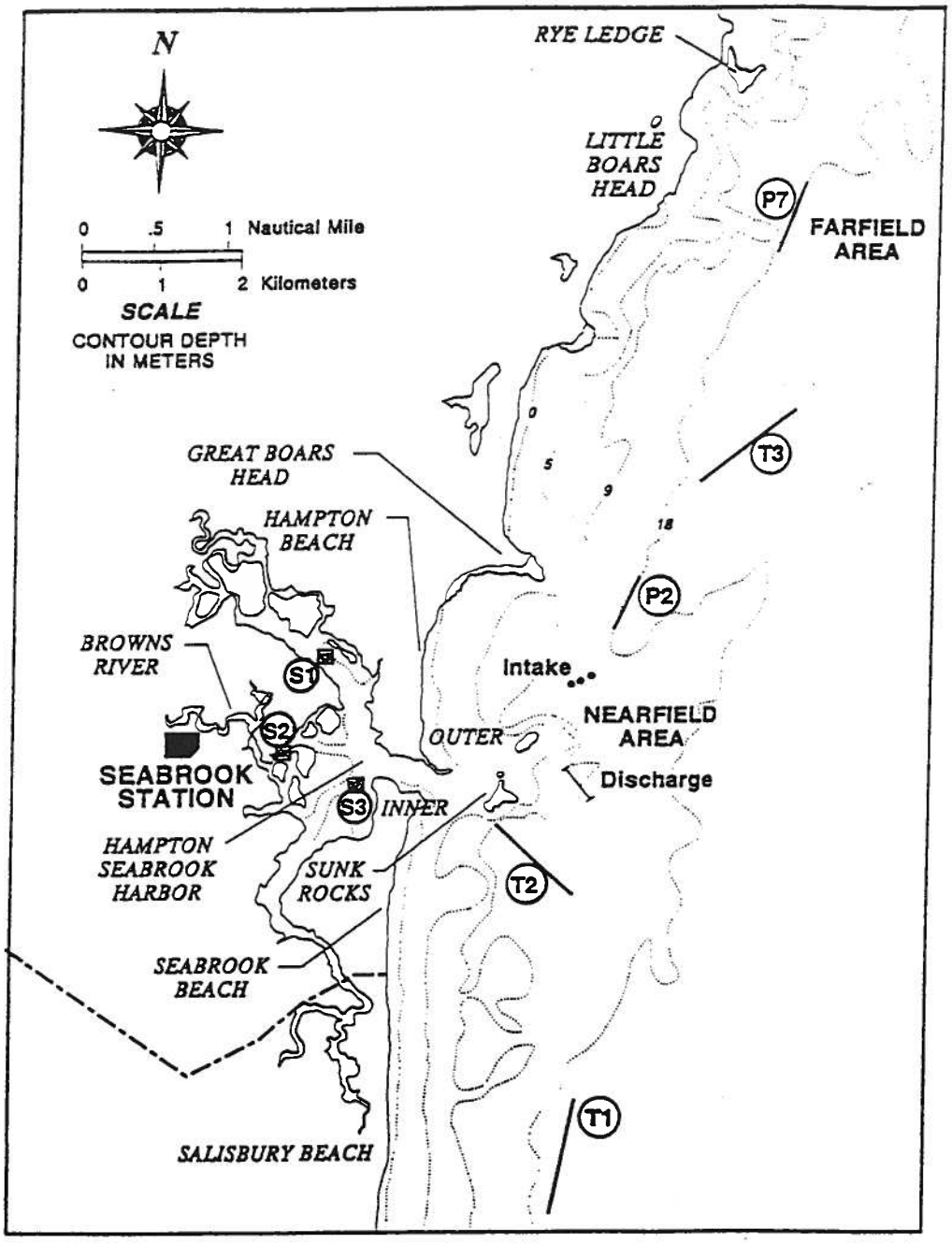
   No differences were detected with ANOVA between the two nearfield ichthyoplankton stations (P2 and P5) for nine selected taxa. In addition, the numerical classification (cluster analyses) for fish eggs and larvae showed that species composition was very similar between P2 and P5. An additional analysis examining differences between the two nearfield stations was performed using paired testing (Wilcoxon's signed-ranks test), which showed similar abundances at the stations for eight of nine selected species tested (see part 5 below). Therefore, based on the length of the preoperational database, which starts in 1975 for P2 and P7 but only in 1986 for P5, sampling will be discontinued at station P5. Stations P2 and P7 will continue to be sampled and the ichthyoplankton study will maintain the BACI design for future impact assessment. ANOVAs for nine selected species were re-calculated using data from only these two stations and compared to results obtained from all three stations. No significant differences were found after data from P5 were excluded from the analyses.

2. **Trawl sampling program** data provide abundance information for species that represent the local demersal fish assemblages, including several that are potentially affected by Seabrook Station and require further evaluation of impact. Therefore, no changes are proposed for this sampling program (see attached), except for increasing the precision of length measurements from 2 to 0.5 cm to improve the utility of the data for assessments. Sampling will continue to take place twice a month at stations T1, T2, and T3.

3. **Seine sampling program** data provide abundance information for species that represent the local estuarine fish assemblage, including several that are potentially affected by Seabrook Station and require further evaluation of impact. Therefore, no changes are proposed for this sampling program (see attached), except for increasing the precision of length measurements from 2 to 0.5 cm to improve the utility of the data for assessments. Sampling will continue to take place twice a month at stations S1, S2, and S3 from April through November.

4. **Selected species** will be examined as in previous annual reports and will include the Atlantic herring, rainbow smelt, Atlantic cod, pollock, hakes, Atlantic silverside, cunner, American sand lance, Atlantic mackerel, winter flounder, and yellowtail flounder.

5. Changes in the **sex ratio** of fishes as a result of thermal impacts was noted in a comment by one regulatory agency to be a potential issue related to fish population stability. However, a review by a member of the Seabrook Station Ecological Advisory Committee (see attached) indicated that this would not be a likely effect because of the short exposure to increased temperature caused by plant operation. Therefore, no data on sex ratios of fishes collected will be gathered.



LEGEND

—— (P) = Ichthyoplankton Tows

—— (T) = Otter Trawls

■ (S) = Seine Hauls

Ichthyoplankton (P2 and P7), otter trawl (T1, T2, and T3), and seine (S1, S2, and S3) sampling stations.

FINFISH

PROPOSED PROGRAM	PAST PROGRAM
1) <u>Ichthyoplankton</u>	
• **Stations/Sampling frequency:** P2 and P7 sampled four times a month	• **Stations/Sampling frequency:** P2, P5, and, P7 sampled four times a month
• **Replicates:** 1 sample collected and processed	• **Replicates:** 2 collected; 1 processed
• **Total samples/year:** 96	• **Total samples/year:** 288 collected; 144 processed
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae
2) <u>Otter Trawl</u>	
• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly	• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly
• **Replicates:** 2	• **Replicates:** 2
• **Total samples/year:** 144 (likely not always achievable due to lobster pots at T2)	• **Total samples/year:** 144 (not always achieved due to lobster pots at T2)
• **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Data collected:** species abundance; length measurements to nearest 2 cm

FINFISH (continued)

PROPOSED PROGRAM	PAST PROGRAM
3) **Beach Seine**	
• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November	• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November
• **Replicates:** 2	• **Replicates:** 2
• **Total samples/year:** 48	• **Total samples/year:** 48
• **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Data collected:** species abundance; length measurements to nearest 2 cm
Mid-water gill net	
• This program element deleted.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly in February, June, and October
	• **Replicates:** 2 24-h sets
	• **Total samples/year:** 18
	• **Data collected:** species abundance, length measurements
	•
Surface/near-bottom gill net	
• This program element deleted.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly
	• **Replicates:** 2 24-h sets
	• **Total samples/year:** 144
	• **Data collected:** species abundance, length measurements

ENTRAINMENT AND IMPINGEMENT

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objectives of the entrainment and impingement sampling programs are to provide quantitative measures of the losses of marine organisms from Seabrook Station operation and the data needed to assess these losses at the population level. Enhanced monitoring is warranted given the ecological and economic importance of many finfishes, lobster, and bivalve shellfish. Enhanced entrainment (ichthyoplankton and bivalve) and fish impingement sampling procedures in use at Seabrook Station are currently being developed and will be available for review.

1. **Ichthyoplankton entrainment** samples will be taken 4 times a month over a period of up to 24 hours that encompasses both day and night. Previously, entrainment samples were taken only during the day. This change should provide more accurate entrainment estimates as densities of some species are greater in the water column during the night than during the day. Further, some smaller larvae may be extruded though the 505-μm mesh net presently used. Therefore, a program modification will be made to sample ichthyoplankton with both 0.333- and 0.505-μm mesh nets. After completion of a mesh evaluation study, the entrainment sampling methods will be finalized to result in an improved procedure for the estimation of entrainment impact.

    - Entrainment estimates of fish eggs and larvae are one of the most direct measures of plant operational impact and should be as accurate as possible. A direct comparison of taxa collected in entrainment samples with those collected at station P2 indicated several discrepancies in dominant taxa. These differences may be due, in part, to sampling at night at P2 versus day sampling for entrainment. Other ichthyoplankton studies have shown that some fish larvae are more susceptible to entrainment and capture by plankton nets at night. Therefore, entrainment sampling will include ichthyoplankton collected during the night. This can be accomplished by reducing water flow through the entrainment nets and collecting a sample over a long period (up to 24 h) that encompasses both day and night. Since the 24-h samples are effectively composite samples, no replicates need to be taken. If nets become clogged during entrainment sampling, they can be cleaned and samples combined until sampling has been completed. This method has an additional advantage in that a larger volume of water than in the past will be sampled. To determine any differences that may have resulted from the previous lack of night samples, as many as 16 comparisons between day and night catches on the same date will be made in a special study to be performed over the course of about one year. This work should give an indication of any underestimates of entrainment that may have been made for affected species and should provide necessary data to develop a correction or scaling factor for past data, if needed.

- Nets with a 505-μm mesh have been used for entrainment sampling. Published studies indicated that smaller (predominantly 2 to 5 mm) fish larvae can be extruded through this size mesh. Therefore, paired duplicate sampling using both 505- and 333-mm mesh nets will be conducted for at least 1 year to determine if an appreciable fraction of fish larvae are being missed in entrainment samples because of net extrusion. If no apparent differences are found between the two nets, then future samples can again be taken with 505-μm nets. If differences do exist, then all future entrainment samples will be taken with a 333-μm net. It also may be possible to calculate a correction factor for use with some taxa in modifying previous data to account for undersampled larvae.

2. **Bivalve entrainment sampling** will take place 4 times a month from mid-April through October if at least one circulating water pump is in operation at Seabrook Station. Three replicate samples will be taken during the day on each sampling date.

    - Larvae of the recreationally important soft-shell clam are entrained in relatively small numbers (about 0.1% of the total bivalve entrainment). Apparently, larval densities are not related to spat abundances, which appear to be habitat-limited. Similarly blue mussel larvae, which represented over 50% of both field and entrainment bivalve larvae collected, have not been affected after five years of plant operation, despite numerically-high entrainment estimates. The high fecundity of bivalves, coupled with their relatively long larval life stage, during which they may be carried considerable distances by water currents, makes a localized impact less likely to occur, as these species have evolved to compensate for very high losses in their early life history.

3. **Impingement sampling** will occur at least once a week when the traveling screens at Seabrook Station are rotated for cleaning. Weekly sampling will occur more often when screens are operated frequently, particularly due to heavy debris loading during storm events. In that case, subsampling may be used to estimate fish impingement rather than making a complete census of the catch as done most of the time. The impingement sampling methodology, however, needs further refinement to determine if estimates of this impact are adequate. The addition of a small-mesh screen in front of the screen wash pit water drain in 1996 has eliminated the potential loss of small organisms that may overflow or fall through the mesh of the screen wash collection basket, but some loss of fish may also occur from decomposition because of the long period between screenwashes under normal operation. Therefore, a special study will be performed to determine the extent of the loss of impinged specimens, particularly smaller forms.

    - A special study of at least 1 year in duration (when plant is in full operation) will be completed to determine if small fish are lost due to decay or other reasons during the usual week-long interval that occurs between most sampling events; this would result in an underestimate of impingement. To accomplish this study, screens will be

washed after being held for about 24 hours and, subsequently, for a second time during the week after being held for the remaining 6 days. A numerical comparison of the catches (after adjustments to equalize effort by time), the species composition, and relative sizes of impinged specimens should illustrate whether or not certain taxa or sizes are inadequately represented in present impingement samples. Following the termination of this study, the impingement methodology will again be re-evaluated to optimize the frequency of sampling so that the most accurate impingement estimates can be made.

ENTRAINMENT AND IMPINGEMENT

PROPOSED PROGRAM	PAST PROGRAM
1) <u>Ichthyoplankton entrainment</u>	
• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month over a period up to 24 h encompassing both day and night. In addition, as many as 16 comparisons between day and nigh catches on the same date are proposed as a special study to be performed over the course of a year.	• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month during the day
• **Replicates:** 1 (~24-h composite sample, which represents a sample volume of 8 times greater or more than the past methodology)	• **Replicates:** 3 taken sequentially
• **Total samples/year:** 48; 96 for at least 1 year of operation, with two samples to be collected simultaneously, one with 0.505-mm mesh and one with 0.333-mm mesh; entrainment sampling to be re-assessed following this study.	• **Total samples/year:** 144
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae
2) <u>Bivalve larvae entrainment</u>	
• **Stations/sampling frequency:** Sampled 4 times a month from mid-April through October at the Seabrook Station screenhouse.	• **Stations/sampling frequency:** Sampled 4 times a month from mid-April through October at the Seabrook Station screenhouse.
• **Replicates:** 3 replicates	• **Replicates:** 3 replicates
• **Total samples/year:** 84	• **Total samples/year:** 84
• **Data collected:** Density per m^3	• **Data collected:** Density per m^3

ENTRAINMENT AND IMPINGEMENT (continued)

PROPOSED PROGRAM	PAST PROGRAM
3) <u>Impingement</u>	
• **Stations/Sampling frequency:** Sampling frequency of twice a week for at least for 1 year of operation in a special study to assess the effectiveness of sampling: one ~24-h sample would be compared to a 6-day sample collected during the remainder of the week to determine if there is appreciable decay or loss of small fish on screens; impingement sampling schedule to be re-assessed following this study	• **Stations/Sampling frequency:** Sampled weekly when plant was operating
• **Replicates:** N/A	• **Replicates:** N/A
• **Total samples/year:** maximum of 104 (subsamples may be taken during storm events)	• **Total samples/year:** maximum of 52 (subsamples may be taken during storm events)
• **Data collected:** species abundance, representative length measurements to nearest 0.5 cm; debris load (seaweed/shell)	• **Data collected:** species abundance; representative length measurements to nearest 1.0 cm; debris load (seaweed/shell)

MARINE MACROBENTHOS

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objective of the marine macrobenthos program is to determine whether differences that exist among benthic communities at sites in the Hampton-Seabrook area can be attributed to power plant construction and operation. One potential impact on the local macrobenthos from Seabrook Station operation is temperature-related community alteration to areas directly exposed to the discharge thermal plume. Habitats in the upper portion of the water column (i.e., intertidal and shallow subtidal zones) are most susceptible to this impact. Thermal impacts are unlikely in deeper areas; however, increased turbidity in discharge water resulting from transport of suspended solids and entrained organisms could occur, increasing sedimentation rates and decreasing light transmission.

The focus of the proposed long-term monitoring program after 5 years of plant operation is to monitor those habitats most likely to reflect effects of potential impacts from Seabrook Station (thermal plume effects and increased turbidity/sedimentation). While no evidence of impacts has been detected to-date, this habitat merits continued monitoring at this time, given its predominance in the in the area, its ecological importance, and the long-term cyclic nature of the benthic communities.

1. Effort will be focused on station pairs with nearfield stations closest to the source of impacts (Seabrook discharge), and with longest existing preoperational/operational period time-series. These stations are most likely to reflect impacts, if they occur.

    - **B17/B35** - Shallow subtidal zone is hard benthos habitat, most susceptible to thermal plume exposure, although little evidence of impacts have been shown after 5 years of plant operation.

    - **B1/B5** - Intertidal zone, while less vulnerable to thermal plume effects than the shallow subtidal, will continue to be monitored because of regulator concerns for possible impacts to the Outer Sunk Rocks, the intertidal habitat nearest to the discharge.

    - **B19/B31** - Mid-depth zone would be most susceptible to potentially increased turbidity/sedimentation from the discharge, although little evidence of this type of impact has been demonstrated to date.

2. Sampling design and data analyses for these sites would be similar to previous years, maintaining the historic time-series:

    - Destructive sampling

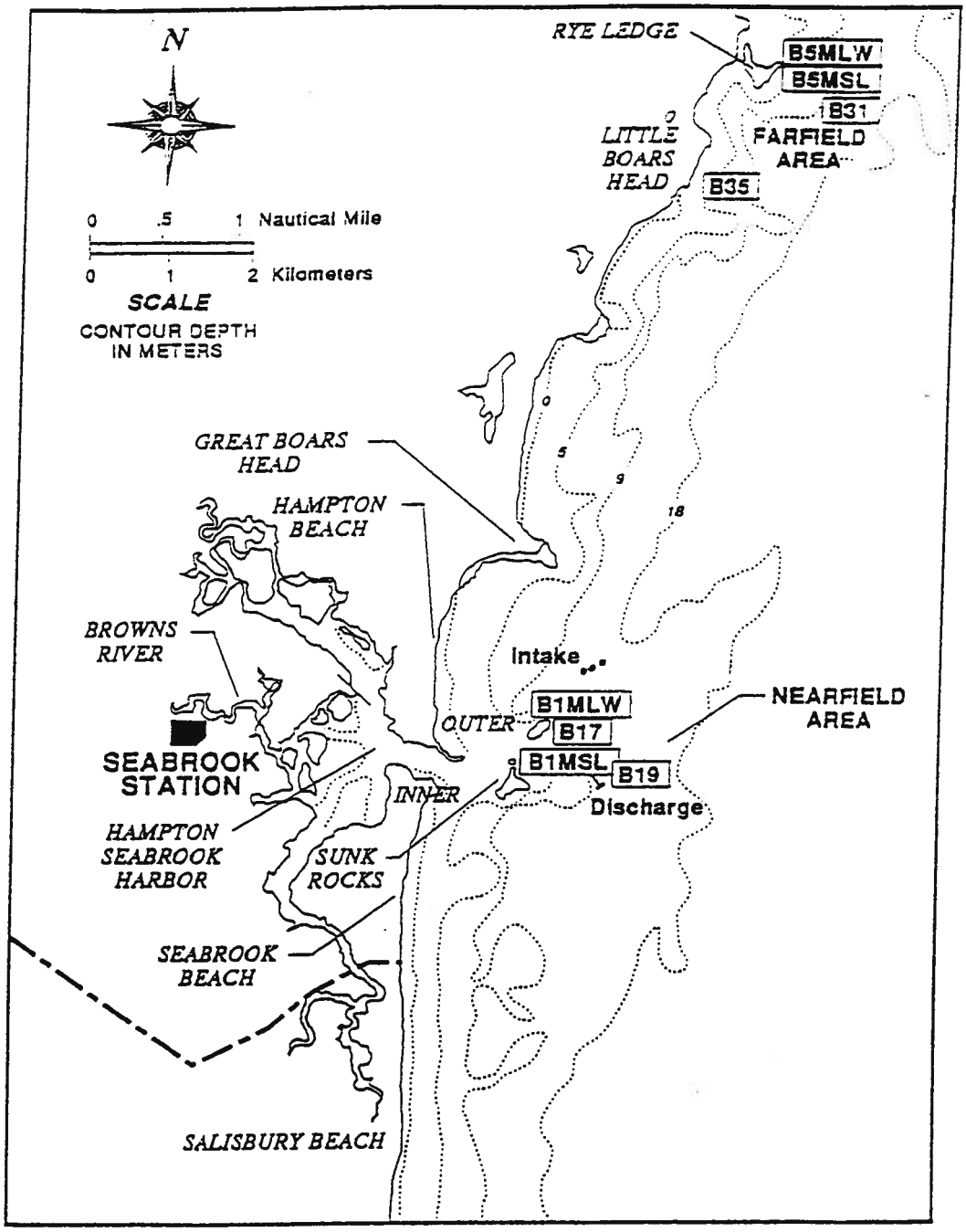
- Non-destructive transects (shallow subtidal, mid-depth and intertidal) and quadrats (intertidal)

- General algae (collections made in conjunction with destructive sampling)

- Bottom panels (with new wooden panel attached); subsampling of panel would provide replication.

- Study sample collection/processing for "incidental" parameters not analyzed in report would not be conducted (e.g., spirorbids, colonials, annual bottom panels).

3. Additionally, in response to regulator concerns for recent abundance declines of kelps at the nearfield stations, a one-year special study will be conducted to more closely examine trends in kelp abundance in the nearfield area. After consultation with Ecological Advisory Committee members, NUEL is preparing a final proposal and study plan for this work which will be presented at the fall 1997 Technical Advisory Committee meeting.



LEGEND

☐ = benthic samples

Marine macrobenthos sampling stations for proposed Long-Term Biological Monitoring Program for Seabrook Station.

MARINE MACROBENTHOS

PROPOSED PROGRAM	PAST PROGRAM
1) Destructive Sampling	
• **Stations/Sampling frequency:** B1MLW/B5MLW (Intertidal), B17/B35 (Shallow subtidal), B19/B31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW (Intertidal), B17/B35 (Shallow subtidal), B19/B31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth) sampled 1X per year
• **Replicates:** 5	• **Replicates:** 5
• **Total samples/year:** 90	• **Total samples/year:** 110
• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa	• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa, Spirorbid counts, length and/or reproductive status of some dominant fauna, colonial abundance
2) Non-Destructive Sampling (No Changes Proposed)	
• **Stations/Sampling frequency:** B1MSL/B5MSL (intertidal quads and transects), B17/B35 and B19/31 (Shallow subtidal and mid-depth) 3X per year	• **Stations/Sampling frequency:** B1MSL/B5MSL (intertidal quads and transects), B17/B35 and B19/31 (Shallow subtidal and mid-depth) 3X per year
• **Replicates:** Intertidal quads-6 (2 each in 3 zones), Intertidal transects-3, Subtidal transects-6	• **Replicates:** Intertidal quads-6 (2 each in 3 zones), Intertidal transects-3, Subtidal transects-6
• **Total samples/year:** 126	• **Total samples/year:** 126
• **Data collected:** % frequency/cover of intertidal dominants; % frequency of understory subtidal reds, kelp, urchin and *Modiolus* counts	• **Data collected:** % frequency/cover of intertidal dominants; % frequency of understory subtidal reds, kelp, urchin and *Modiolus* counts

MARINE MACROBENTHOS (continued)

PROPOSED PROGRAM	PAST PROGRAM
3) General Algae	
• **Stations/sampling frequency:** B1MLW/B5MLW (intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW tidepools, B1MSL/B5MSL tidepools, B1MLW/B5MLW, B1MSL/B5MSL (Intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth intake) sampled 1X per year
• **Replicates:** 1	• **Replicates:** 1
• **Total samples/year:** 18	• **Total samples/year:** 40
• **Data collected:** presence/absence of algal taxa	• **Data collected:** presence/absence of algal taxa
4) Bottom Panels	
• **Stations/Sampling frequency:** B19/31 (Mid-depth) triannual panels 3X/year	• **Stations/Sampling frequency:** B19/31 (Mid-depth), B04/B34(Deep); triannual panels 3X/year, annual panels 1X per year
• **Replicates:** 1 panel (4 subsamples)	• **Replicates:** 1panel
• **Total samples/year:** 24 subsamples	• **Total samples/year:** 28
• **Data collected:** counts of selected dominant taxa, *Teredo* sp. counts in attached wooden panel	• **Data collected:** counts of selected dominant taxa

EPIBENTHIC CRUSTACEA

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objective of the epibenthic crustacea monitoring program is to assess potential entrainment effects on larval crabs and lobsters, and discharge-related effects on juvenile and adult forms. This objective has been successfully met, so the proposed program would remain essentially the same as in previous years, due to these species' recreational importance and high profile with the public and regulators. Proposed changes would improve our ability to detect impacts and still maintain continuity with historically reported data.

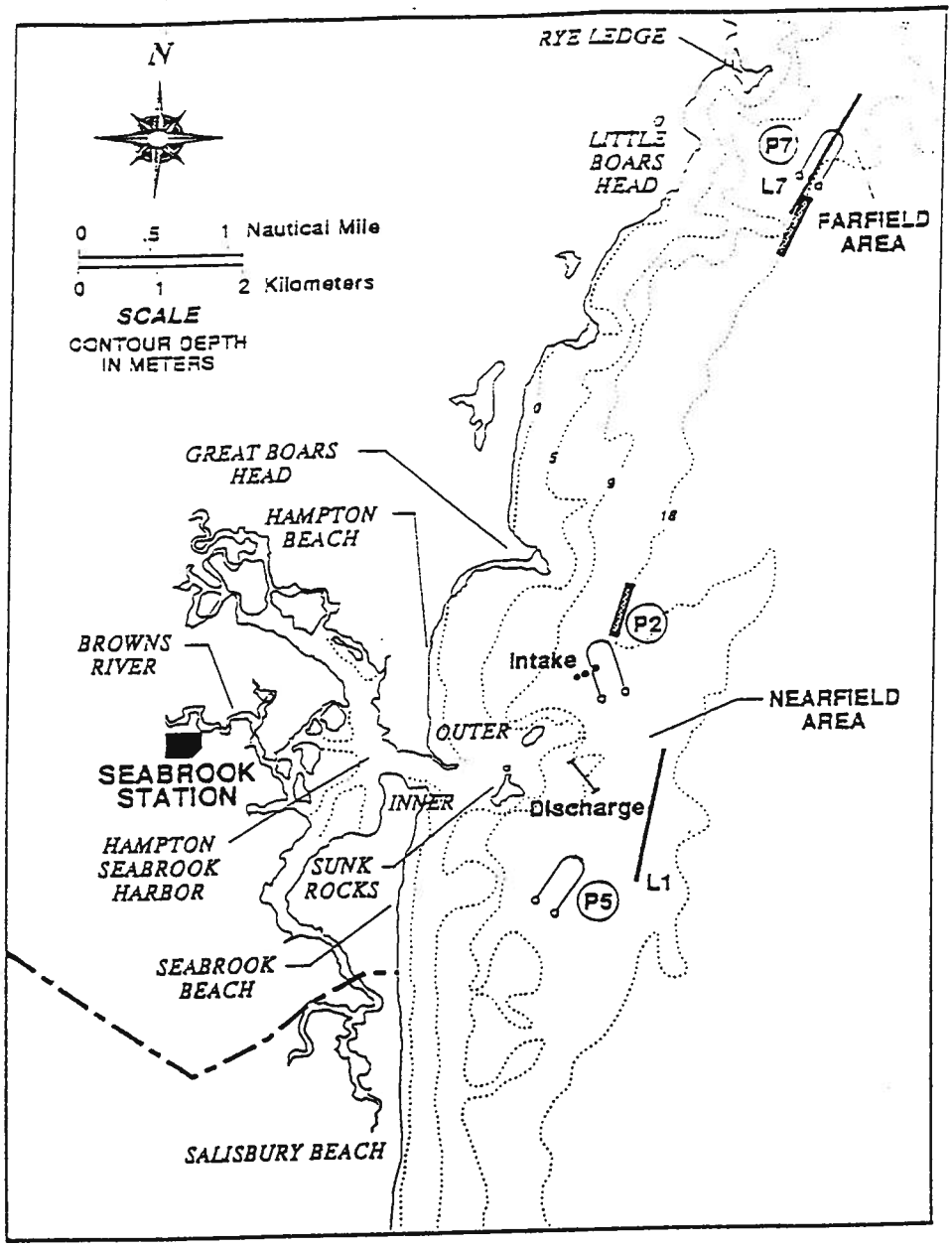
1. Adult Lobster/Crab Survey would continue unchanged. Additionally, *Cancer* crabs will be enumerated in impingement samples.

2. Lobster/crab larvae sampling design and data analyses for these sites would remain almost identical to previous years, maintaining the historic time-series presented in reports:

    - No changes are proposed for the lobster larvae neuston sampling program.

    - *Cancer* spp. larvae sample replicates would be reduced from 3 to 1 (through the macrozooplankton program) and only stations P2 and P7 would be sampled; analysis indicated that the ability to detect impacts is not affected.

3. New Hampshire Fish and Game requested that additional data be provided on lobster molt stage and the presence of V-notches. North Atlantic is pursuing plans to have this data collected by the commercial lobsterman who currently performs the lobster sampling program.



LEGEND

= Lobster larvae (neuston)

P = Jonah and rock crab larvae (macrozooplankton)

L = Lobster traps (15 traps)

Epibenthic crustacea sampling stations for proposed Long-Term Biological Monitoring Program for Seabrook Station.

EPIBENTHIC CRUSTACEA

PROPOSED PROGRAM	PAST PROGRAM
1) Adult Lobster/Rock Crab	
• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.	• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.
• **Replicates:** 1 (30 traps)	• **Replicates:** 1 (30 traps)
• **Total samples/year:** 156	• **Total samples/year:** 156
• **Data collected:** Lobster/crab abundance, carapace length, determination of sex, molt stage, and presence of V-notch	• **Data collected:** Lobster/crab abundance, carapace length, sex determination
2) Lobster Larvae Neuston (No changes proposed)	
• **Stations/Sampling frequency:** P2, P5 and P7; 1X per week from mid-May to mid-Oct.	• **Stations/Sampling frequency:** P2, P5 and P7; 1X per week from mid-May to mid-Oct.
• **Replicates:** 1	• **Replicates:** 1
• **Total samples/year:** 63	• **Total samples/year:** 63
• **Data collected:** lobster larvae density	• **Data collected:** lobster larvae density
3) *Cancer* spp. larvae (macrozooplankton sampling)	
• **Stations/Sampling frequency:** Station P2 and P7 sampled twice per month	• **Stations/Sampling frequency:** Stations P2, P5, and P7 sampled twice per month
• **Replicates:** 1 sample	• **Replicates:** 4 replicates collected; 3 replicates processed
• **Total samples/year:** 48	• **Total samples/year:** 288 collected; 216 processed
• **Data collected:** Density per $1000m^3$	• **Data collected:** Density per $1000m^3$

MYA ARENARIA

Proposed Long-Term Environmental Monitoring Program for Seabrook Station

The objectives of the proposed Mya arenaria program are to ensure the continuity of the current database on the soft-shell clam and its predators, and to make available information needed to explain to the public major changes in clam abundance which may occur in the future. Given the local economical and recreational importance of this species and the public level of concern, no changes in this program are proposed. The proposed *Mya arenaria* monitoring program would have three main components:

1) The Hampton Harbor Population Surveys;

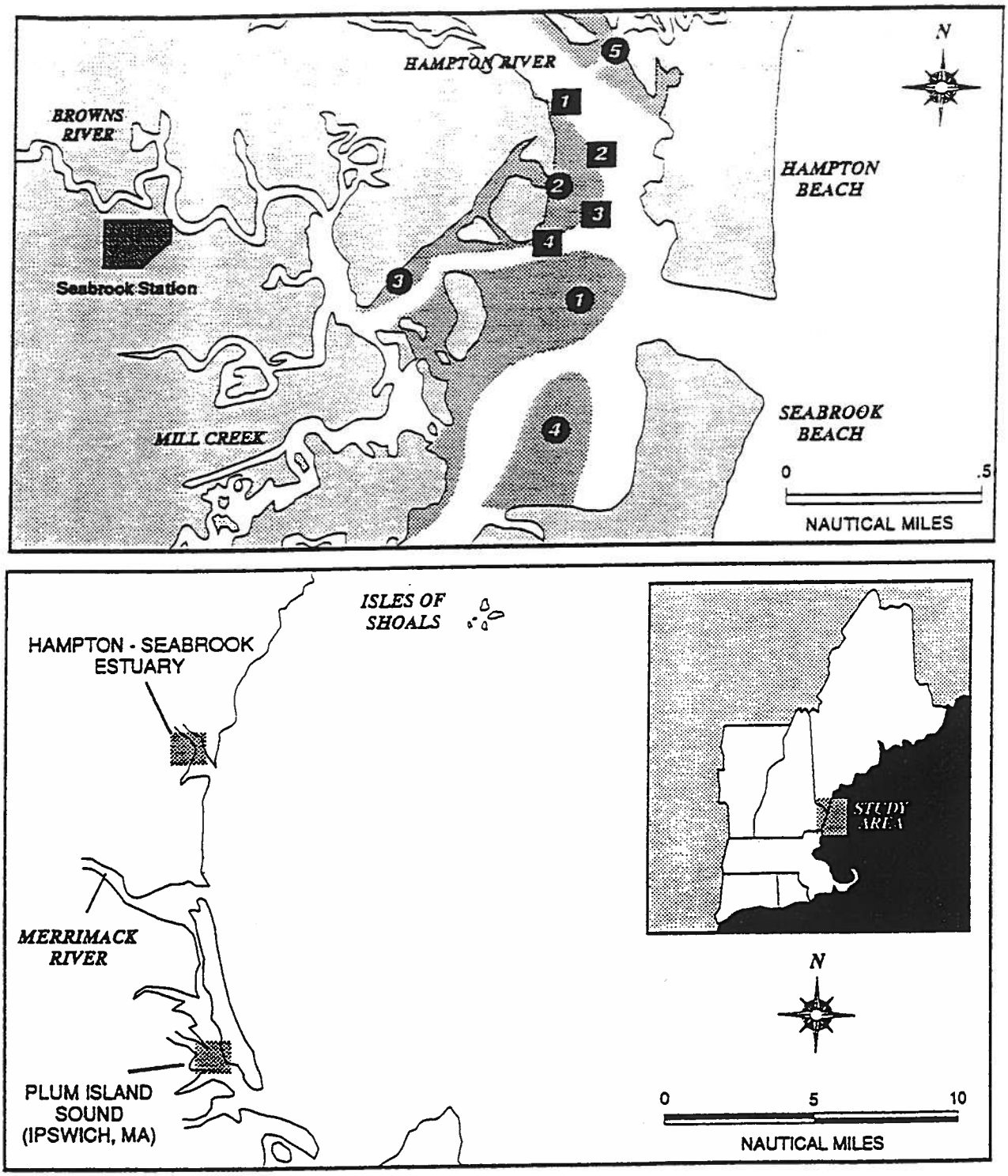
2) The Near/Farfield Study; and

3) The Predator Surveys.

1. The Hampton Harbor Survey would continue the data collection of adult *Mya* at flats 1,2, and 4, and of spat at flats 1 through 5, once per year in the fall. The monthly survey of green crabs on Flat 2 would also continue unchanged.

2. The Nearfield/Farfield Study would be the same as in the past; this study provides valid data for statistically testing whether future clam abundance declines, mass mortalities, etc. can be attributed to plant operation.

3. The green crab surveys and clam-digger counts would continue unchanged. However, an effort would be made to investigate other measures of annual exploitation rates because some reviewers of the draft proposal indicated that clam-digger counts did not appear very reliable.



LEGEND

- ● = Clam Flats
- ■ = Green Crab Traps
- ▒ = Spat Sampling Sites

Hampton-Seabrook estuary and Plum Island Sound soft-shell clam *(Mya arenaria)* and green crab *(Carcinus maenas)* sampling areas. Seabrook Operational Report, 1994.

MYA ARENARIA

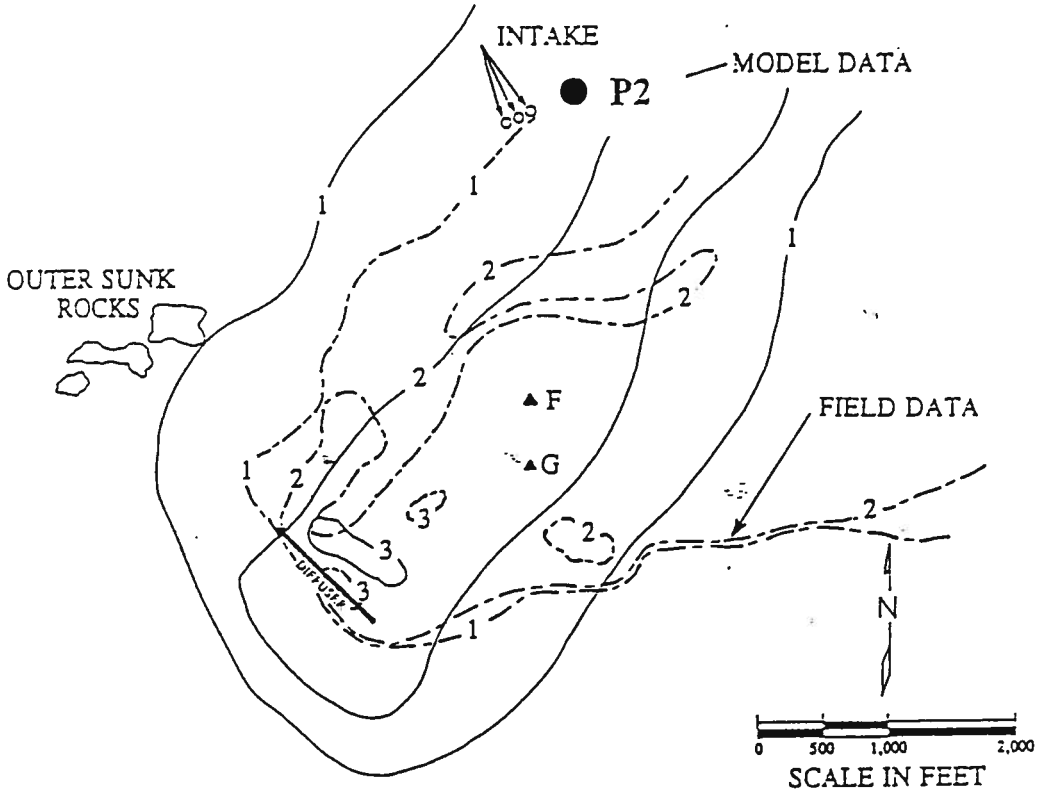
PROPOSED PROGRAM	PAST PROGRAM
1) Random survey - Hampton Harbor	
• **Stations/Sampling frequency:** same as before; no changes.	• **Stations/Sampling frequency:** *Mya* adults - flats 1,2,4 / *Mya* spat - flats 1-5; once per year in the fall.
• **Replicates:** determined by historical variability	• **Replicates:** varies
• **Data collected:** Density by size class starting at 1 mm	• **Data collected:** Density by size class
2) Nearfield/Farfield Study - no changes proposed	
• **Stations/Sampling frequency:** 10 stations each in Hampton Harbor and Plum Island Sound, once per year in the fall.	• **Stations/Sampling frequency:** 10 stations each in Hampton Harbor and Plum Island Sound, once per year in the fall.
• **Replicates:** 3	• **Replicates:** 3
• **Total samples/year:** 60	• **Total samples/year:** 60
• **Data collected:** Seed clam (1-12 mm) density	• **Data collected:** Seed clam (1-12 mm) density

MYA ARENARIA

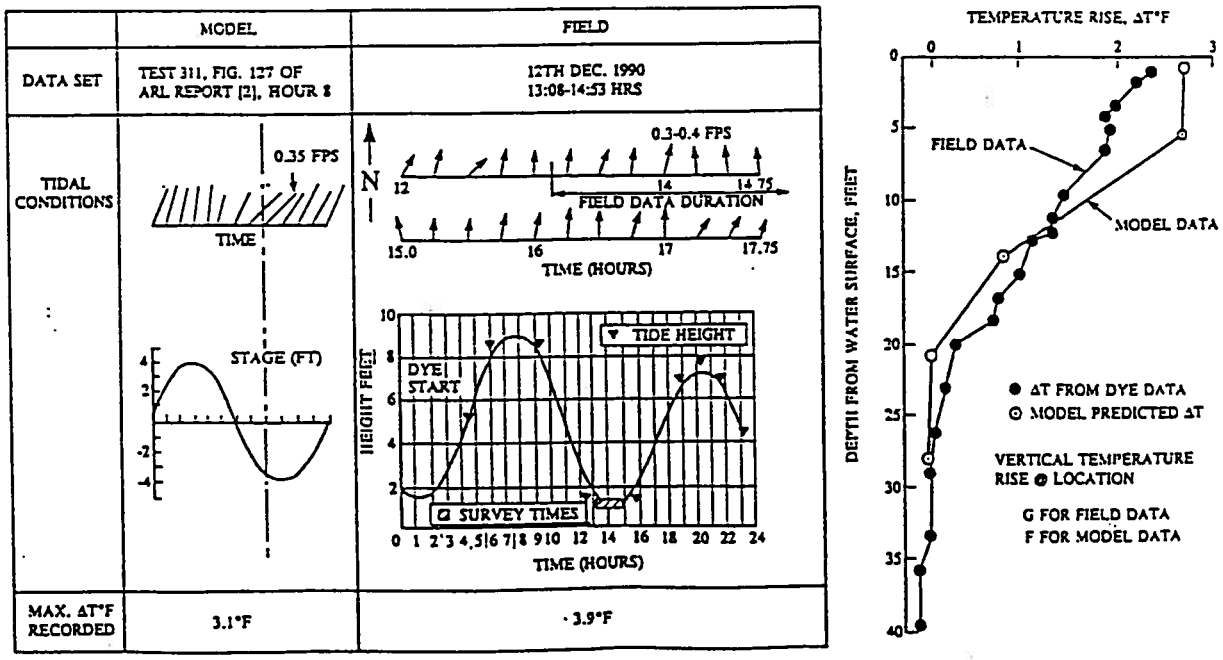
PROPOSED PROGRAM	PAST PROGRAM
3) Predator Surveys	
a) Clam digger counts Investigate other options to estimate annual exploitation rate. • **Stations/Sampling frequency:** Stations 1,2,3,4 and 5; once per week except from June through August • **Replicates:** 1 • **Total observations/year:** 190 • **Data collected:** Number of diggers per flat.	**a) Clam digger counts** • **Stations/Sampling frequency:** Stations 1,2,3,4 and 5: once per week except from June through August • **Replicates:** 1 • **Total observations/year:** 190 • **Data collected:** Number of diggers per flat.
b) Green Crabs - no changes proposed • **Stations/Sampling frequency:** Stations 1-4 within *Mya* Flat 2 in Hampton Harbor; twice monthly except Feb. and Mar. • **Replicates: 2** • **Total samples/year:** 160 • **Data collected:** Monthly CPUE	**b) Green Crabs** • **Stations/Sampling frequency:** Stations 1-4 within *Mya* Flat 2 in Hampton Harbor; twice monthly except Feb. and Mar. • **Replicates:** 2 • **Total samples/year:** 160 • **Data collected:** Monthly CPUE

4) Bivalve Larvae: discussed with zooplankton evaluation

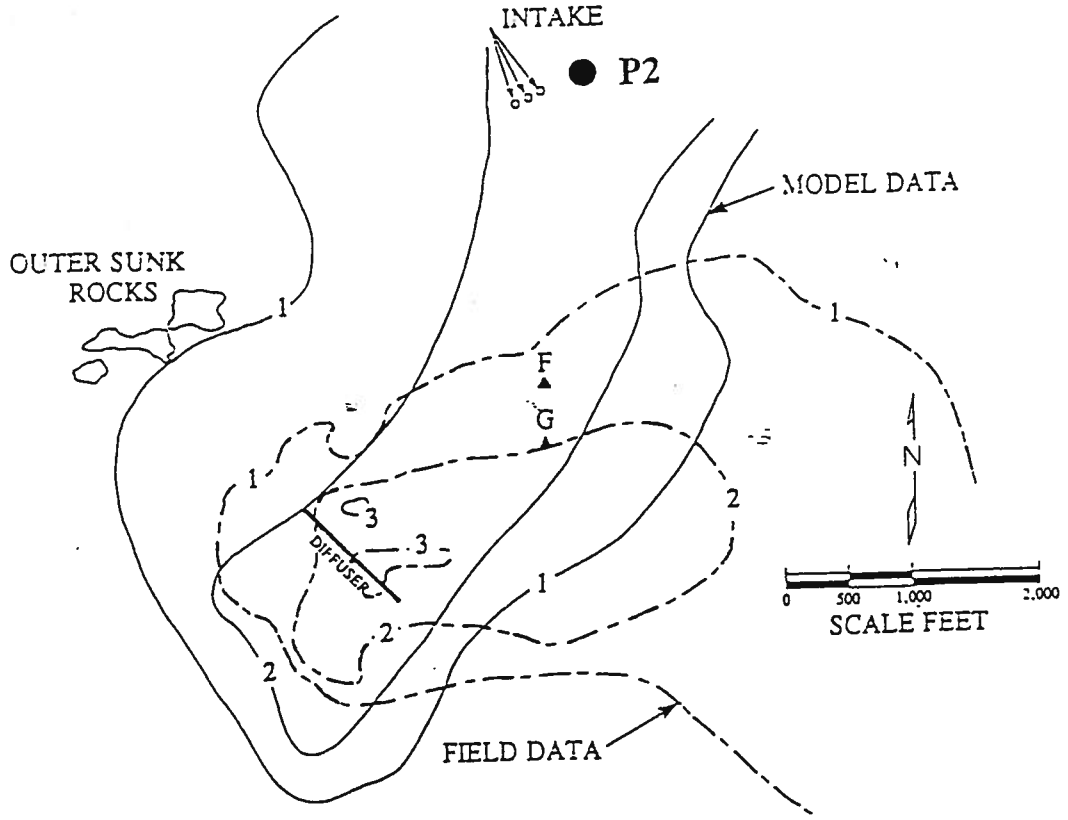
ATTACHMENT 1 TO NYE-97027



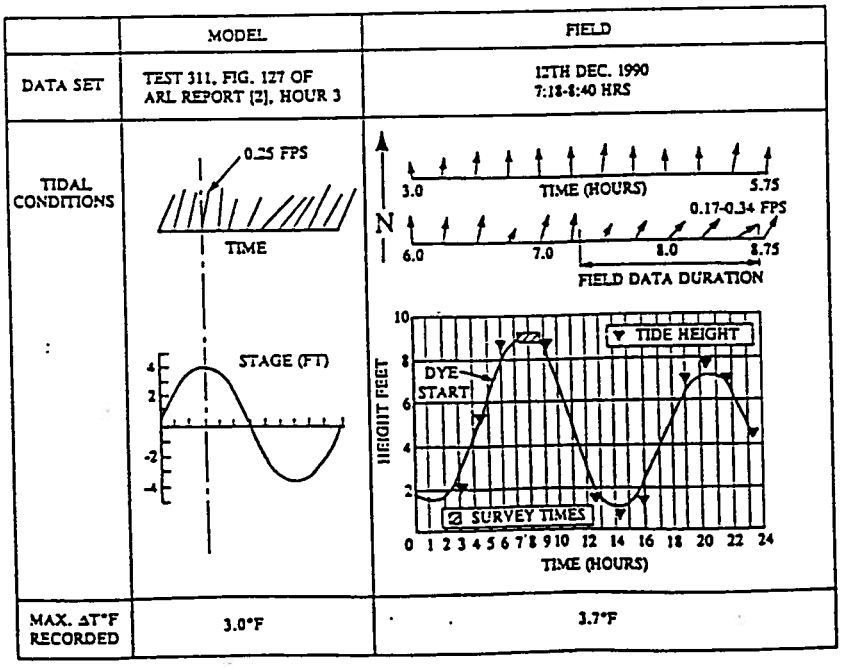
P5

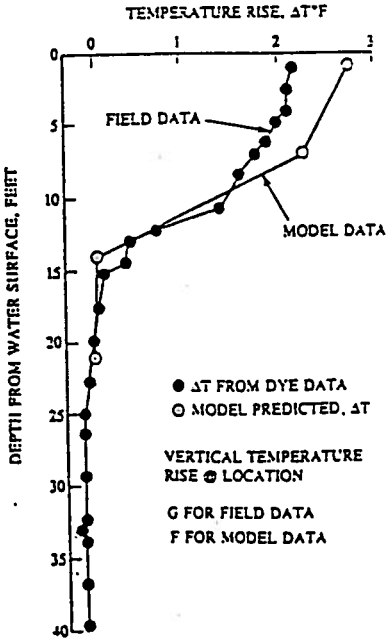


Attachment 1. Location of nearfield plankton stations P2 and P5 in relation to Seabrook Station thermal plume isotherms (°F) based on model and field data under various tidal conditions.

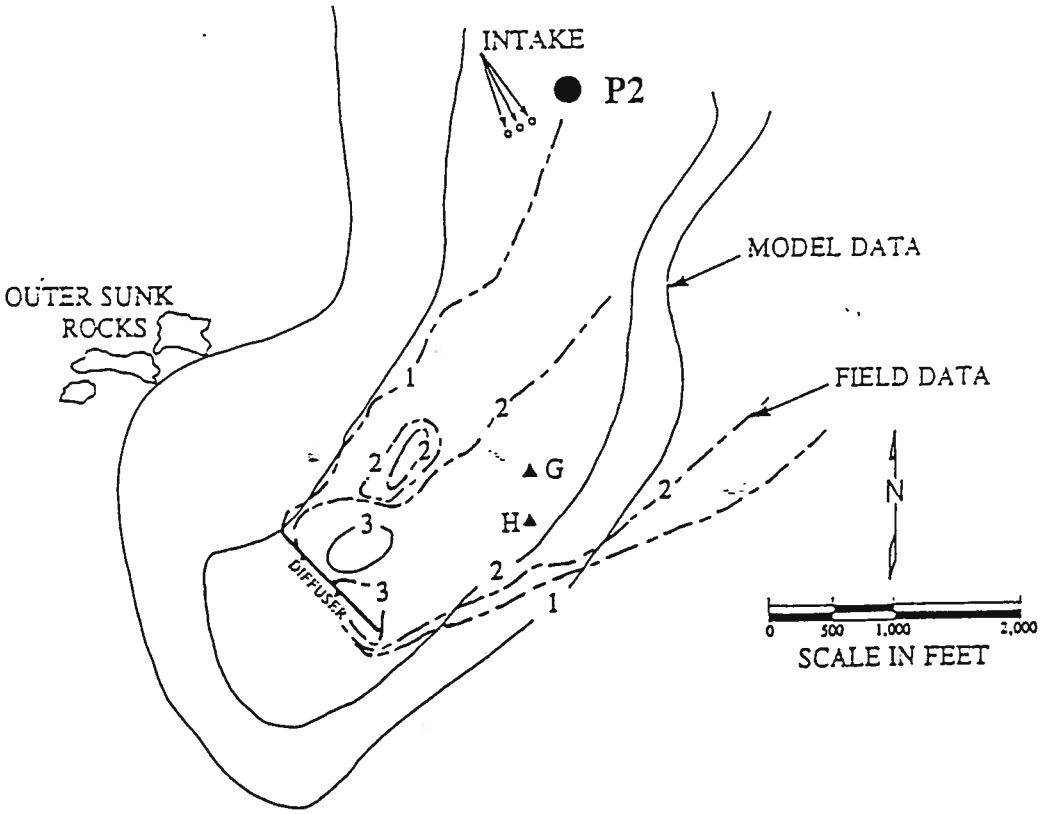


P5

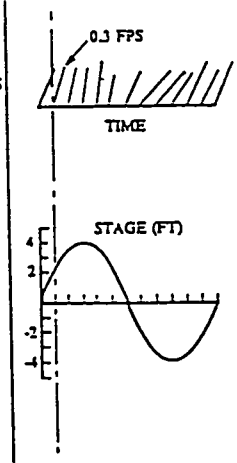
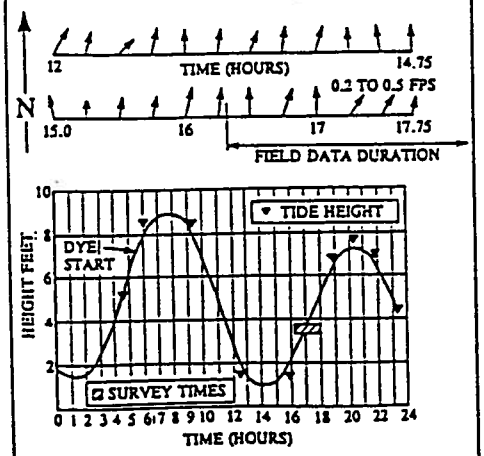


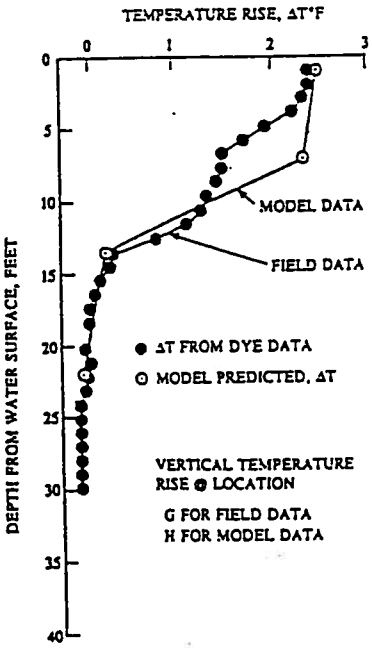


Attachment 1, continued

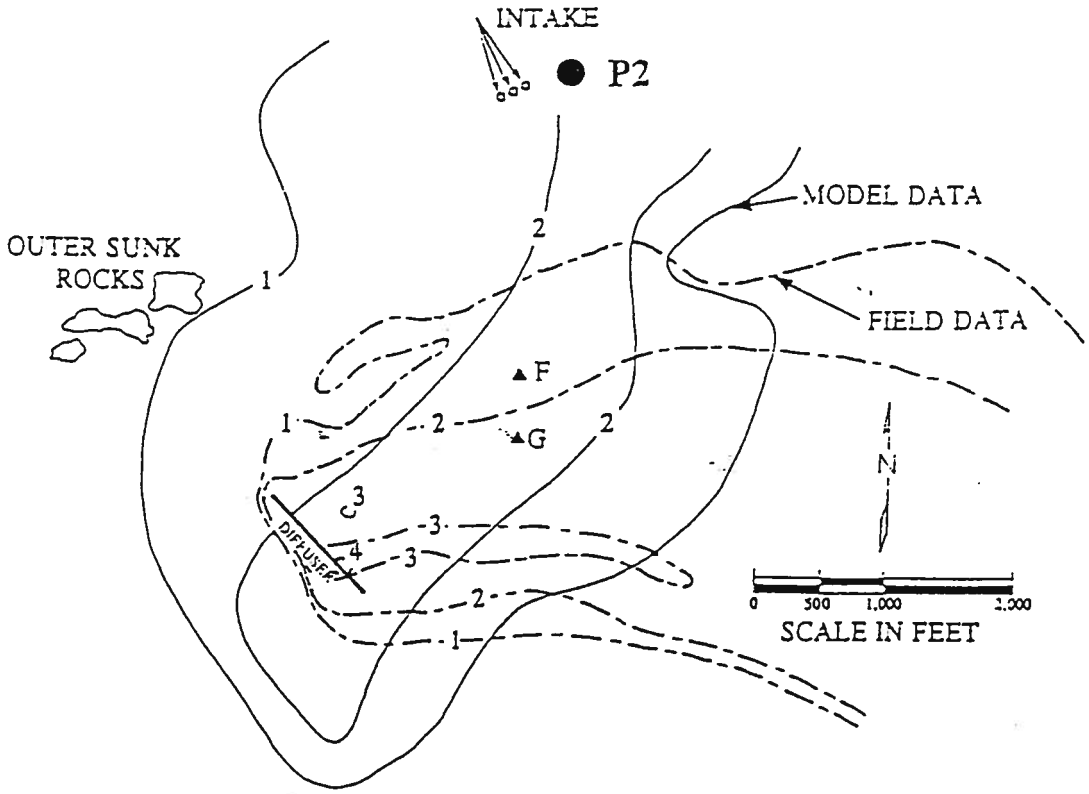


P5

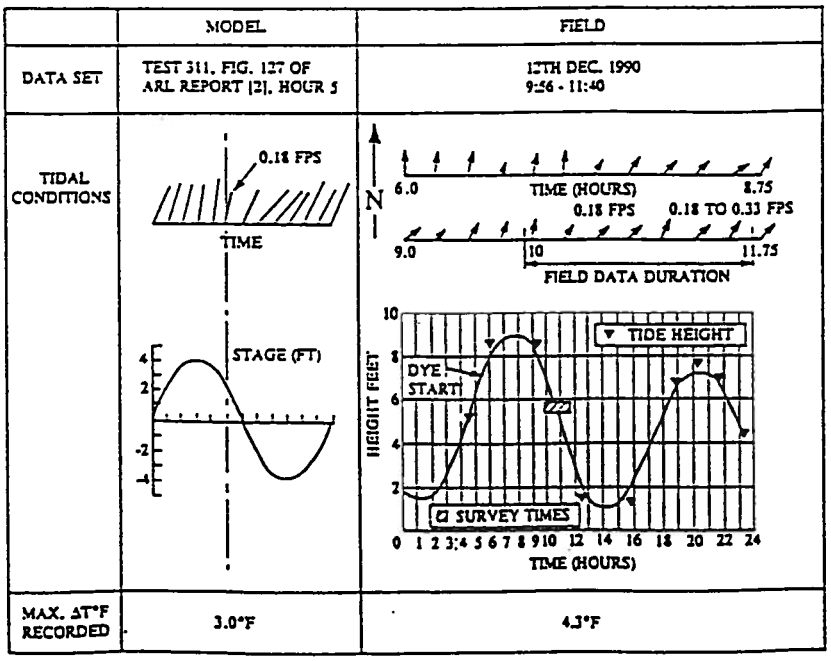
	MODEL	FIELD
DATA SET	TEST 311, FIG. 125 OF ARL REPORT [2], HOUR 1	12TH DEC. 1990 16:18 - 17:58 HRS
TIDAL CONDITIONS		
MAX. ΔT°F RECORDED	3.1°F	3.9°F

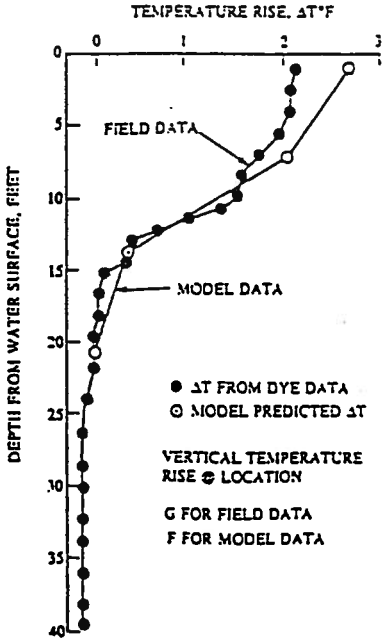


Attachment 1, continued



● P5





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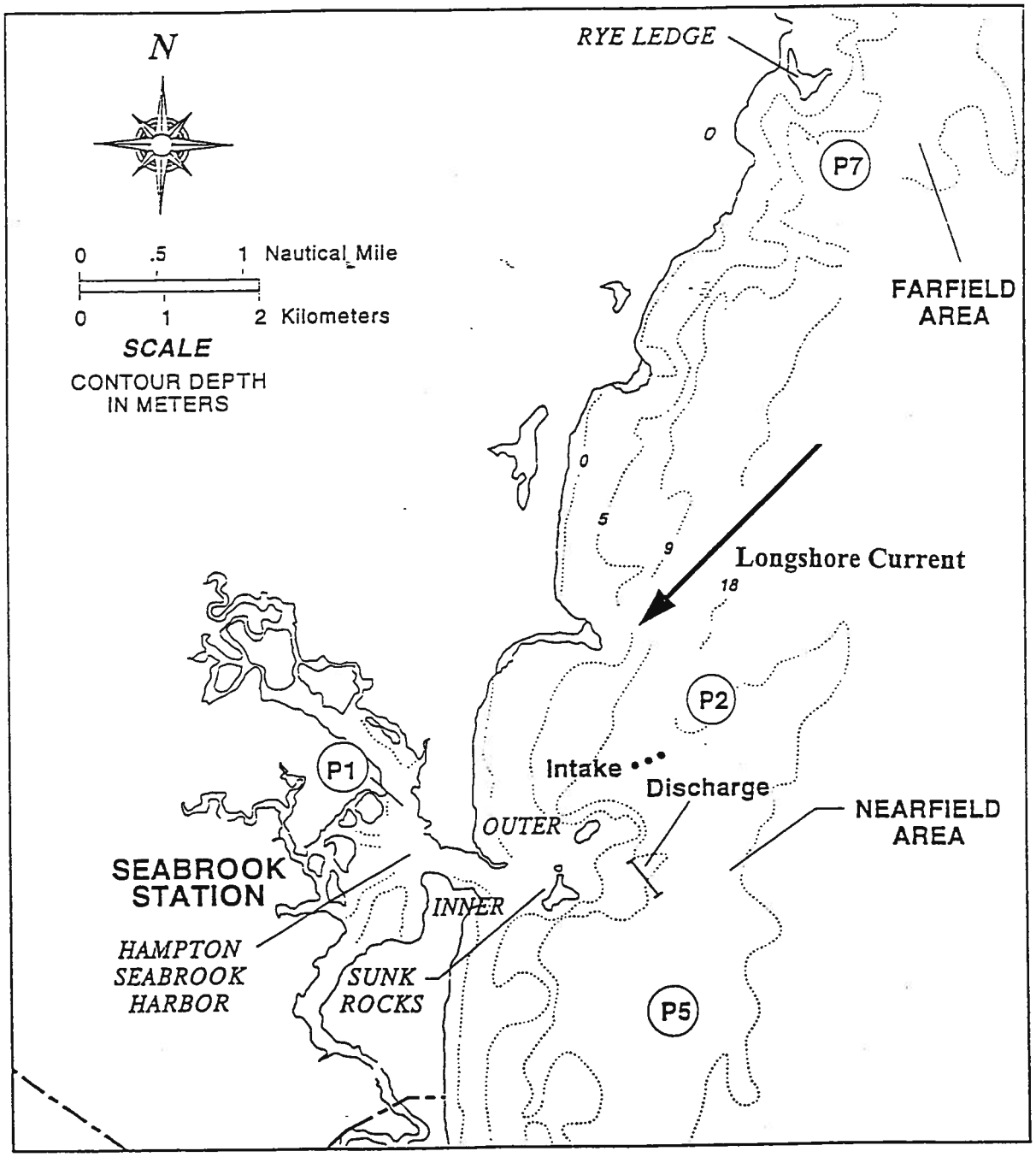
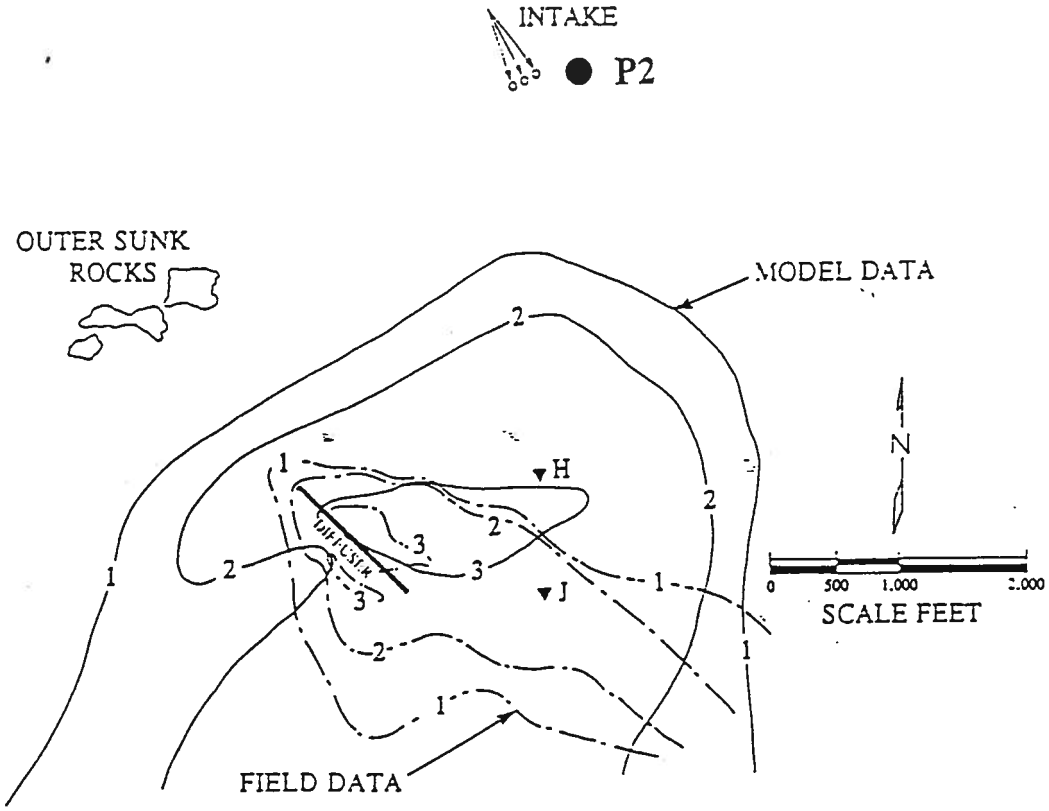
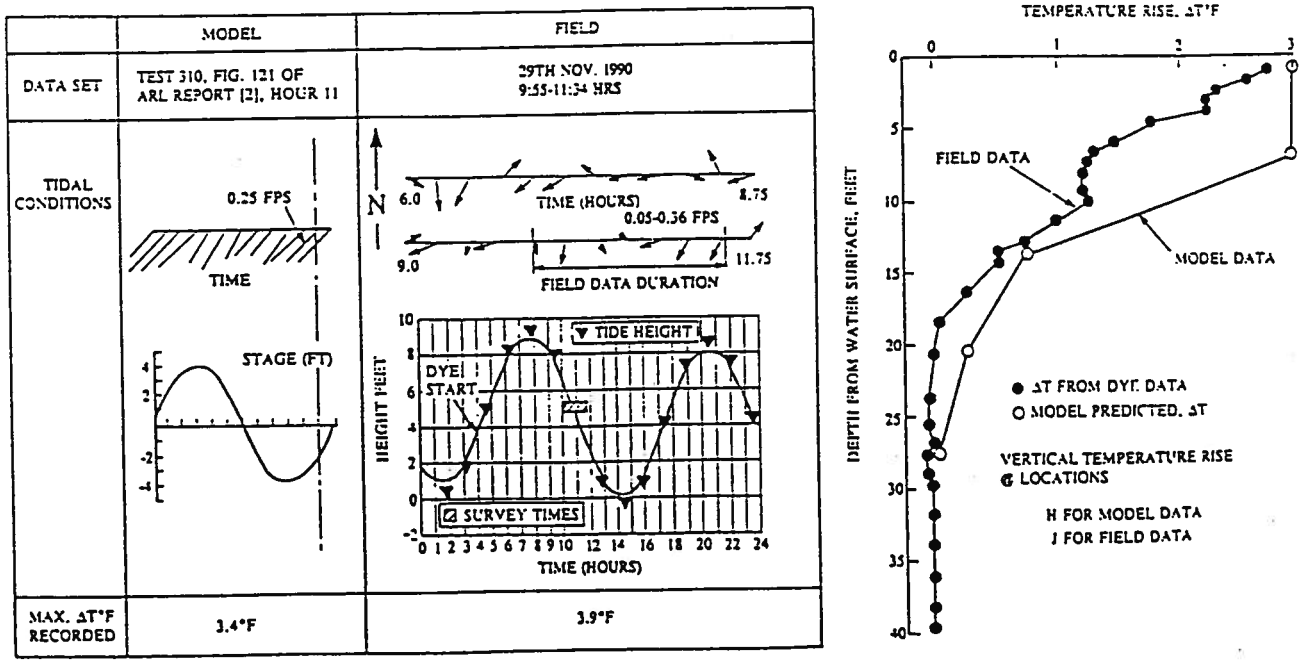
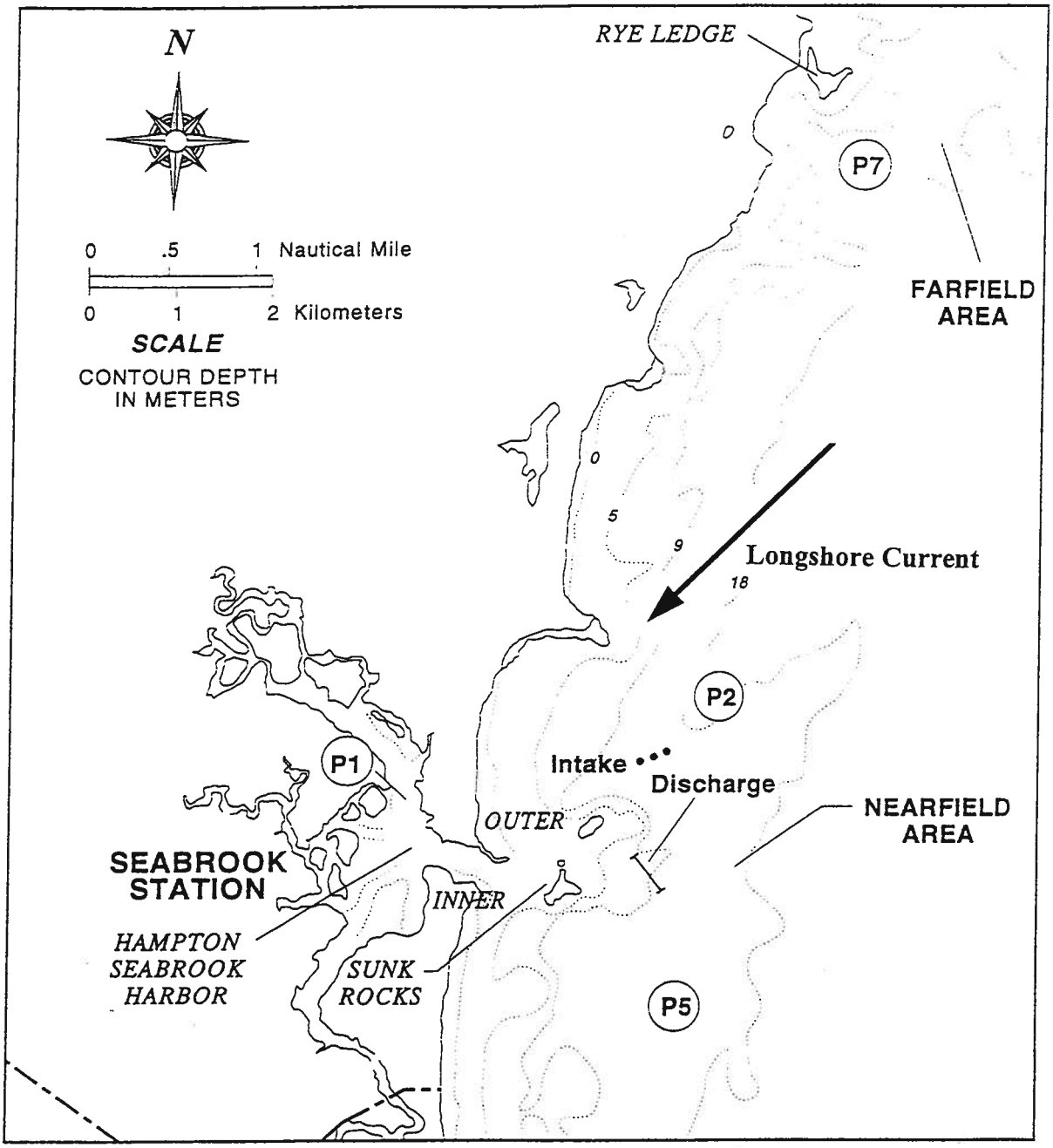


Attachment 1, continued. The New Hampshire coastal area corresponding to the Hampton-Seabrook Harbor, showing the location of Seabrook Station, the plant's intake and discharge, the plankton sampling stations (P1, P2, P5 and P7), and an arrow corresponding to the prevailing direction of the longshore current in the area.





Attachment 1, continued



Attachment 1, continued. The New Hampshire coastal area corresponding to the Hampton-Seabrook Harbor, showing the location of Seabrook Station, the plant's intake and discharge, the plankton sampling stations (P1, P2, P5 and P7), and an arrow corresponding to the prevailing direction of the longshore current in the area.

ATTACHMENT 2 TO NYE-97027

Attachment 2

Some Comments and Suggestions Related to Multivariate Statistical Analyses and Result Presentation in Response to Regulatory Concerns for Seabrook Monitoring Program Modifications

S.B. Saila

Background—

The past decade or more has seen an enormous increase in the development and application of multivariate methods in ecology and environmental monitoring. This has been especially true of techniques for exploring pattern in data sets and for providing succinct summaries and displays. It, therefore, seems appropriate to carefully review and assess the multivariate methodologies currently in use at Seabrook Station.

Many types of data are collected, but in community studies, the primary data is usually species abundance.

- It is suggested that greater emphasis be placed on the visual display of the results of multivariate analysis. Simple graphical methods can be used for preliminary inspection. Scatter plots are commonly used for biovariate data. For multivariate data, various types of shapes, such as glyphs and stars can be effectively used for representing a large number of variables. Pie charts and three dimensional perspective views may also be helpful in some cases.
- It is also suggested that a critical review of existing multivariate procedures be conducted. In particular, it is believed to be useful to consider non-hierarchical as well as hierarchical methods. These should include principal component analysis and various clustering algorithms.
- An easy introduction to this subject area is: B. Flury and H. Riedwyl. 1988. Multivariate statistics - A practical approach. Chapman and Hall, New York.
- Further specific detail regarding multivariate procedures related to the Seabrook Monitoring Program will be forthcoming.

25934

North Atlantic

North Atlantic Energy Service Corporation
P.O. Box 300
Seabrook, NH 03874
(603) 474-9521

The Northeast Utilities System

AUG 29 1996

NPDES Permit No. NH0020338
NYE-96021

Mr. Carl DeLoi
New Hampshire State Program Unit
Environmental Protection Agency
John F. Kennedy Building
Boston, MA 02203

Seabrook Station
Long-Term Environmental Studies Program Proposals

North Atlantic Energy Service Corporation (North Atlantic) submits herein the Long-Term Environmental Studies Program Proposals to be discussed at the Seabrook Station Technical Advisory Committee (TAC) Working Group Meeting on Thursday, September 5, 1996.

The enclosed working draft documents evaluate each of the seven major Seabrook Station Environmental Monitoring Programs, and include five years of environmental monitoring data, from Seabrook Station's operational period (August 1990-December 1995). The monitoring programs evaluated are:

- Water Quality
- Zooplankton
- Fish
- Marine Macrobenthos
- Epibenthic Crustacea
- Soft-Shell Clam
- Phytoplankton

The purpose of this TAC Working Group Meeting is to prepare the TAC for the anticipated post five-year Seabrook Station Environmental Monitoring Program modifications that will be formally submitted to the agencies later this year. Seabrook Station's Ecological Advisory Committee Members will provide their endorsement of the program proposals as part of that formal submittal.

The full TAC has the ultimate authority to make recommendations to the EPA Regional Administrator and the Director of the NH Water Supply and Pollution Control Division who are responsible for approving or disapproving program modifications (Seabrook Station NPDES Permit Part I.A.11.c). This

review and approval process was discussed at the November 1995, Seabrook TAC Meeting and discussed with the EPA at the February 26, 1996 meeting in Boston, as well as in North Atlantic's March 28, 1996 submittal[1].

An outline of the current program and the proposed long-term monitoring program is attached as Enclosure 1. The agenda for the September 5, 1996 meeting is also attached (Enclosure 2).

The meeting will be held in the Lower Level Conference Room at the Seabrook Station Science & Nature Center on September 5, 1996 at 9:30 a.m. Should you require additional information regarding this matter, please contact Mr. Ronald A. Sher, Senior Scientist at (603) 474-9521, extension 2729.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

Bruce L. Drawbridge
Executive Director
Nuclear Station Safety and Oversight and
Senior Site Officer

[1] North Atlantic letter NYE-96005, dated March 28, 1996, "1996 Seabrook Station Environmental Monitoring Program Modifications," B. L. Drawbridge (North Atlantic) to C. DeLoi (EPA)

cc (with Enclosure)

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ENCLOSURE 1 TO NYE-96021

CURRENT SEABROOK STATION
ENVIRONMENTAL STUDIES PROGRAM

The Seabrook Station Environmental Monitoring Program is an extensive study that evaluates the balanced indigenous population of organisms off coastal New Hampshire. The program, formally initiated in 1977, has collected information on every trophic level and community type of marine organisms. The study design was established to examine natural variability of these communities in the area of potential impact of Seabrook Station along with a farfield area outside any potential influence. Any change in the nearfield area not paralleled by a change in the farfield area would suggest a potential impact, warranting further study. A key element of the program has been to focus the studies in the areas of potential power plant impact. These include:

Intake effects:	Entrainment of zooplankton Impingement of finfish and lobsters
Discharge effects (thermal plume):	Phytoplankton Lobster larvae Intertidal/shallow subtidal benthos Fouling community
Discharge effects (detrital rain):	Mid-depth/deep benthos Lobsters/crabs

PROPOSED LONG-TERM SEABROOK STATION
ENVIRONMENTAL STUDIES PROGRAM

Five years of environmental monitoring since Seabrook Station began operating in 1990 has shown no detectable impacts to the balanced indigenous populations. The Seabrook Technical Advisory Committee (TAC) agreed that five years of environmental data collection during the power plant operating period would be sufficient to evaluate the effectiveness of the current program. Therefore, North Atlantic, in conjunction with Northeast Utilities, Normandeau Associates and the Seabrook Ecological Advisory Committee, has developed a proposal for a long-term monitoring program that contains four basic elements:

1. FOCUS ON PROGRAMS THAT DIRECTLY MEASURE PLANT EFFECTS

   - Improved entrainment sampling
   - Improved impingement monitoring

2. FOCUS ON PROGRAMS THAT ARE MOST LIKELY TO SHOW POTENTIAL PLANT EFFECTS ON THE BALANCED INDIGENOUS POPULATION

- Thermal plume: Lobster larvae
  Shallow water benthos
  Bottom panels

- Intake: Fish eggs and larvae
  Macrozooplankton

3. REDUCE PROGRAM REDUNDANCIES

- Focus on one nearfield station (P2), and farfield counterpart (P7)

- Reduce sample replication when appropriate

4. MAINTAIN CONTINUITY OF SOFT-SHELL CLAM DATABASE

- Continue all population surveys as in the current program

ENCLOSURE 2 TO NYE-96021

Seabrook Station
Technical Advisory Committee
Working Group Meeting

Thursday, September 5, 1996

Science & Nature Center
Lower Level Conference Room

Agenda

9:30 a.m.	Purpose of Meeting
9:30 a.m.	Seabrook Station Environmental Studies Update
9:45 a.m.	Environmental Studies Program Overview
10:15 a.m.	Discussion of Individual Programs

- Fish and Shellfish (Epibenthic Crustacea and Soft-Shell Clam)
- Benthos
- Zooplankton
- Water Quality

12:00 p.m.	Lunch
12:30 p.m.	Discussion of Individual Programs (Continued)
1:30 p.m.	Other Environmental Studies Program Matters

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WATER QUALITY

Summary of the Proposed Monitoring Program after 5 Years of Plant Operation

The objectives of the proposed water quality program are to acquire environmental data, characterize conditions at Seabrook sampling stations, provide explanatory variables to support conclusions drawn from other aspects of the monitoring program, and help distinguish between long-term and short-term trends in the vicinity of Seabrook Station. The program focuses on areas that are most likely to detect potential power plant effects and will provide data to explain biological variability.

1. Water temperature, salinity and dissolved oxygen are biologically important parameters that influence the distribution of fish, plankton and benthic organisms. Measurement of these parameters should be accomplished with dependable field instruments, utilizing current analytical technology, and minimizing difficulties associated with handling and storage of glass bottles, and generation and disposal of hazardous wastes from Winkler titrations.

2. Comparisons of recent data to the historical database will allow determination of whether changes have occurred since Seabrook Station began operation; comparisons between the nearfield (P2) and farfield (P7) stations will distinguish between localized (i.e., potentially power plant-related) and regional changes. Stations P2 and P7 have the longest time-series of concurrent data collection.

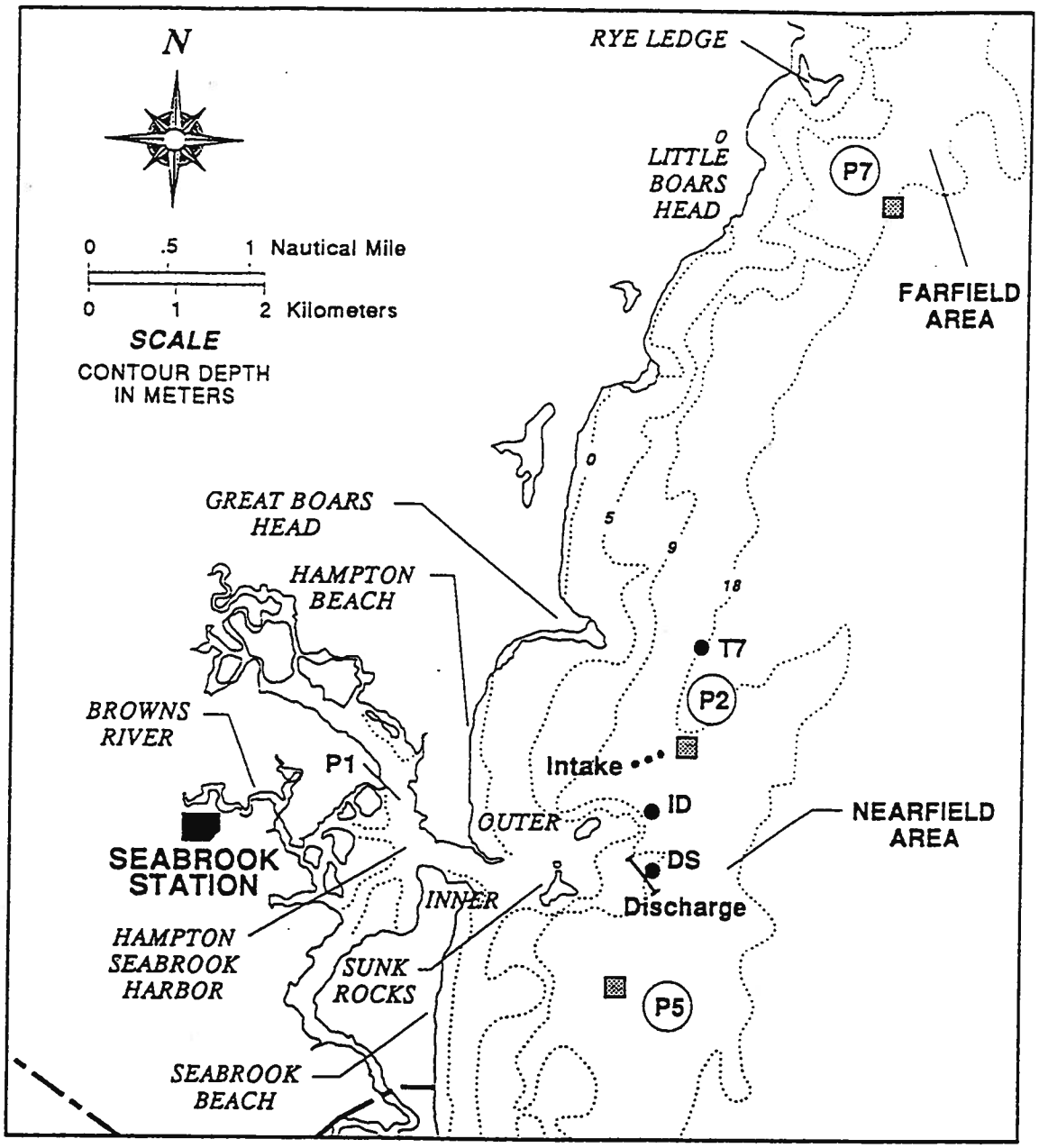
3. Modifications to past programs will have minimal effect on ability to detect power plant impact, should it occur:

    - suspension of nutrient sampling - no impacts shown to date (see Phytoplankton evaluation); inherently high variability and lack of credible mechanism for impact make it unlikely that they ever could show impact.

    - deletion of sampling station P5 (discharge) - this station is actually over 1.5 km from the discharge, too far to be affected by power plant operation, and too far to even be considered a nearfield station. Discharge effects will continue to be assessed by the continuous temperature monitoring program.

WATER QUALITY

PROPOSED PROGRAM	PAST PROGRAM
1) Offshore Temperature Profiles, Salinity & Dissolved Oxygen Measurement	
• **Stations/Sampling frequency:** P2, P7/4 times per month (concurrent with ichthyoplankton sampling)	• **Stations/Sampling frequency:** P2 (intake), P5 (discharge), P7 (farfield)/4 times per month
• **Methodology:** all parameters measured surface and bottom with field probe; additional temperature readings will be made every 2 meters to the bottom	• **Methodology:** S-C-T probe at 2m depth intervals for temperature (~10 readings/profile); water samples taken near surface and near bottom (2 reps for DO) and analyzed in lab (S-C-T probe for salinity, Winkler titration for DO)
• **Total samples/year:** 96 profiles (48 trips x 2 sta.)	• **Total samples/year:** 144 profiles (48 trips x 3 sta.)
2) Estuarine Water Quality (Temperature and Salinity)	
• no change from past program	• **Station/Sampling frequency:** HH (Hampton Harbor)/recorded weekly at high and low slack tides
	• **Total samples/year:** 104/parameter (52 wks x 2 tidal stages)
3) Continuous Temperature Monitoring	
• no change from past program	• **Stations:** DS (discharge) and T7 (farfield; both stations sampled for 316/NPDES compliance)
4) Nutrients	
none - no impact shown to date; inherently high variability and lack of mechanism for impact make it unlikely that they ever could show impact.	• **Stations/Sampling frequency:** P2, P5, P7/once per month in Jan., Feb., Dec., twice per month Mar. through Nov.
	• **Total samples/year:** 63 for each nutrient
	• **Data collected:** whole near-surface water concentrations of total phosphorus, orthophosphate, nitrate, nitrite, ammonia



LEGEND

▩ = water quality stations

● = continuous temperature monitoring stations

Figure 1. Water quality sampling stations. Seabrook Operational Report, 1994.

WORKING DRAFT

EVALUATION OF SEABROOK STATION WATER QUALITY MONITORING PROGRAM AFTER FIVE YEARS OF PLANT OPERATION

Prepared for

NORTH ATLANTIC ENERGY SERVICE CORPORATION
P.O. Box 300
Seabrook Station
Seabrook, New Hampshire 03874

Prepared by

NORTHEAST UTILITIES SERVICE COMPANY
Safety, Health & Environmental Services
Aquatic Services Branch
Waterford, Connecticut 06385-0128

Reviewed and endorsed by

NORMANDEAU ASSOCIATES, INC
25 Nashua Road
Bedford, New Hampshire 03310

August 1996

Evaluation of the Seabrook Station Water Quality Monitoring Program After Five Years of Plant Operation

Introduction

Monitoring of water quality in the vicinity of Seabrook Station has been one component of the environmental studies designed to assess the impacts associated with construction and operation of the power plant. Water quality data were collected to aid in interpreting information from the biological monitoring programs, and to determine whether the operation of the Seabrook Station Circulating Water System has had a measurable effect on the physical and chemical characteristics of the water column. Parameters measured in this program include water temperature, salinity, dissolved oxygen, and the nutrients orthophosphate, total phosphorus, nitrite, nitrate and ammonia. This report assesses the effectiveness of the current program in meeting the original objectives after five years of power plant operation, and proposes modifications to enhance our ability to assess any potential changes to the environment that might be related to operation of Seabrook Station.

Current Methodology

Water quality monitoring encompasses four studies: 1) offshore temperature, salinity and dissolved oxygen measurement at the plankton sampling stations P2 (intake), P5 (discharge) and P7 (farfield); 2) analyses of dissolved chemical nutrients at P2, P5 and P7; 3) continuous temperature measurement at a nearfield (DS) and a farfield (T7) site; and 4) estuarine temperature and salinity measurement in Hampton Harbor. Offshore temperature, salinity and dissolved oxygen measurements began in 1979 at stations P2 and P5, and in 1982 at station P7. Sampling at P2 and P7 continued to the present; sampling at P5 was suspended from January 1982 until July 1986, but P5 has been sampled

continuously and concurrently with P2 and P7 from July 1986 to present. At all stations, temperature profiles were taken at the near surface (-1 m) and at 2-m increments four times per month from January through December. Water temperature was measured with a field thermistor probe; near-surface and near-bottom salinity was measured either in the field, with a conductivity meter, or in the lab, from samples collected in wax-sealed glass bottles. Dissolved oxygen in near-surface and near-bottom water was determined in the lab, by Winkler titration. Near-surface water samples for nutrient analysis were collected during daylight hours from stations P2, P5 and P7 once per month in January, February and December, and twice monthly from March through November. Nutrient sampling began at stations P2 and P5 in 1978 and at P7 in 1982. Sampling continued until 1981 at P5, and until 1984 at P2 and P7. Sampling resumed at all three stations in July 1986, and has continued to present. Continuous surface water temperature data from discharge (DS) and farfield (T7) areas have been collected since 1990 as part of Seabrook Station's NPDES permit compliance program. Estuarine water temperature and salinity have been recorded weekly since May 1979, at high and low slack tidal stages in Hampton Harbor.

Summary of Results to Date

Seventeen years of sampling (though not concurrently at all stations) allow characterization of several water quality parameters at offshore sites in the vicinity of Seabrook Station. For instance, surface water temperatures follow a predictable seasonal cycle with minima near 0°C in February/March, and maxima around 19-21°C, usually in August (NAI 1996). Bottom water temperature minima were similar to those at the surface, but bottom waters warmed more slowly. When thermal stratification was strongest (again, usually in August), bottom water temperatures were 6-7°C colder than surface temperatures. Bottom water temperatures typically peaked in September, with maxima around 15-17°C. There has been considerable year-to-year variability, but among-station variability was low. As the same patterns and trends were seen at all stations (including farfield), the changes are region-wide, and not attributed to power plant

operation. For both surface and bottom water temperatures, ANOVA modeling showed the Preop-Op X Station interaction term to be non-significant, indicating no power plant effect (NAI 1996).

Similarly, salinity varies seasonally and from year to year, but very little among stations. Surface salinities are affected by freshwater runoff, lowest (20-25‰) in spring (owing to storms and snowmelt) and highest in late autumn-winter (33-35‰); bottom salinity is less affected by runoff or precipitation, and remains more constant with time (29-35‰). Surface and bottom dissolved oxygen concentrations also exhibited seasonal patterns; levels were highest during winter months (11-16 mg/L), and lowest from August through October (5-7 mg/L). This pattern was related to water temperature; relative oxygen concentration was close to 100% saturation throughout the year. As with water temperature, ANOVA modeling for surface and bottom salinities and dissolved oxygen concentrations showed the Preop-Op X Station interaction terms to be non-significant, indicating no effect of power plant operation (NAI 1996).

Concentrations of dissolved chemical nutrients, measured at the offshore sites, also exhibit distinct seasonal patterns. For instance, nitrate-nitrogen is the limiting nutrient for phytoplankton growth, and is depleted from surface waters during the spring phytoplankton bloom, remaining at very low levels (typically below detectable limits) throughout the summer when the water column is stratified. Similarly, nitrite-nitrogen, orthophosphate and total phosphorus, although non-limiting, are also utilized by phytoplankton, and are found at minimum concentrations in summer, and at higher levels in winter, after vertical stratification has broken down and nutrient-rich deep water has mixed with nutrient-depleted surface water. Of the nutrients sampled, only ammonia-nitrogen did not show a seasonal cycle, but rather remained at a relatively constant (but low) level throughout the year. For all nutrients, ANOVA modeling showed that the interaction of the main effects (Preop-Op X Station) was not significant; again, indicating no power plant impact (NAI 1996). Because nutrient concentrations are so tightly

coupled to phytoplankton abundance, further discussion of nutrient sampling is included in the evaluation of the phytoplankton program (NUSCO 1996).

Operational data from continuous temperature sensors allow further characterization of surface water temperatures in the immediate vicinity of the Seabrook Station discharges (DS) and at a farfield site (T7), and have verified thermal plume predictions. In winter, surface water near the discharges is typically 1-2°C warmer than ambient, owing to the upwelling of less dense, heated effluent. However, in summer, the effluent entrains a volume of cold bottom water as it rises to the strongly stratified surface layer, actually lowering temperature at DS, relative to ambient at T7.

Water quality data (temperature and salinity) have also been collected in the Hampton Harbor estuary since 1979. Data from station HH were originally intended to support biological monitoring studies (e.g., benthos, fish, soft-shell clam), and to provide a basis for comparison to Brown's River, and allow assessment of the impacts associated with construction of Seabrook Station and discharge from a settling basin into Brown's River. However, in April 1994, this discharge was diverted to the offshore discharge tunnel, and with no further source of impact to the estuary, sampling at Brown's River was suspended after 1994. Sampling at HH has continued, primarily to provide information about water quality near recreational shellfish monitoring beds and finfish monitoring sites.

Recommendations

The objectives of the water quality monitoring program are: 1) to collect data to aid in interpreting information from the biological monitoring programs, and 2) to determine whether the operation of the Seabrook Station Circulating Water System has had a measurable effect on the physical and chemical characteristics of the water column. The second objective has clearly been met; after 17 years of sampling, including 5 years of power plant operation, we have characterized seasonal patterns for water quality

parameters, and have documented differences and trends among years and among stations. However, statistical analyses show that, for all parameters measured, the Preop-Op X Station interaction term has been non-significant, indicating that the differences were region-wide, and not associated with Seabrook Station operation. The first objective is currently being met; it is an ongoing effort to measure explanatory physical variables that may affect the algae and animals that are studied in other sections of the monitoring program. The proposed modifications to the water quality program are intended to focus efforts in areas that will provide the most useful data for biological monitoring purposes, without affecting our ability to detect power plant impact, should it occur.

The first recommendation is a reiteration of the one made after evaluating the phytoplankton sampling program (NUSCO 1996), and takes into account: 1) that nutrient concentrations in waters near Seabrook Station are tightly coupled to uptake and release rates from phytoplankton; 2) that the phytoplankton source community in the Gulf of Maine is extremely large and the turnover rate extremely rapid; and 3) that no reasonable mechanism exists whereby Seabrook Station could affect nutrient concentration or the phytoplankton community. Therefore, we propose to suspend nutrient analyses at the offshore phytoplankton stations.

The second recommendation, also in agreement with those of other evaluations (e.g., Phytoplankton, Zooplankton, Ichthyoplankton, Epibenthic Crustacea), is the deletion of all water quality sampling at station P5. This station is approximately 1.5 km from the Seabrook Station discharge, too far to be affected by power plant operation, and too far to be even considered a nearfield station. The continuous temperature recorder site at DS is much more representative of water temperature in the immediate vicinity of the discharge. Suspension of sampling at P5 will simplify nearfield-farfield comparisons, and will increase the length of usable preoperational database from 3 years (1987-1989, when all 3 stations were sampled concurrently) to 8 years (1982-1989, when P2 and P7 were both sampled).

The final recommendation is merely to modify techniques used to acquire the water quality data. Water temperature, salinity and dissolved oxygen should be measured, whenever possible, with dependable field probes, incorporating recent advances in analytical technology, and minimizing difficulties associated with handling and storage of glass bottles, and generation and disposal of hazardous wastes from Winkler titrations. In particular, small, relatively inexpensive data loggers are available for temperature recording; these can be placed in the field for several months at a time. If appropriate, this capability can be added to other monitoring programs (e.g., Marine Macrobenthos, Epibenthic Crustaceans).

In summary, the Water Quality Program will be less of a stand-alone monitoring effort, and more of a supplement to the other environmental studies, providing explanatory variables to support conclusions drawn from other aspects of the monitoring program, and helping to distinguish between long-term and short-term trends in the Seabrook area.

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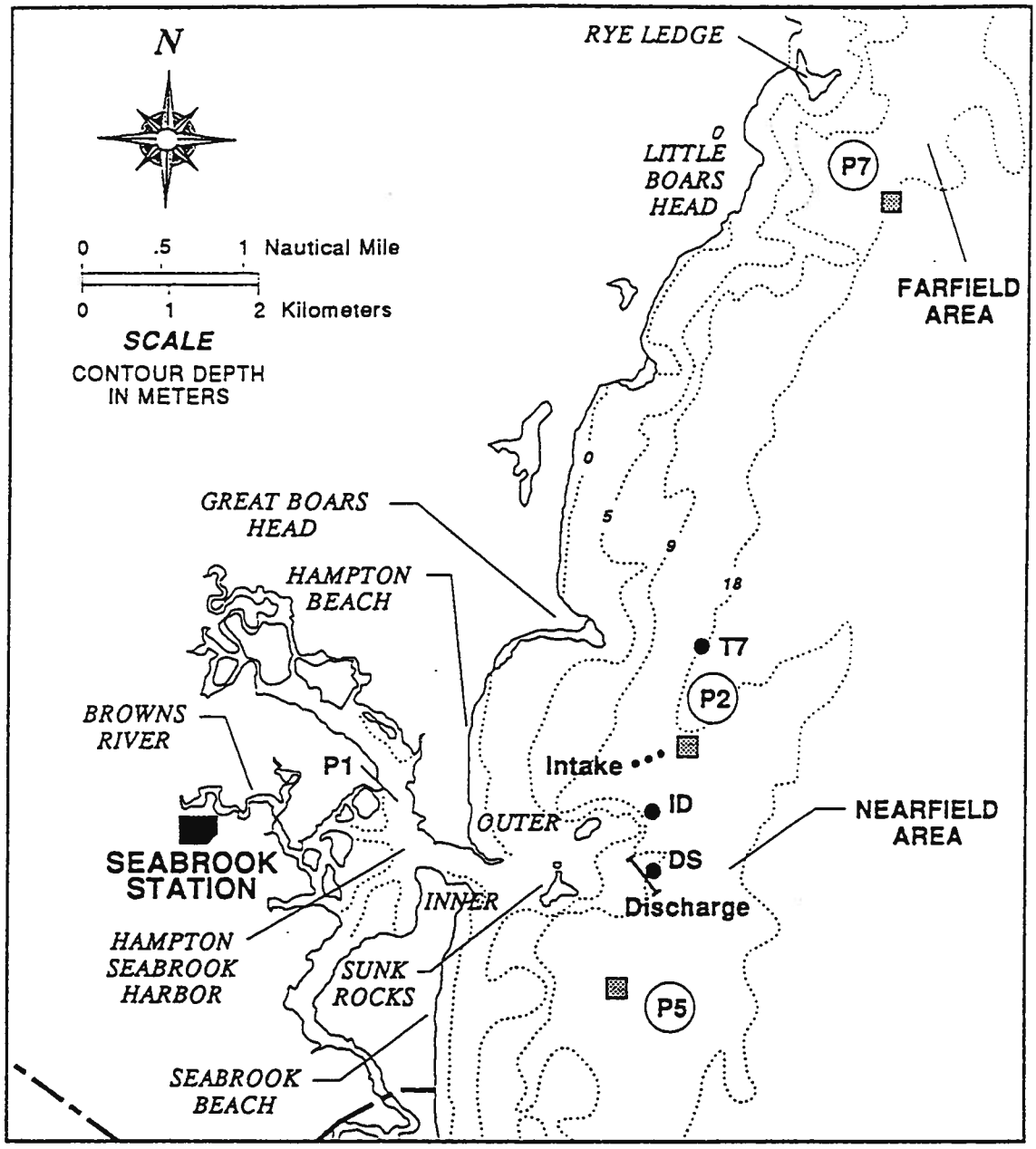

LEGEND

▩ = water quality stations

● = continuous temperature monitoring stations

Figure 1. Water quality sampling stations. Seabrook Operational Report, 1994.

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ZOOPLANKTON

Summary of the Proposed Monitoring Program after 5 Years of Operation

The objective of the proposed zooplankton program is to monitor the effects of Seabrook Station operation on larger zooplankton, which, based on life history information, have greater potential for plant impact. A modified macrozooplankton sampling design would retain sufficient sensitivity to detect potential plant operational impacts on these larger planktonic organisms. Programs for microzooplankton and bivalve larvae are proposed to be discontinued because of the high reproductive capacity of the potentially affected organisms and the lack of significant findings from the monitoring programs after five years of plant operation. Therefore, these programs have served their purpose as part of the Seabrook Station environmental monitoring studies.

1. **Microzooplankton program,** which monitors meroplankton (early developmental stages of benthic invertebrates) and holoplankton (which spend their entire life in the water column), is recommended to be discontinued because after 5 years of plant operation the program has met its objective of assessing potential impact on this community, and none has been detected.

    - The meroplankton taxonomic groups (Bivalvia, Gastropoda, Polychaeta, and Cirripedia) are extremely abundant and, depending on the length of their planktonic stage, can be dispersed over long distances. Successful recruitment is dependent on suitable benthic habitat. If impacts to meroplankton affected subsequent recruitment, they would be reflected in the macrobenthos community. To date, no such impacts have been obsrved.

    - Due to the rapid generation times and food limitations affecting abundance for tintinnids and rotifers, the potential for impacts from Seabrook Station is very low and, not surprisingly, impacts have not been detected for these holoplankton groups.

    - From examination of the data on the dominant copepods collected in the microzooplankton program, it is apparent that the loss of individuals due to through-plant entrainment would have minimal effects on their populations in the Hampton-Seabrook area. Rapid generation turnover rates and large reproductive capacities of these organisms enable them to compensate for high natural mortality and environmental perturbations. Because of their high thermal tolerance, thermal plume entrainment should not affect these organisms.

    - In addition, it has been well documented that other coastal marine power plants do not appreciably affect zooplankton communities, and, as a result, their long-term microzooplankton studies have been concluded.

2. **Bivalve larvae programs** (combined both field and entrainment programs) provided abundance information and analyses for bivalves which indicated no significant effect of Seabrook Station operation after five years, and it is recommended that, because both programs have met their objects, they be concluded.

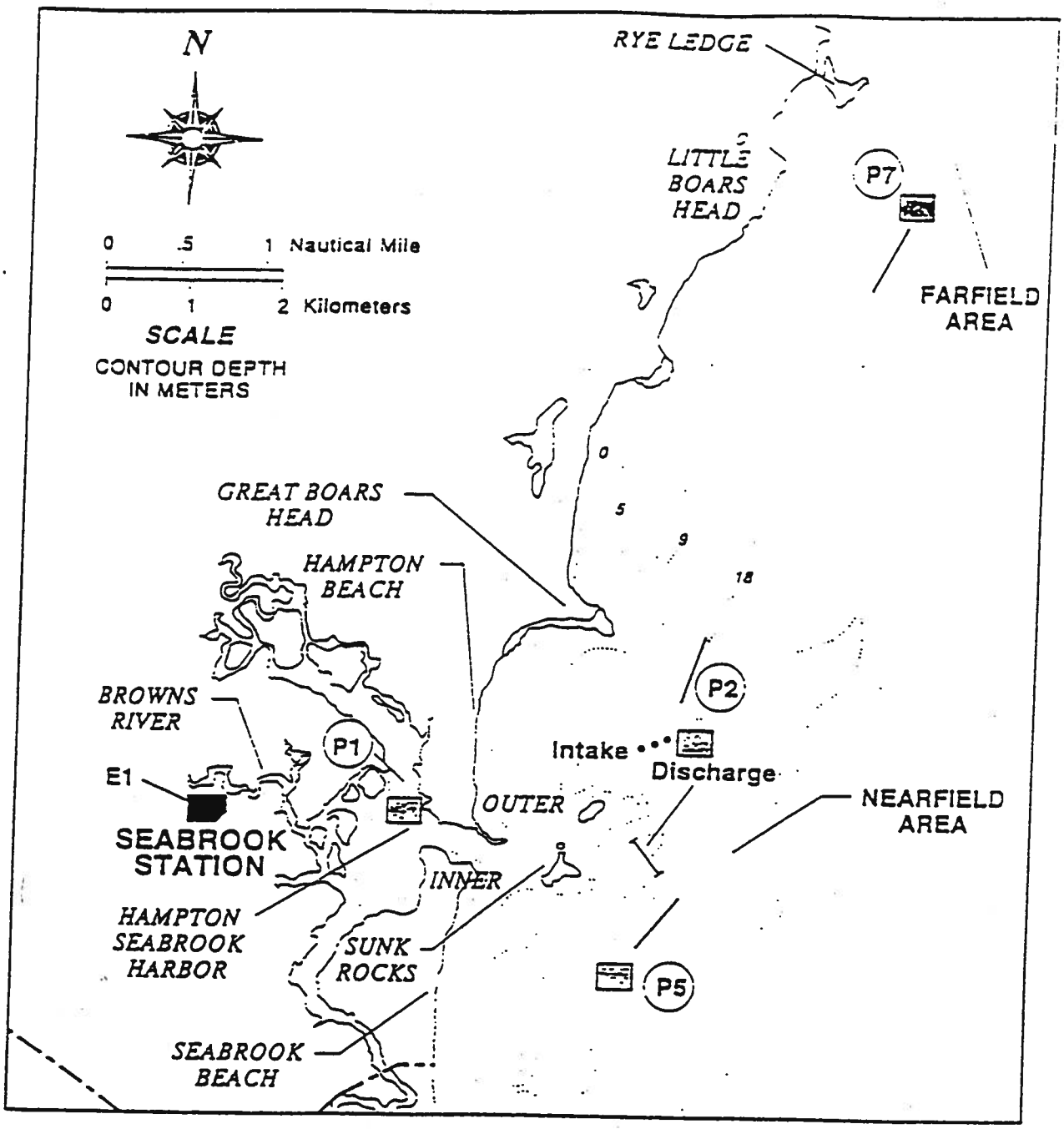
    - Larvae of the recreationally important soft-shell clam are entrained in relatively small numbers (about 0.1% of the total bivalve entrainment). Apparently, larval densities are not related to spat abundances, which appear to be habitat-limited. Similarly blue mussel larvae, which represented over 50% of both field and entrainment bivalve larvae collected, have not been affected after five years of plant operation, despite numerically-high entrainment estimates. The high fecundity of bivalves, coupled with their relatively long larval life stage, makes a localized impact less likely to occur, as these species have evolved to compensate for very high losses in their early life history.

    - Although plant impact is unlikely, monitoring of the important soft-shell clam resource in Hampton-Seabrook as spat will continue (see Soft-shell Clam evaluation.

3. **Macrozooplankton** modifications were based on the results of analyses of data collected through 1995. It is proposed that macrozooplankton collections be reduced from three to one sample per sampling date at stations P2 and P7. Station P5 would no longer be sampled.

    - Results from ANOVAs for each selected species, using the proposed sampling design, indicated that there would be minimal loss in sensitivity to detect a potential plant operational impact. The estimated variances for the critical interaction and error terms were similar with either one sample at two stations (proposed) or with three replicates at three stations (current), suggesting that current sample replication is redundant.

    - The sampling of only one of two nearfield stations will not reduce the ability of the program to detect potential plant operational impacts using the BACI ANOVA model, nor affect additional analyses (i.e., numerical classification and MANOVA).



LEGEND

——— = zooplankton stations

▭ = bivalve larvae stations

Zooplankton sampling stations near Seabrook Station.

ZOOPLANKTON

PROPOSED PROGRAM	PAST PROGRAM
1) Microzooplankton	
• After 5 years of plant operation, no impacts have been detected for selected dominant taxa tested with ANOVA; these taxa have short generation times and are ubiquitous in the Gulf of Maine. Not detecting an impact was anticipated and that outcome has been demonstrated. Therefore other plankton communities will be followed to demonstrate continuance of balanced indigenous populations; this program would not continue.	• **Stations/Sampling frequency:** Stations P2, P5, and P7 - surface and bottom samples - monthly December through February and twice a month March through November • **Replicates:** 4 collected; 2 processed • **Total samples/year:** 504 collected; 252 processed • **Data collected:** Density per m^3
2a) Bivalve larvae	
• Individuals collected in this program are early developmental stages of benthic invertebrates that have a high fecundity to compensate for very high losses during their early life history and are dispersed over a large area by currents. After 5 years of plant operation, no impacts have been detected for selected dominant and commercially important species tested with ANOVA. Other programs that examine the success of their recruitment to the benthic community will continue, therefore this program would be discontinued.	• **Stations/Sampling frequency:** Stations P1, P2, P5, and P7 sampled weekly from mid-April through October • **Replicates:** 2 replicates • **Total samples/year:** 224 • **Data collected:** Density per m^3

ZOOPLANKTON (continued)

PROPOSED PROGRAM	PAST PROGRAM
2b) Bivalve larvae entrainment	
• The primary reason for this program was the concern of entraining soft-shell clam larvae. Annual entrainment estimates after 5 years of plant operation show that these larvae are a minor component (about 0.1%) of the total bivalve entrainment. In addition, there was no relationship found between larval abundance and spat set (see soft-shell clam evaluation). Therefore this program would not continue.	• **Stations/sampling frequency:** Sampled 4 times a month from April through October at the Seabrook Station screenhouse. • **Replicates:** 3 replicates • **Total samples/year:** 84 • **Data collected:** Density per m^3
3) Macrozooplankton	
• **Stations/Sampling frequency:** Stations P2 and P7 sampled twice per month • **Replicates:** 1 sample • **Total samples/year:** 48 • **Data collected:** Density per $1000m^3$	• **Stations/Sampling frequency:** Station P2, P5 and P7 sampled twice per month • **Replicates:** 4 replicates collected; 3 replicates processed • **Total samples/year:** 288 collected; 216 processed • **Data collected:** Density per $1000m^3$

WORKING DRAFT

EVALUATION OF SEABROOK STATION ZOOPLANKTON SAMPLING PROGRAMS AFTER FIVE YEARS OF PLANT OPERATION

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Evaluation of Seabrook Station Zooplankton Sampling Programs After Five Years of Plant Operation

Introduction

Seabrook Station, an 1150-Mwe nuclear-fueled power plant, is located in Seabrook, New Hampshire. The station uses Atlantic Ocean water to condense steam and cool vital equipment associated with the service water system. The station has three mid-water (about 17 ft off-bottom) intake structures located in depths of about 55 ft approximately 1.3 mi offshore of Hampton Beach (Fig. 1). Water withdrawn through a 19-ft diameter tunnel travels about 3.25 mi to the plant, having a transit time of around 70 min. The station is permitted to use up to 2.70 X 10^6 $m^3 \cdot day^{-1}$ (31.3 $m^3 \cdot s^{-1}$) of seawater, 95% for non-contact condenser cooling water and 5% for service water systems. Water used at the station is released through the onsite Discharge Transition Structure (DTS) and travels 3.1 mi through another 19-ft diameter tunnel to eleven diffusers located about 1 mi offshore of the mouth of Hampton-Seabrook Harbor at a depth of approximately 55 ft. The diffusers discharge water towards the surface at a velocity of about 15 $ft \cdot sec^{-1}$. The average monthly increase in temperature (ΔT) at the DTS can be up to 39°F and the maximum daily ΔT cannot exceed 41°F. The rise in temperature of the receiving waters cannot be greater than 5°F, except within 100 ft of the diffusers, where this limit only applies at the surface. This area is the nearfield jet mixing region. Previous hydrothermal modeling and field studies demonstrated that the area of the discharge plume is relatively small, with a surface temperature increase of 3°F encompassing an area of approximately 32 acres around the area of the discharge (Teyssandier et al. 1974; Padmanabhan and Hecker 1991).

Zooplankton are ecologically important in aquatic ecosystems and occupy trophic levels between primary producers (mainly phytoplankton in pelagic marine systems) and higher level consumers. The term zooplankton generally refers to a diverse group of species encompassing many phyla. Zooplankton can be generally classified into three functional groups. Holoplankton spend their entire lives in the water column and include many small

crustaceans (e.g., copepods and cladocerans), rotifers, and protozoans. Meroplankton primarily consist of larval forms, particularly of benthic invertebrates such as mollusks and annelids that eventually settle out of the plankton. Tychoplankton are principally benthic invertebrates (e.g., some amphipods) that become planktonic by active migration into the water column.

Zooplankton studies at Seabrook Station began in July 1976 and include three offshore programs, microzooplankton, macrozooplankton, and bivalve larvae, and after plant start-up, larval bivalve entrainment sampling was initiated. Each of these programs was established separately and has unique sampling methods. However, because the two bivalve programs are closely linked for assessment of Seabrook Station impact, they will be considered together in this evaluation.

Offshore zooplankton studies were initiated to establish baseline data suitable for assessing the effects of station operation by describing the seasonal, annual, and spatial trends in abundance and distribution and community composition of zooplankton in the nearshore waters off Hampton and Seabrook. Sampling also took place within the Hampton-Seabrook Harbor estuary for bivalve larvae because of the valuable soft-shell clam (*Mya arenaria*) recreational fishery there. Seabrook Station began commercial operation in August 1990. Once online, potential impacts of plant operation on zooplankton included entrainment of all life stages of micro- and macrozooplankton and bivalve larvae through the condenser cooling-water system and effects associated with the discharge of heated condenser cooling water from the diffuser system, such as plume entrainment.

Three stations were used to provide abundance data for both micro- and macrozooplankton: P2 and P5, termed nearfield, and P7, farfield (Fig. 1). Bivalve larvae were also sampled at these three locations plus an additional station, P1, established within the Hampton-Seabrook Harbor. Once Seabrook Station began operation, entrained bivalve larvae were sampled at the plant intakes. Sampling gear and frequency of sampling for each of these specific programs

varied and will be discussed separately below for each. Further detailed descriptions of methods, including laboratory processing, are found in NAI (1996a).

Data provided by the sampling programs were used in several types of analyses. These are described in detail in NAI and NUSCO (1994) and NAI (1996a, b, c, d) and include multivariate numerical classification and multivariate analysis of variance (ANOVA) of various zooplankton assemblages; graphical comparisons of annual abundance of selected species; and a fixed effects ANOVA model using specific abundance data for selected species. Data for the ANOVA model met the criteria for a Before-After/Control-Impact (BACI) design (Stewart-Oaten et al. 1986), where sampling was conducted prior to and during plant operation and sampling station locations included both potentially impacted and non-impacted control sites.

The purpose of this evaluation is to critically examine the methodologies and findings for each of the four zooplankton sampling programs after 5 years of Seabrook Station operation. The effectiveness of each program will be assessed and proposals will be made to: 1) maintain current work, 2) enhance or modify programs where necessary, or 3) reduce sampling in cases where the data collected, after 5 years of operations, indicates no plant impact and are no longer necessary for further assessment.

Evaluation of Present Zooplankton Sampling Programs at Seabrook Station With Recommendations For Future Studies

Microzooplankton

Review of sampling methodology. The small planktonic forms considered as microzooplankton were collected using a pump with the discharge filtered through a 76-µm mesh net. Data used for analyses are from two replicate samples collected at two depths (near-surface and bottom). Two stations are located in potentially impacted areas (nearfield),

one near the offshore intake (P2) and the other near the offshore discharge diffuser system (P5), and a third is a non-impacted, farfield control station (P7) that is approximately 7 km north of the discharge area (Fig. 1). Samples were collected twice a month from March through November and monthly in December through February. Sampling at all three stations occurred from July through December 1986 and from April 1990 through the present. In addition, station P2 was sampled from January 1978 through December 1984 and station P7 from January 1982 through December 1984.

The inconsistencies in the sampling time-series at all stations caused some limitations in the data used for analyses, particularly for impact assessment using the Before-After/Control-Impact sampling design of Stewart-Oaten et al. (1986) and statistical testing based on ANOVA models. These data were used for numerical classification and MANOVA. For microzooplankton, numerical classification used data only from station P2. Separate MANOVA tests were conducted on preoperational (stations P2 and P7) and operational (all stations) databases and, therefore, did not test the critical Preop-Op X Station interaction term. ANOVA tests used data from only stations P2 and P7, as P5 did not have a full year of preoperational data available. Also, there was a fairly short preoperational period (January 1982 through December 1984) for the BACI design.

Sampling program evaluation. The microzooplankton taxa and life stages in the Hampton-Seabrook area that composed about 95% of the individuals collected since 1978 at station P2 were representative of two distinct life history strategies, the holoplankton and meroplankton (Table 1). Dominant holoplankton groups collected were copepods (nauplii, copepodites, and adults), tintinnids (loricated protozoan ciliates), and rotifers. The major meroplankton groups were mollusk veligers (Bivalvia and Gastropoda) and larval polychaetes and barnacles (Cirripedia). Copepod nauplii were the most abundant and included the taxonomic categories of Copepoda, *Oithona* sp., and *Pseudocalanus/Calanus* spp. For the combined copepod life stages of copepodites and adults, *Oithona* sp. (probably *O. similis*) was the most abundant (10.7 % of the individuals collected), followed by *Pseudocalanus* sp. (6.2%), and *Temora longicornis* (3.7%). Predominant, but lesser abundant, holoplankton were the copepods

Acartia sp. and *Microsetella norvegica* and the cladocern *Evadne* sp. Most of these taxa were commonly reported in other studies conducted in the northwest Atlantic Ocean (Jeffries and Johnson 1973; Carter and Dadswell 1983; Sherman et al 1983; McLaren et al. 1989; Kane 1993).

A comparison of the abundance of selected microzooplankton taxa (*Pseudocalanus* sp., *Oithona* sp., and *Eurytemora herdmani*) at stations P2 and P7 for data collected through 1995 indicated no plant operational effects, based on no significant ($p \leq 0.05$) differences detected in the critical Preop-Op X Station interaction term from the BACI-design ANOVA (Table 2). The only station difference found was for *Oithona* sp., which were more abundant at nearfield station P2 than at the farfield control station P7. Similarly, results from analyses on community composition at station P2 showed that 92% of all collection dates clustered into three groups, which were termed winter/spring, spring/summer, and late summer/fall (Fig. 2). Temporally, these dominant groups remained relatively consistent among the preoperational and operational periods.

Potential impacts of the operation of Seabrook Station on the microzooplankton community in the Hampton-Seabrook area are through-plant and thermal-plume entrainment of individuals. Possible changes in species abundance and community composition would be related to the life history stage affected and the ability of the population to replace lost individuals.

The meroplankton taxonomic groups collected in the microplankton program (Bivalvia, Gastropoda, Polychaeta, and Cirripedia) are early developmental stages of benthic invertebrates, which typically are extremely abundant and, depending on the length of their planktonic stage, can be dispersed over long distances. Planktonic development is the most common reproductive strategy among temperate marine invertebrates (Epifanio 1988). After larval development and dispersal, the transformed individuals are recruited to the benthic community. Successful recruitment is dependent on suitable benthic habitat and these later developmental stages are monitored at Seabrook Station by the Marine Macrobenthos

program. Therefore, if impacts were to occur to meroplankton stages of these species they should be evident in reduced recruitment, which has not been evident after five years of Seabrook operation (NAI 1996a).

The major holoplankton taxonomic groups are Copepoda, Tintinnidae, and Rotifera, but most marine zooplankton surveys and studies have focused on copepods. Phylogenetically, the tintinnids and rotifers are relatively primitive and have rapid generation times. Tintinnids are protozoan ciliates that use cell division for reproduction and are common in the temperate Atlantic Ocean (Sleigh et al. 1996). Their abundance in Long Island Sound was reported by Capriulo and Carpenter (1983) to have been directly related to the availability of nanoplankton. Many rotifer species are cosmopolitan and primarily found in freshwater (Barnes 1968). Most of their reproduction is probably by parthenogentic females as males have not been identified for many species (Reid 1961). Due to the rapid generation times and food limiting abundance for tintinnids and rotifers, the operation of Seabrook Station likely does not have any adverse effects on their abundance in the Hampton-Seabrook area.

For the microzooplankton community, the copepod component is usually the most scrutinized in power plant studies in the marine environment (discussed below). In the microzooplankton program, copepods are categorized by developmental stage (nauplius, copepodite, and adult). The copepod species or genera collected in the microzooplankton program have relatively short generation times, indicating rapid turnover rates. Landry (1983), in a laboratory study conducted at 15°C, determined that the generation time of seven copepods, including *Acartia clausii*, *A. tonsa*, and *Pseudocalanus* sp. (three genera that are predominant in the Hampton-Seabrook area), ranged from 19 to 21 days among all species examined. McLaren et al. (1989) estimated from field data the number of generations per annual season on the Scotian Shelf as five for *Pseudocalanus newmani* and three to four for *Oithona similis*. Depending upon water temperature, McLaren (1965) noted that *Pseudocalanus* sp. generation time varied from 25 to 50 days, and it was estimated to be 55 to 60 days at 5°C by Davis (1984). *P. minutus* generation time was determined to be 35 days at 8°C, but this decreased to 21 days at 12.5°C

(McLaren 1978). *O. similis* matures from about 40 to 90 days; this rate also varied with temperature, ranging from 42 days at 13.5°C to 67 days at 9°C (McLaren 1978). McLaren (1978) also reported the generation times for *Temora longicornis* as 39 days at 8.5°C and 35 days at 13.5°C and for *Calanus fimarchicus* as 46 days at 10°C and 11.5°C. *Acartia clausi* matures in 21 (20°C) to 65 days (5°C) and *A. tonsa* from 10 (20°C) to 31 days (10°C) (Durbin and Durbin 1981). *Eurytemora herdmani* at the copepodite stage CI matures in 8 days at 15°C and 20 days at 5°C (McLaren and Corkett 1981).

As well as rapid maturation, female copepods have high egg production, expressed as eggs·female^{-1}·day^{-1}, with reports for *A. tonsa* of 25-40 eggs (Dagg 1977) and 5.6-56.6 (Bellantoni and Peterson 1987); *P. minutus* of 4 (Dagg 1977) and 4.5 (Corkett and McLaren (1969); *P. elongatus* of 0.7-3.4 (Corkett and Zillioux 1975); and *T. longicornis* of 4.7-17.3 (Corkett and Zillioux 1975). Also, McLaren and Corkett (1981) found on average 22.4-26.6 eggs per egg sac for *E. herdmani*.

Less is known about mortality rates of copepods in marine systems. However, natural mortality rates were estimated from field data collected in the Hampton-Seabrook area for *O. similis* and *E. herdmani* from the nauplius through adult stages, which were 92.8 and 99.3%, respectively (NAI 1974). For both species, more than 75% of the mortality occurred during the nauplius developmental stage; copepod nauplii represent over 25% of the microzooplankton collected at station P2 from 1978 through 1995 (Table 1).

Effects of other east coast ocean- and estuarine-sited power plants on zooplankton. Zooplankton studies were included in many environmental monitoring programs, particularly during the 1970s, because no data bases were available at the time to illustrate potential effects of coastal power plant operation on zooplankton communities. Both baseline and operational-period studies were customarily required to prepare environmental statements necessary for the licensing of power plants under various provisions of the Clean Water Act administered by the U.S. Environmental Protection Agency (YAEC 1982) and, in some cases, by Technical Specifications of the U.S. Nuclear Regulatory Commission. Consequently, there exists

considerable information from zooplankton studies designed specifically to address the impact of once-through cooling water systems of power plants. Many of the studies at these power plants evaluated entrained zooplankton or populations found in discharge canals, which represent worst cases in terms of impacts. Cooling-water flows at the coastal power plants were generally similar in magnitude, although Seabrook Station for its size (1150 MWe) has a lower demand for cooling water (31.3 $m^3 \cdot s^{-1}$) and higher ΔT (39°F) for its discharge than the nine other plants (Table 3). Brief summaries of these studies are provided as an appendix to this evaluation.

Although the focus for the power plant studies differed, ranging from short-term or experimental studies involving only copepods to relatively long-term monitoring of diverse zooplankton communities, many of the studies observed similar effects and had final conclusions that led to the termination of the zooplankton sampling programs. A review of completed studies (see appendix for citations) showed that impacts to zooplankton by power plant operation were localized and of short duration. Impacts were greatest on the earliest life stages or when chlorine was used as a biocide. Effects were also greatest when water temperatures exceeded some threshold, which for most copepod species was typically 29°C or greater. In a number of instances zooplankters were apparently killed during through-plant entrainment and abundances in the immediate vicinity of the discharge was significantly less than at the intake. However, when entrainment densities were compared with stations a short distances from the plant discharge, no differences were found. No changes in abundance, biomass, or species composition were found overall, with no long-term deleterious effects to zooplankton populations as a whole. Because of the ability of most zooplankton to endure brief exposures to high temperatures with little mortality, thermal plume entrainment was found to be an insignificant effect. Because no significant long-term changes were found, it is not surprising that the monitoring of zooplankton at other northeastern power plants has been discontinued for a decade or more.

In addition to studies done at specific coastal power plants, several reviews (Tetra Tech, Inc. 1978; LMS 1979; YAEC 1982) also summarized relevant findings and made generalized conclusions about ocean-sited power plant impact on zooplankton. These references noted that no long-term changes were found in species composition of zooplankton communities as a result of power plant operation. Any compositional changes found were transitory and limited to the immediate area of plant discharges. In fact, some stations saw localized increases in zooplankton abundance within the discharge. The quick dilution and cooling of heated discharges meant that exposure to high temperatures was usually brief due to rapid thermal plume dispersion in marine waters. Thermal plume entrainment did not cause mortalities nor were there statistically significant differences found for variables when compared to control sites. The absence of wide-spread effects in the marine environment was not unexpected as coastal oceanic zooplankton have high thermal tolerances and rapid reproductive rates. These plants only affected a very small portion of the receiving water body due to relatively small amounts of water withdrawn from large open coastal water bodies that are constantly replenished by longshore transport. Marine zooplankton species are widely distributed with relatively short generation times, so only a small fraction of their populations is affected by power plant operation. These reviews concluded that deleterious power plant effects on zooplankton in marine ecosystems were unlikely and plant operation would not cause harm to this trophic level.

Recommendations. Based on the life history of the dominant copepods collected in the microzooplankton program, it is apparent that the loss of individuals due to through-plant entrainment would have little or no effect on their populations in the Hampton-Seabrook area. Because of high thermal tolerances, thermal plume entrainment should not affect these organisms. The populations of copepods and other holoplankters have rapid generation turnover rates, high reproductive rates, and a high natural mortality, enabling them to rapidly compensate for environmental perturbations. The inshore microzooplankton community is ubiquitous in the waters of the Gulf of Maine and the dominant species have wide distributional ranges. Coastal marine power plants do not appreciably affect zooplankton

communities. Thus, it is not surprising no significant findings of impact were found by the microzooplankton sampling program at Seabrook Station. In addition, effects to higher trophic levels that depend upon microzooplankton as prey are also unlikely. The microzooplankton monitoring has served its purpose by demonstrating this lack of plant impact. Therefore, it is proposed that microzooplankton studies be concluded after the completion of five years of monitoring during Seabrook Station operation.

Bivalve Larvae and Bivalve Larvae Entrainment

Review of sampling methodology. Bivalve larvae samples were taken in the field using a 0.5-m plankton net having 76-µm mesh. Samples were collected weekly from mid-April through October at four stations: Hampton Harbor, P1; nearfield stations P2 and P5; and farfield station P7 (Fig. 1). Collections were taken at P2 beginning in July 1976, at P7 in April 1982, at P1 in July 1986, and P5 was sampled from July through December 1986 and April 1988 through the present. Two simultaneous 2-min oblique tows were taken at each station, unless clogging occurred, in which case vertical tows were made. Sample volumes averaged about 9 m^3 for oblique tows and 3 m^3 for vertical tows. Data collected were used to describe the spatial and temporal distributions of eleven taxa of umboned bivalve veliger larvae (common names from Turgeon et al. 1988): *Mytilus edulis* (blue mussel), *Anomia squamula* (prickly jingle), *Hiatella* sp. (hiatella), *Modiolus modiolus* (northern horsemussel), Solenidae (razor clams, including *Ensis directus*, Atlantic jackknife; *Siliqua costata*, Atlantic razor; and *S. squama*, rough razor), *Mya truncata* (truncate softshell), *M. arenaria* (softshell), *Spisula solidissima* (Atlantic surfclam), *Macoma balthica* (Baltic macoma), *Placopecten magellanicus* (sea scallop), and *Teredo navalis* (naval shipworm). All other species collected were grouped collectively as Bivalvia.

Bivalve larvae entrainment samples have been taken at the Seabrook Station circulating water pumphouse since June 1990, just prior to plant start-up (earlier samples taken from July 1986

through June 1987 will not be discussed here). Nets of 76-µm mesh were deployed in a double-barrel collector described in detail in NAI (1996a); volume filtered averaged about 7 m^3. Collections were made up to four times a month during the day and coincided with offshore bivalve sampling whenever possible. Three replicate samples were taken on each date. Samples were not taken during plant outages or when sampling equipment malfunctioned; no sampling occurred in 1994. Bivalve larvae were identified to the same twelve taxonomic categories as given above for the Bivalve Larvae program. Entrainment estimates for each taxon were calculated by multiplying the monthly average daily volume of circulating water by the number of days represented by each sampling date and then summing by month.

Sampling programs evaluation. As the data from larval bivalve station P1 are only used in conjunction with *Mya arenara* studies, the utility of continued sampling at this station will appear in the Soft-shell Clam evaluation. Effects of Seabrook Station bivalve entrainment were assessed directly from the magnitude of the entrainment estimates, from analyses of community and taxon-specific trends in abundance during the preoperational and operational periods using the BACI ANOVA model, and from abundance information available for settled life stages for some of the species from the Marine Macrobenthos (NAI 1996b), Surface Panels (NAI 1996c), and Soft-shell Clam (NAI 1996d) monitoring programs at Seabrook Station.

Field-collected larval bivalve collections from 1988 through 1995 were dominated by blue mussel (Table 4). Prickly jingle and hiatella were also abundant, but soft-shell clam larvae were relatively scarce, making up only 0.4% of the catch.

Annual totals of entrained bivalve larvae varied, depending not only upon variations in larval abundance and in the presence of larvae in offshore waters, but also on plant operation and sampling gear availability (e.g., no samples taken after June in 1992 or in all of 1994). The largest annual total was during 1995, when 27 trillion larvae were estimated to have been

entrained (Table 5). This was more than 50% larger than the next highest estimate (18 trillion) during 1993. Other factors, such as water temperature, also likely affected the spawning and larval stage duration of various bivalve species and their availability. For example, the high entrainment in 1995 was due, in part, to very high densities of blue mussel veligers found offshore (NAI 1996a). Peak numbers of larvae at the plant and in offshore samples were not always synchronous. Entrainment and offshore abundance of blue mussel larvae usually coincided during mid-June through July, but prickly jingle larvae were most numerous offshore in June, but in entrainment samples during July and August.

The blue mussel was by far the most abundant larval bivalve entrained, making up about half of the total (Table 5). Another quarter of the total was made up by the prickly jingle and 11.5% by hiatella. The recreationally and commercially important soft-shell clam and sea scallop only made up 0.1% or less of the total in entrainment collections. Both species had peak entrainment in 1993, with totals of 22.5 and 16.9 billion larvae entrained, respectively. The percent species composition in entrainment collections was generally similar to that seen in the field bivalve sampling program (Table 4), even though the data used came from different time periods.

Bivalve abundance information is available from a number of sources. Since the beginning of environmental studies at Seabrook Station, much interest in potential plant effects centered on the soft-shell clam, which was recognized as an important species for concern (NAI 1971). Even after the proposed estuarine intake was moved offshore, this species remained as a focus for study and the soft-shell clam has been treated as a distinct sampling program during Seabrook Station environmental studies. As such, a separate evaluation of the soft-shell clam sampling program was prepared. However, since the field bivalve sampling and bivalve entrainment studies originated to a large degree from concerns over the local soft-shell clam resource, it will be discussed briefly here. A comparison of larval soft-shell clam abundance at stations P1 and P2 with spat densities in Hampton Harbor indicated that larval and spat abundances were not related (see the Soft-shell Clam evaluation for further details). Since recruitment success of soft-shell clams was not dependent upon larval abundance, the number

of larvae entrained are not relevant to the future abundance of clams in Hampton Harbor. Results of ANOVA indicated that preoperational-operational differences in abundance for both larvae at the three plankton stations and seed (1-12 mm) clams settling in Hampton Harbor and Plum Island Sound, MA were consistent among stations (Table 6). This further suggested no effect by Seabrook Station on this species.

Blue mussels dominated the assemblage of bivalve larvae in both field and entrainment collections. Spawning of blue mussels in the Gulf of Maine is probably limited to periods when water temperatures are above 10-12°C (Podniesinski and McAlice 1986). In Long Island Sound, Fell and Balsamo (1985) found spawning to be asynchronous both within and among local populations and occurred over a 2- to 3-month period. Spawning of Long Island Sound populations was also restricted by limited food availability for most of the year and was therefore sporadic (Newell et al. 1982). Depending upon temperature, larval development requires 3 to 5 weeks and metamorphosis may be delayed until suitable settlement conditions are encountered (Bayne 1976). Based on these aspects of blue mussel reproduction, mussels collected as part of larval bivalve monitoring are present in the water column over a long period, and recruitment in the Hampton-Seabrook area from non-local sources is likely as larvae are carried into the area by water currents. For blue mussel larvae, the Preop-Op X Station interaction term was not significant, indicating no plant effect (Table 6). In fact, blue mussel larvae have been more abundant during the operational period than the preoperational period.

Near Seabrook Station, settlement of Mytilidae (primarily the blue mussel) in the nearfield and farfield areas was monitored monthly on short-term surface panels (NAI 1996c). Results from this study indicated that Mytilidae settlement increased from the preoperational period to operational period in the nearfield area, with no between-period difference in the farfield area (Table 6). This type of relationship between nearfield and farfield trends, while resulting in a significant interaction term of the ANOVA model, is not consistent with a power plant impact. Similarly, Mytilidae densities (mostly newly settled spat) were also monitored in intertidal, shallow subtidal and mid-depth horizontal ledges near the discharge as part of the marine

macrobenthos destructive sampling program (NAI 1996b). For all three depth zones, the interaction term was not significant (Table 6), indicating that entrainment or other potential impacts from Seabrook operation have not affected Mytilidae settlement and recruitment in the nearfield area.

The lack of impacts to settled Mytilidae determined from monitoring studies is not surprising, as the life cycle and reproductive strategy for *Mytilus edulis* greatly reduces the potential for impacts from larval entraiment. Average-sized individual female *M. edulis* can produce 7-8 x 10^6 eggs (Seed and Suchanek 1992), while larger individuals can produce as many as 40 x 10^6 eggs (Thompson 1979). High fecundity is essential, since natural mortality of larvae (from starvation and predation) approaches or exceeds 99% (Bayne 1976; Lutz and Kennish 1992). Large differences between fecundity and recruitment also suggest tremendous mortality during the larval period (Thorson 1950), which can last from 1-2 months (Bayne 1976). Within a given area, mussel spawning and larval occurrence are generally predictable (Fell and Balsamo 1985; Podniesinski and McAlice 1986); juvenile abundance is more erratic, as settlement appears to be correlated with suitable substrate for attachment (Newell et al. 1991). High natural mortality, wide dispersal of larvae, and the lack of evidence for a relation between larval abundance and subsequent recruitment to natual habitats make impacts from Seabrook operation unlikely.

Another common bivalve in larval samples, the northern horsemussel, is also monitored in the destructive marine macrobenthos study. This species has a reproductive strategy similar to that of the blue mussel. Results of an ANOVA performed on densities at mid-depth macrobenthos stations revealed no indications of power plant impact (Table 6). Settlement and early recruitment of Mytilidae and two other common bivalve larvae taxa (prickly jingle and hiatella) are monitored on subtidal bottom panels. For all three taxa, abundance increases were observed at nearfield and farfield stations during the operational period, relative to the preoperational period, indicating no effect from plant operation (NAI 1996b). For larvae of razor clams and hiatella, no significant nearfield-farfield differences were found. The interaction terms for both taxa, however, were significant. Densities of razor clams during the operational period remained similar to the preoperational period at stations P2 and P7, but declined at P5. Densities of

hiatella increased during the operational period at each of the three stations, but the change was only significant for station P2. Annual time-series plots of abundance indicated generally similar trends in density over all years for both taxa (NAI 1996a). Consequently, the significant interaction term was probably not biologically significant and is likely unrelated to Seabrook Station operation.

Besides through-plant entrainment effects, larval bivalves can be entrained within the Seabrook Station thermal plume. Barker and Stewart (1978) performed temperature tolerance experiments with soft-shell clam and blue mussel larvae to determine their potential mortality after passing through the condenser cooling-water system of a power plant, which would be considerably more likely to cause mortality than thermal plume entrainment. For example, they reported mortality of 1-day-old soft-shell clam was only 10% when exposed to a ΔT of 15°C for 60 to 180 minutes. In general survival was good, except at relatively high temperatures and over long exposure periods. Also, tolerance to high temperatures increased with age. Water temperature at time of spawning was also considered to be an important factor for survival of entrained bivalve larvae, with larvae spawned at higher temperatures likely to experience higher mortality. Thus, it appears that bivalve larvae would not be appreciably affected by thermal plume entrainment at Seabrook Station.

Recommendations. Results from several sampling programs that provided abundance information and analyses for bivalves indicated no significant effect of Seabrook Station operation. Larvae of the important soft-shell clam are entrained in relatively small numbers. Apparently, larval densities are not related to spat abundances, which are likely controlled by environmental factors. Similarly, the dominant blue mussel has not been affected by station operation despite numerically high entrainment estimates. The high fecundity of bivalves plus their relatively long larval life stage makes a localized impact less likely to occur as these species have evolved to compensate for very high losses in their early life history. The field bivalve and bivalve entrainment programs have served a useful purpose in documenting no significant changes for the selected species. Because no plant impacts have been found, nor

are any likely, it is recommended that these sampling programs be concluded after the completion of five years of studies during Seabrook Station operation. Although plant impact is unlikely, monitoring of the important soft-shell clam resource in Hampton-Seabrook Harbor, however, will continue, as proposed in the Soft-shell Clam evaluation.

Macrozooplankton

Review of sampling methodology. The present macrozooplankton sampling design consists of two stations located in potentially impacted areas (nearfield), one near the offshore intake (P2) and the other near the offshore discharge diffuser system (P5), and a non-impacted (farfield) or control station (P7) that is approximately 7 km north of the discharge area (Fig. 1). These stations have been sampled consistently since July 1986. In addition, station P2 was sampled from January 1978 through December 1984 and P7 from January 1982 through December 1984. Primarily, only data since 1987 have been used for impact assessment because these collections met the Before-After/Control-Impact sampling design requirements (Stewart-Oaten et al. 1986) and were amenable to statistical testing based on ANOVA models. In addition, these data were used for numerical classification and MANOVA. For ANOVAs, abundance of the following four selected macrozooplankton species were examined: *Calanus finmarchicus* (copepodites and adults separately), *Carcinus maenas* (larvae), *Crangon septemspinosa* (zoeae and post-larvae) and *Neomysis americana* (all life stages combined). For these selected species, all annual data from twice monthly collections were included in the analyses, except for *C. maenas* larvae, which occur seasonally and for which analyses were restricted to data collected from June through September (NAI 1996a).

Data used in the analyses were from three randomly selected replicates of four samples collected in two consecutive tows (NAI 1996a). Collections were made with paired 1-m diameter 505-µm mesh nets at each station on two sampling dates per month, usually from alternate weeks. For the 1995 data analyses, the $\log_{10}$ transformed replicate sample densities

were averaged. The ANOVA model was a two-way factorial design with nested effects. The main effects were operational periods (Preop-Op) and stations (Station), and the model included their interaction term (Preop-Op X Station). Nested temporal effects were years within operational periods (Year(Preop-Op)) and months within year (Month(Year)). For both nested terms, variation was partitioned ignoring stations (stations combined). A fixed-effects model was assumed with all sources of variation tested against the residual mean-square (Error) term. Type III (SAS Institute Inc. 1985) sums of squares were used for the analyses because the cells in the factorial design contained unequal numbers of observations (Freund et al. 1986). To separate preoperational from operational periods the 1990 data were excluded because part of that year was preoperational and the remaining operational. The source of variation of primary concern for power plant impact assessment was the Preop-Op X Station interaction (Thomas 1977; Green 1979; Stewart-Oaten et al. 1986). Through 1995, no significant interactions have been detected for the four selected macrozooplankton species (NAI 1996a), indicating no effect of Seabrook Station operation on their abundance.

Sampling program evaluation. Traditionally, replicate sampling has been conducted to estimate plankton abundance because of their suspected patchy distribution. The 8 years of macrozooplankton data (1987-95, excluding 1990) collected at three stations provided a long time-series to evaluate whether there has been enough variability among the three replicate samples to warrant their continued collection and if data from only one (P2) of the two nearfield station was sufficient. Therefore, the macrozooplankton program evaluation will attempt to determine whether the present program would be affected in its ability to detect plant operational impacts if the number of replicates was reduced from three to one and if nearfield station P5 was not sampled.

The effect of using data from only one sample per date at the present three stations and with only one of the two nearfield stations was simulated by recomputing the previously described ANOVAs using data from all three replicates and comparing these results to those obtained by using only the first replicate sample collected at the three stations and at only stations P2 and P7. These changes were evaluated on the similarity of results obtained from the ANOVAs for

each of the selected species. Of particular concern were the results from testing the source of variation for the Preop-Op X Station interactions and whether the Error terms were reasonably stable. The interaction term was examined statistically with separate F-tests constructed as ratios of corresponding mean squares, where the larger of the two mean squares was the numerator (Snedecor and Cochran 1967). The similarity of error mean squares of the ANOVA models were examined because this term accounted for all unexplained variance or "natural noise", and thus, contributed critically to the final sensitivity of every F-test.

Evaluation results. Comparisons among the three ANOVAs (three stations-three replicates versus three stations-one sample and two stations-one sample) for each selected species showed similar results in assessing potential plant impact (Tables 7 through 11). Based on the sources of variation that were significant ($p \leq 0.05$) in each ANOVA, a comparison of the models for three stations-three replicates and the three stations-one sample showed that the only significant differences in F-test were for the Preop-Op and Year(Preop-Op) terms for *C. finmarchicus* copepodites (Table 7). For the comparison of three replicates at three stations versus one sample at two stations there were several differences: the Preop-Op and Year(Preop-Op) terms for *C. finmarchicus* copepodites; Year(Preop-Op) and Station terms for *C. finmarchicus* adults (Tables A and B). No differences were found for *C. maenus* larvae, *C. septemspinosa* zoeae and post-larvae, and for *N. americana* (Tables 9 through 11). Further, the critical interaction (Preop-Op X Station) term was not significant in any ANOVAs. Of particular importance was that the residual mean squares (i.e., Error terms) were similar, although slightly larger for both the simulated three stations-one sample and two stations-one sample models (particularly for *C. finmarchicus* adults), which indicated that a reduction to one sample per date would result in a minimal increase in the estimate of the unexplained variance (Fig. 3).

The minimal loss in sensitivity to detect possible operational effects with a reduction in sampling was further supported by the results of F-tests, which compared the mean squares of the Preop-Op X Station term (Table 12). The only significant ($p \leq 0.05$) difference in mean

squares was for *C. fimarchicus* copepodites for three replicates at three stations versus one sample at two stations. Between-tows variability was negligible probably because replicate tows at the same location were collected only a few minutes apart.. It is also important to remember that in Before-After/Control-Impact sampling designs, the true replication units are the sampling dates rather than the tows on each sampling date (Stewart-Oaten et al. 1986).

Reducing the number of replicates from three to one sample and stations (P2 and P7 only) could also affect the taxa composition data used in the numerical classification and MANOVA. Using all the data (three replicates) collected at three stations from 1987-95, a total of 107 taxa were identified, with the most abundant taxa comprising about 96% of the total (Table 13). Using data from only the first replicate collected at the three stations, 105 taxa would have been identified. For only one sample taken at stations P2 and P7, 103 taxa were present. The two species lost for the three station-one sample simulation were *Nebalia bipes* and *Spirontocaris phippsii* and for the two station-one sample simulation two additional taxa were not present, *Campylaspis rubicunda* and *Heteromysis formosa*. These taxa are rare and each accounted for less than 0.1 % of the species composition. They probably would have been excluded from the analyses based on the selection criteria for "dominant" taxa (NAI 1996a). Frequency distributions of taxa using the three station-three replicates and the simulated three station-one sample and two station-one sample were compared using the chi-square goodness-of-fit test (Sokal and Rohlf 1969). No significant difference was detected ($X^2 = 41.1$ and 89.4, respectively with df = 106). Similarly, for the top 20 taxa (Table 13), which accounted for over 95% of the macrozooplankton abundance during 1987-95, the contributions from each taxon showed almost no change regardless of whether three replicates or one sample at three stations and two stations were used in the calculation. Therefore, the reduction to one sample per sampling date will not appreciably alter the results from numerical classification or MANOVA analyses.

Recommendations. The similarity in results from the three ANOVAs for each selected species indicated that there would be minimal loss in sensitivity to detect a potential plant operational impact if the collections of macrozooplankton were reduced to one sample per

date at stations P2 and P7. The estimated variances for the critical interaction and error terms were similar with either one sample at two stations or with three replicates at three stations, suggesting that current sample replication is redundant. Therefore, it is proposed that macrozooplankton collections be reduced from three to one sample per sampling date at stations P2 and P7. This will not reduce the ability of the program to detect potential plant operational impacts using the BACI ANOVA model nor affect additional analyses (i.e., numerical classification and MANOVA).

Conclusions

The zooplankton sampling program at Seabrook Station will focus on the larger macrozooplankton, which, based on life history information, have more potential to be affected by plant operation. This sampling is proposed to be modified to increase sampling efficiency without losing information critical for impact assessment. Because of the capacity of the targeted organisms for reproduction and the lack of significant findings from the monitoring programs, microzooplankton, field bivalve, and bivalve entrainment programs are proposed to be discontinued, having served their purpose as part of the Seabrook Station environmental monitoring studies. Although plant impact is unlikely, monitoring of the important soft-shell clam resource in Hampton-Seabrook Harbor is proposed to continue (see the Soft-shell Clam evaluation).

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Table 1. Dominant microzooplankton taxa and life stages in the Hampton-Seabr(represent 95% of the individuals collected at station P2 from 1978 through 1995.

Taxa	Developmental stage	Percentage
Bivalvia	veliger	18.2
Copepoda	nauplius	15.9
Oithona sp.	nauplius	11.4
Oithona sp.	copepodite and adult	10.7
Tintinnidae		8.8
Pseudocalanus/Calanus spp.	nauplius	8.6
Pseudocalanus sp.	copepodite and adult	6.2
Rotifera		4.0
Temora longicornis	copepodite and adult	3.7
Gastropoda	veliger	1.7
Polychaeta	larva	1.5
Acartia sp.	copepodite and adult	1.2
Microsetella norvegica	copepodite and adult	1.0
Evadne sp.		1.0
Cirripedia	larva	0.9

Table 2. Summary of potential effect of Seabrook Station operation on selected microzooplankton taxa and life stages based on results from the BACI ANOVA models (from NAI 1996a).

Taxa	Lifestage	Operational Period Similar to Preoperational Period?	Differences Among Stations?	Preop / Op Differences[a] Consistent Among Stations?
Eurytemora sp.	copepodite	no Preop > Op	no	yes
Eurytemora herdmani	adult	no Preop > Op	no	yes
Pseudocalanus / Calanus sp.	nauplii	no Preop > Op	no	yes
Pseudocalanus sp.	copepodite	yes	no	yes
Pseudocalanus sp.	adult	no Preop > Op	no	yes
Oithona sp.	nauplii	yes	no	yes
Oithona sp.	copepodite	no Preop < Op	yes P2 > P7	yes
Oithona sp.	adult	no Preop < Op	no	yes

[a] Based on Preop-Op X Station interaction term from the ANOVA.

Table 3. Characteristics of east coast ocean- and estuarine-sited power plants and studies that provided information on microzooplankton for comparison to Seabrook Station.

Power plant	State	Number of generating units	Net generation (MWe)[a]	Cooling-water flow ($m^3 \cdot sec^{-1}$)[a]	ΔT (°F)[b]	Years reported for studies of microzooplankton[c]
Crane	MD	2	385	16.4	10.1-12.1	1974-75
Calvert Cliffs	MD	2	1620	73.0	12.0	1974-81
Chalk Point	MD	2	656	30.0	15.0	1963-79[d]
Indian River	DE	1	347	17.0	10.8	1970-71
Oyster Creek	NJ	1	620	29.0	23.0	1975-78
Millstone	CT	3	2680	117.7	21.4	1970-82[d]
Brayton Point	MA	4	1590	46.8	26.6	1972-76
Pilgrim	MA	1	655	20.3	29.0	1973-75
Maine Yankee	ME	1	855	26.6	28.8	1969-77[d]
Seabrook	NH	1	1150	31.3	39.0	1978-present[d]

[a] Electrical generation and nominal cooling-water flow combined for all units.
[b] Average nominal value for all units at full load or ΔT reported at the time of the studies.
[c] Studies at power plants other than Seabrook Station believed to be terminated following the last year given.
[d] Years during which data were collected varied; not inclusive for all aspects of these particular studies.

Table 4. Percent of total density for the twelve selected bivalve taxa taken at stations P2, P5, and P7 from 1988 through 1995.

Taxa	Percent
Mytilus edulis	56.3
Anomia squamula	19.5
Hiatella sp.	12.5
Modiolus modiolus	5.2
Bivalvia	2.2
Solenidae	2.0
Spisula solidissima	0.8
Macoma balthica	0.6
Mya truncata	0.6
Mya arenaria	0.4
Placopecten magellanicus	<0.1
Teredo navalis	<0.1

Table 5. Estimated numbers (in billions) of bivalve larvae entrained at Seabrook Station from 1990 through 1995.

Taxa	June-Oct 1990	Apr-Aug 1991	Apr-June 1992[a]	Apr-Oct 1993[b]	Apr-Oct 1995	Total	%
Mytilus edulis	3991.3	1687.4	121.9	10050.7	13213.0	29082.3	51.4
Anomia squamula	1691.4	250.8	6.8	3922.7	8905.9	14777.6	26.1
Hiatella sp.	876.6	451.2	189.8	2405.5	2598.2	6521.3	11.5
Modiolus modiolus	909.7	160.1	0.2	1283.9	546.4	2900.3	5.1
Bivalvia	155.2	36.9	14.5	334.3	795.1	1336.0	2.4
Solenidae	61.1	12.7[c]	75.6	102.5	1092.3	1331.5	2.4
Mya truncata	249.0	6.5	1.1	2.1	27.6	286.3	0.5
Spisula solidissima	69.0	4.3	0.0	48.5	112.5	234.3	0.4
Mya arenaria	8.1	0.6	0.2	22.5	4.3	35.7	0.1
Macoma balthica	26.5	1.1	0.0	0.2	2.0	29.8	<0.1
Placopecten magellanicus	0.6	0.7	0.1	16.9	6.2	24.5	<0.1
Teredo navalis	<0.1	15.9	0.0	0.0	4.8	20.7	<0.1
Annual total	8038.5	2628.2	410.2	18189.8	27308.3		

[a] Equipment failure in June; no samples taken thereafter.
[b] No entrainment samples taken in 1994 due to plant shutdown and sampling equipment malfunctions.
[c] Not given in NAI (1992b); estimated from data given in NAI (1992a).

Table 6. Summary of potential effects of Seabrook Station operation on selected larval bivalve taxa based on results from the BACI ANOVA models (from NAI 1996a, b, c, d).

Taxa / Sampling Program	Operational Period Similar to Preoperational Period?	Differences Among Stations?	Preop / Op Differences[a] Consistent Among Stations?	Multiple Comparisons[b]
Mya arenaria Larval Bivalve	no Preop > Op	no	yes	-
Mya arenaria Nearfield/farfield flats seed clam (1-12 mm) density	yes	yes Plum Is. Sound > Hampton Harbor	yes	-
Mytilus edulis Larval Bivalve	no Op > Preop	no	yes	-
Mytilidae[c] Surface Panels[d]	no Op > Preop	no	no	B19Op B31Pr B31Op B19Pr
Mytilidae[c] Macrobenthos[d] (Intertidal)	no Preop > Op	yes B1 > B5	yes	-
Mytilidae[c] Macrobenthos (Shallow sudtidal)	yes	yes B35 > B17	yes	-
Mytilidae[c] Macrobenthos (Mid-depth)	no Preop > Op	yes B31 > B19	yes	-
Hiatella sp. Larval Bivalve	yes	no	no	P2Op P2Pr P5Pr P7Pr P5Op P7Op
Modiolus modiolus Macrobenthos (Mid-depth)	no Preop > Op	no	yes	-
Solenidae Larval Bivalve	yes	no	no	P2Op P2Pr P5Op P7Op P7Pr P5Pr

[a] Based on Preop-Op X Station interaction term from the ANOVA.
[b] Ranked in decreasing order; LS means test used for significant interaction term.
[c] Primarily *Mytilus edulis*.
[d] See the Surface Panels and Marine Macrobenthos evaluations for additional details.

Table 7. *Calanus finmarchicus* copepodites: Comparison of results from three analysis of variance tests, the first based on three replicate samples at three stations, the second on one sample at three stations and the third on one sample at two stations, 1987-95.

Source of variation	df	MS	F-value	P
	Three stations - Three replicate samples			
Preop-Op	1	3.18	5.51	0.019
Year (Preop-Op)	6	1.31	2.26	0.037
Month (Year)	88	10.88	18.82	0.001
Station	2	3.30	5.70	0.004
Preop-Op X Station	2	0.23	0.40	0.672
Error	470	0.58		
	Three stations - One sample			
Preop-Op	1	1.83	2.42	0.121
Year (Preop-Op)	6	1.29	1.71	0.117
Month (Year)	88	11.34	15.00	0.001
Station	2	8.07	10.67	0.001
Preop-Op X Station	2	0.30	0.40	0.669
Error	470	0.76		
	Two stations - One sample			
Preop-Op	1	0.39	0.48	0.487
Year (Preop-Op)	6	1.29	1.60	0.146
Month (Year)	88	7.99	9.92	0.001
Station	1	6.83	8.47	0.004
Preop-Op X Station	1	>0.01	0.00	0.994
Error	282	0.81		

Table 8. *Calanus finmarchicus* adults: Comparison of results from three analysis of variance tests, the first based on three replicate samples at three stations, the second on one sample at three stations and the third on one sample at two stations, 1987-95.

Source of variation	df	MS	F-value	P
	Three stations - Three replicate samples			
Preop-Op	1	0.151	0.18	0.674
Year (Preop-Op)	6	5.40	6.33	0.001
Month (Year)	88	6.01	7.05	0.001
Station	2	3.91	4.59	0.011
Preop-Op X Station	2	0.43	0.50	0.605
Error	470	0.85		
	Three stations - One sample			
Preop-Op	1	0.97	0.68	0.410
Year (Preop-Op)	6	4.95	3.47	0.002
Month (Year)	88	6.17	4.33	0.001
Station	2	7.61	5.34	0.005
Preop-Op X Station	2	0.94	0.66	0.517
Error	470	1.42		
	Two stations - One sample			
Preop-Op	1	0.05	0.04	0.848
Year (Preop-Op)	6	3.01	2.09	0.055
Month (Year)	88	4.20	2.91	0.001
Station	1	3.42	2.37	0.125
Preop-Op X Station	1	0.68	0.47	0.492
Error	282	1.44		

Table 9. *Carcinus maenas* larvae: Comparison of results from three analysis of variance tests, the first based on three replicate samples at three stations, the second on one sample at three stations and the third on one sample at two stations, June through September of 1987-95.

Source of variation	df	MS	F-value	P
	Three stations - Three replicate samples			
Preop-Op	1	0.07	0.11	0.743
Year (Preop-Op)	6	3.19	4.95	0.001
Month (Year)	24	2.78	4.31	0.001
Station	2	0.33	0.51	0.604
Preop-Op X Station	2	0.16	0.25	0.779
Error	156	0.65		
	Three stations - One sample			
Preop-Op	1	0.14	0.19	0.664
Year (Preop-Op)	6	2.89	3.77	0.002
Month (Year)	24	2.72	3.55	0.001
Station	2	1.28	1.68	0.190
Preop-Op X Station	2	0.40	0.53	0.591
Error	156	0.77		
	Two stations - One sample			
Preop-Op	1	0.04	0.05	0.828
Year (Preop-Op)	6	1.76	2.28	0.043
Month (Year)	24	1.67	2.15	0.005
Station	1	2.55	3.29	0.073
Preop-Op X Station	1	0.05	0.07	0.798
Error	94	0.77		

Table 10. *Cangon septemspinosa* zoea and post-larvae: Comparison of results from three analysis of variance tests, the first based on three replicate samples at three stations, the second on one sample at three stations and the third on one sample at two stations, 1987-95.

Source of variation	df	MS	F-value	P
	Three stations - Three replicate samples			
Preop-Op	1	0.13	0.42	0.517
Year (Preop-Op)	6	2.26	7.17	0.001
Month (Year)	88	8.55	27.12	0.001
Station	2	5.18	16.44	0.001
Preop-Op X Station	2	0.13	0.41	0.662
Error	470	0.32		
	Three stations - One sample			
Preop-Op	1	0.01	0.02	0.894
Year (Preop-Op)	6	1.80	4.60	0.001
Month (Year)	88	8.54	21.81	0.001
Station	2	8.93	22.80	0.001
Preop-Op X Station	2	0.18	0.46	0.634
Error	470	0.39		
	Two stations - One sample			
Preop-Op	1	0.14	0.35	0.553
Year (Preop-Op)	6	1.27	3.15	0.005
Month (Year)	88	5.87	14.60	0.001
Station	1	17.49	43.51	0.001
Preop-Op X Station	1	<0.01	0.01	0.939
Error	282	0.40		

Table 11. *Neomysis americana:* Comparison of results from three analysis of variance tests, the first based on three replicate samples at three stations, the second on one sample at three stations and the third on one sample at two stations, 1987-95.

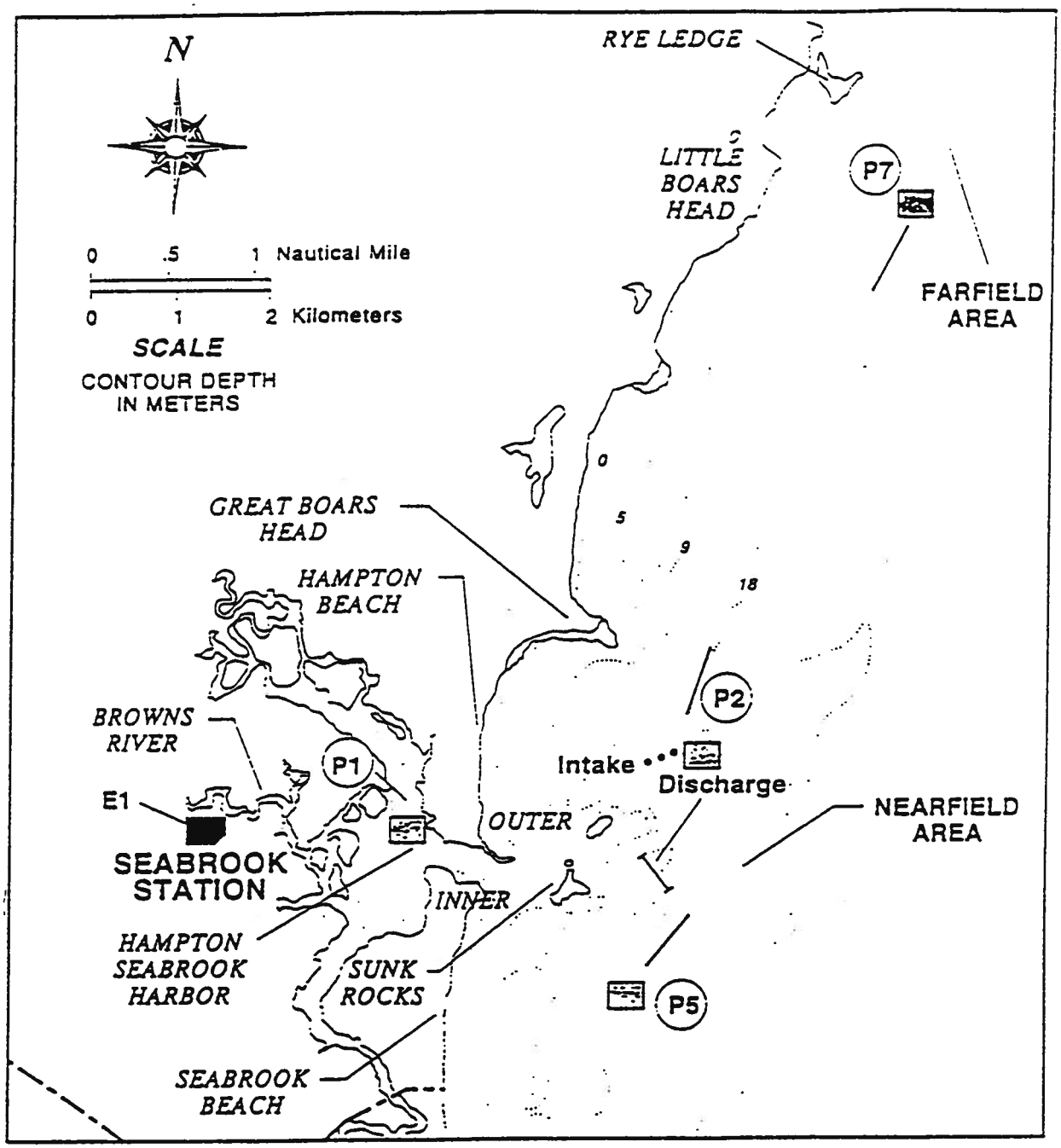
Source of variation	df	MS	F-value	P
	Three stations - Three replicate samples			
Preop-Op	1	0.14	0.25	0.618
Year (Preop-Op)	6	6.61	11.70	0.001
Month (Year)	88	2.53	4.47	0.001
Station	2	37.49	66.35	0.001
Preop-Op X Station	2	0.06	0.11	0.893
Error	470	0.57		
	Three stations - One sample			
Preop-Op	1	0.04	0.05	0.821
Year (Preop-Op)	6	6.84	9.74	0.001
Month (Year)	88	2.74	3.90	0.001
Station	2	65.44	93.21	0.001
Preop-Op X Station	2	0.17	0.24	0.786
Error	470	0.70		
	Two stations - One sample			
Preop-Op	1	0.07	0.09	0.764
Year (Preop-Op)	6	3.48	4.68	0.001
Month (Year)	88	1.81	2.43	0.001
Station	1	130.32	175.45	0.001
Preop-Op X Station	1	0.29	0.39	0.534
Error	282	0.74		

Table 12. Comparison of the relative contribution to macrozooplankton abundance for the top 20 taxa using the actual database of three replicate samples at the three stations to two simulated databases: one sample at three stations and one sample at two stations (P2 and P7). These taxa represent over 95% of the total macrozooplankton abundance from 1987 through 1995.

Taxa	% contribution with 3 repicates and 3 stations	% contribution with 1 sample and 3 stations	% contribution with 1 sample and 2 stations
Cirripedia	27.9	27.8	21.0
Centropages typicus	21.6	21.5	24.0
Calanus finmarchicus	14.5	14.1	13.4
Cancer spp.	5.7	6.0	7.6
Temora longicornis	4.7	4.6	5.3
Eualus pusiolus	2.5	2.6	3.3
Meganyctiphanes norvegica	2.2	2.3	2.7
Oikopleura sp.	2.2	2.4	2.4
Centropages sp.	2.0	2.1	2.3
Metridia sp.	1.5	1.5	1.7
Evadne sp.	1.5	1.4	1.3
Limacina retroversa	1.4	1.5	1.8
Mysis mixta	1.4	1.2	1.3
Podon sp.	1.3	1.4	1.6
Carcinus maenas	1.2	1.1	1.1
Thysanoessa sp.	1.1	1.3	1.2
Pseudocalanus sp.	0.9	0.9	1.0
Obelia sp.	0.9	0.9	1.0
Tortanus discaudatus	0.8	0.8	1.0
Centropages hamatus	0.8	0.8	0.9

Table 13. Results of F-tests to determine significant ($P \leq 0.05$) differences between mean squares (MS) for the interaction term from three analysis of variance (ANOVA) tests for the selected macrozooplankton species (see Tables 1-5). One ANOVA was based on three relicate samples at three stations, the second was based on one sample at three stations, and the third was based on one sample collected at two stations. F-values were calculated by dividing the larger of the two MS by the smaller.

	3 replicates at 3 stations vs. 1 sample at 3 stations		3 replicates at 3 stations vs. 1 sample at 2 stations	
Taxa	F-value	P	F-value	P
Calanus finmarchicus copepodites	1.32	0.431	5090.39	0.010
Calanus finmarchicus adults	2.20	0.313	1.59	0.486
Carcinus maenas	2.50	0.286	3.14	0.371
Crangon septemspinosa	1.37	0.422	55.72	0.094
Neomysis americana	2.65	0.274	4.51	0.316



LEGEND

——— = zooplankton stations

▭ = bivalve larvae stations

E1 = Seabrook Entrainment Station

Figure 1. Zooplankton sampling stations near Seabrook Station (from NAI 1996a).

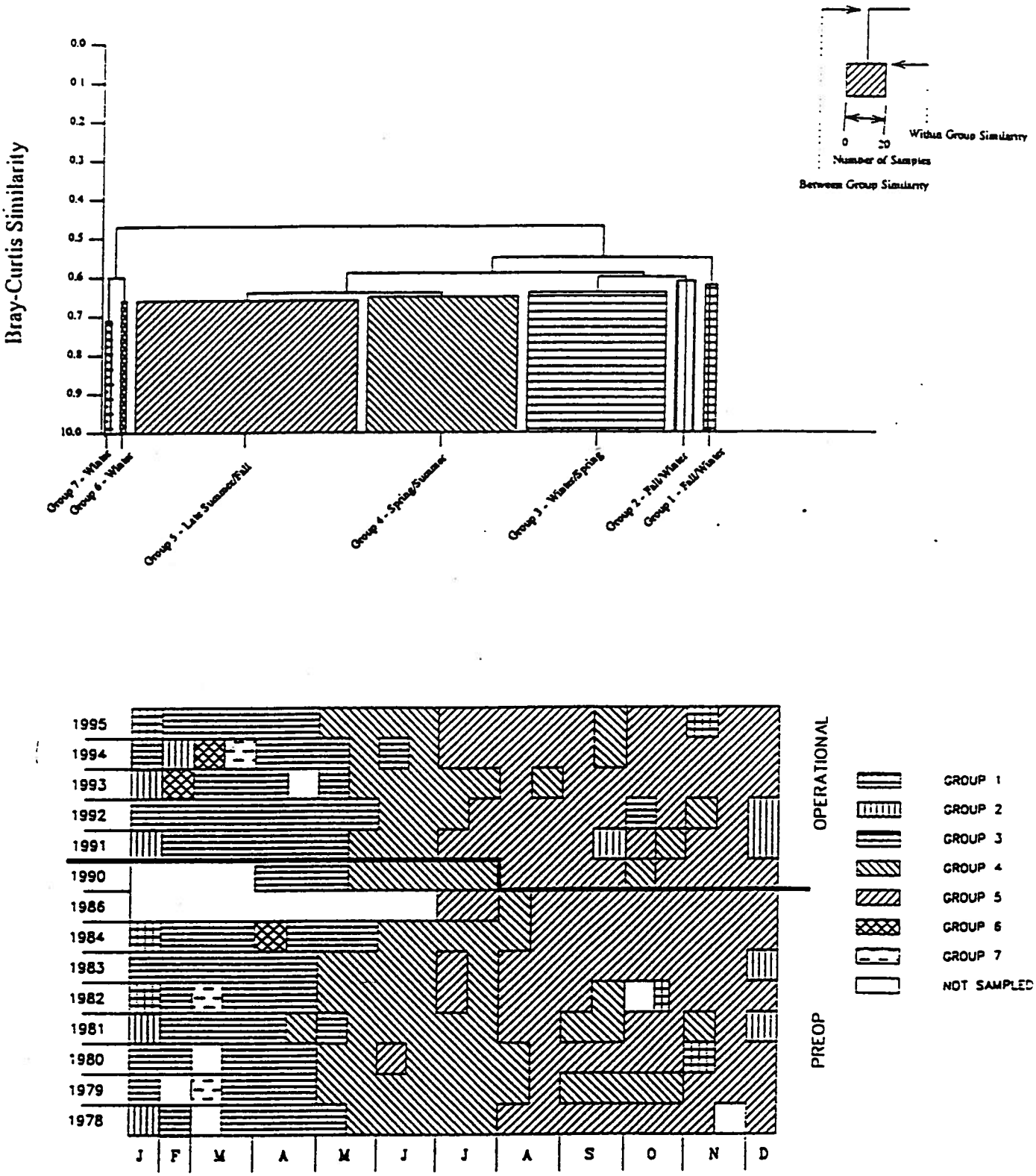
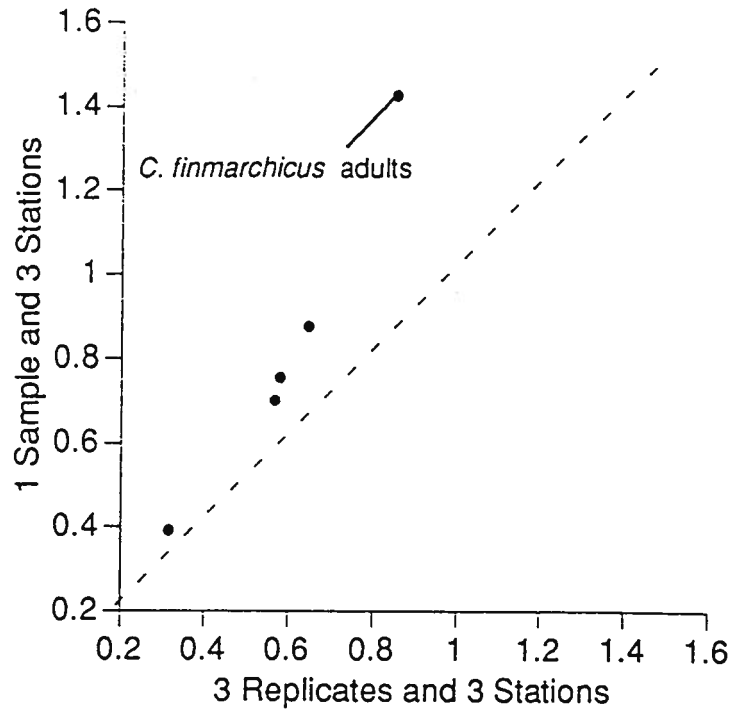


Figure 2. Dendogram and seasonal groups formed by numerical classification of $\log_{10}(X+1)$ transformed microzooplankton abundances (number per m^3) at nearfield station P2 for 1978-84, July-December 1986, and April 1990 through December 1995 (from NAI 1996a).



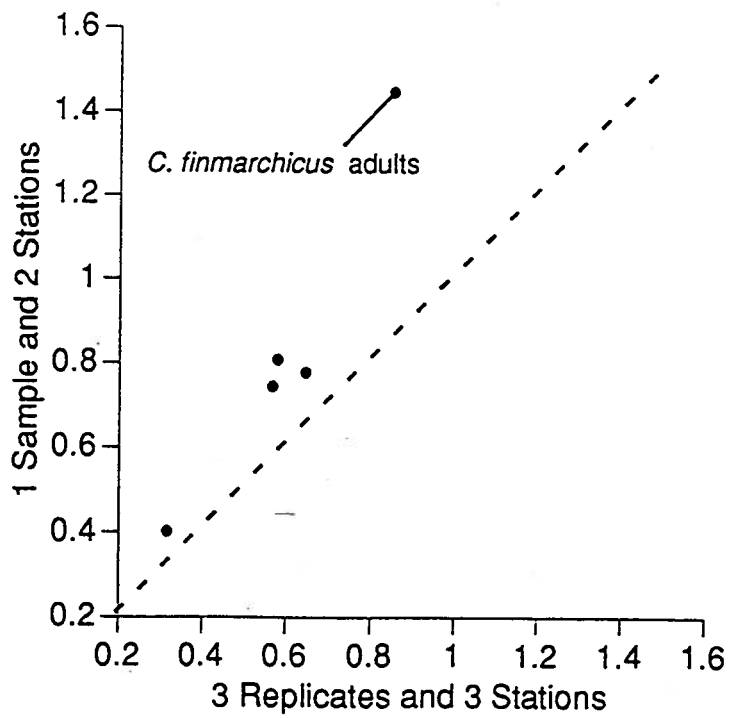


Figure 3. Comparison of error mean squares for the five selected macrozooplankton taxa from three analyses of variances (see Tables A-E). One comparison (top) is based on three replicates at three stations versus one sample at three stations and the other comparison (bottom) is based on three replicates at three stations versus one sample at two stations. The dashed line represents a slope=1.

APPENDIX

Summaries of Other Microzooplankton Studies

The following are brief summaries from a review of microzooplankton studies conducted between 1963 and 1982 at nine electrical generating stations on the eastern coast of the United States; all of these power plants are sited on the ocean or on estuaries. The summaries are ordered geographically from south to north, with generally increasing relevance to Seabrook Station. Operational characteristics of these plants and dates of the zooplankton studies are given in Table 3.

Crane. Experimental studies examining the survival of entrained zooplankton (primarily the copepod *Eurytemora affinis*) were completed at the Crane Power Plant, located on the northwest shore of Chesapeake Bay (Davies et al. 1976). Copepods collected at the intake were held in ambient temperature water (controls) or were placed in water from the plant discharge (ΔT of 10.1-12.1°F). Zooplankton samples collected at the plant discharge were held at that temperature (ΔT) or at an increased temperature that was twice the ΔT. Although there was a tendency for mortalities to increase with experimental temperature, rates were not significantly different among the treatments and among the months (December-March) that were tested. Mortalites noted were greatest for early copepodites and became progressively less for late copepodites and adult copepods. They also observed no significant differences in zooplankton communities (abundance, species percent composition, age structure) resident in the discharge canal, at the intake, or at a control station over the course of a 6-month study. They concluded that power plant entrainment had little effect on microzooplankton populations, which appeared to have a sufficient recovery potential to compensate for entrainment losses.

Calvert Cliffs. Relatively long-term ecological studies for the Calvert Cliffs Nuclear Power Plant were summarized in Heck (1987). The discharge of this plant is released along the 3-m depth contour from a conduit 260 m offshore in the Maryland waters of Chesapeake Bay. Olson

(1987a, b) presented results from a 6-year study of zooplankton in the bay, conducted before and after plant start-up in late 1974 and a 7-year study of through-plant entrainment effects. Dominant microzooplankton included the copepods *Acartia tonsa*, *E. affinis*, and *Oithona* spp.; barnacle (*Balanus* spp.), polychaete, bivalve, and crab larvae; the cladoceran *Podon polyphemoides*, and rotifers. Maximum densities were found during the summer. ANOVA models were used to examine the distribution of various microzooplankton taxa by life stage at six stations near the plant along a 12-km longitudinal transect that included the intake and discharge plume areas. The only significant ($p \leq 0.01$) differences were found for copepod nauplii, which were distributed in a density gradient along a sampling transect. However, this gradient was not consistent from month to month and actually reversed direction during the sampling period. In a previous study of through-plant entrainment Heinle and Millsaps (1977) noted reduced densities of *A. tonsa* nauplii in the discharge area for several years following plant start-up. However, this may have been related to inadequate representation of the water column by their pump sampler, as copepods densities showed a gradient by depth. Olson (1987b) concluded that there were no deleterious effects of Calvert Cliff operation on zooplankton in the region of the plant.

Chalk Point. Biological studies at the Chalk Point Steam Electric Station, located on the Patuxent River, a tributary of Chesapeake Bay in Maryland, were summarized by MMES (1985). Zooplankton were primarily affected by entrainment mortality. The abundance of zooplankton near this station was particularly high and dominant species included *A. tonsa* and *E. affinis*. Through-plant entrainment losses were estimated to be about 20-30% of the specimens entrained, but could reach 80% during plant chlorination, and were predicted to be 90-100% during summer operation when the discharge canal temperature exceeded 35°C. Comparisons between nearfield and farfield stations (with plant at less than full operation) showed reductions of 15-40% in densities at the nearfield stations. However, this was not related to ΔT, but chlorine use. It was concluded that the effects of the station were limited to the immediate vicinity of the plant and the zooplankton populations over a larger, regional area were not affected.

Indian River. Davies and Jensen (1974) noted little effect of the Indian River Station (Delaware) on zooplankton, which was attributed primarily to the low (10.8°F) ΔT for this station. Salinity gradients and diurnal migrations of zooplankton seemed to be more important for their distribution than the plant. Except for late summer or early fall, the zooplankton populations in the discharge canal did not decrease due to passage through the plant. They concluded that zooplankton in the receiving waters of the Indian River estuary did not appear to be affected by losses at the plant as evidenced by similarities in species densities in the mixing zone beyond the discharge canal and in the intake area.

Oyster Creek. Oyster Creek Nuclear Generating Station is located on Barnegat Bay, NJ. The station withdraws cooling water from a bay tributary, Forked River, and discharges into another tributary, Oyster Creek, which has been modified to serve as a discharge canal. Because of station pumping, salinities in these creeks approximate those of the bay. Microzooplankton species composition and abundances at stations located at the mouths of Forked River and Oyster Creek were compared in JCP&L (1978). Copepod nauplii (46%) and rotifers (24%) dominated the microzooplankton. The most abundant copepod species were *Acartia clausi* (= *A. hudsonica*) and *A. tonsa*, which reached maximum abundance between March and July and minimum densities between September and November. No changes in relative species composition were evident between the stations. However, some differences did occur in absolute abundance, with barnacle larvae decreasing 72% at the mouth of Oyster Creek, polychaete larvae 42%, copepod nauplii 19%, unidentified bivalve larvae 25%, *A. tonsa* 57%, and *Acartia* spp. 61%. Conversely, rotifers increased by 103%, cyphonaute larvae 3,547%, gastropod larvae 70%, and dwarf surf clam (*Mulinia lateralis*) larvae 155%. The losses were mostly attributed to through-plant entrainment mortalities. However, in bay-wide surveys, no apparent effects were noted in microzooplankton abundances. JCP&L (1978) concluded that the plant had not produced any changes to this community throughout Barnegat Bay.

Millstone. The largest electrical generating facility in New England is the Millstone Nuclear Power Station, located on eastern Long Island Sound in Waterford, Connecticut. When in operation, all three units discharge heated water into a quarry pond, where the average transit time before the effluent reaches Long Island Sound (LIS) through two openings in the quarry wall is about 85 minutes. NUSCO (1983a) reported that nine taxa of holoplankton (mostly adult or copepodite stages of calanoid copepods) comprised about 90% of the total in through-plant entrainment studies conducted at Millstone Units 1 and 2 from 1976 through 1980; *Acartia hudsonica* and *A. tonsa* made up 60% of the total. Meroplankton were also dominated by a few taxa, primarily gastropod eggs and veligers (54%), barnacle (*Balanus* spp.) larvae (25%), and brachyuran crab larvae (12%). Tychoplankton were much less numerous, although occasionally abundant at night during late winter. Dominants included gammaridean amphipods (72%) and harpacticoid copepods (17%). Two major seasonal components were identified with the winter-spring contingent dominated by *A. hudsonica*, *Pseudocalanus minutus*, and *Temora longicornis*, as well as larval barnacles, gastropods, and polychaetes. The summer-fall community was characterized by *A. tonsa*, *Centropages hamatus*, and *Pseudodiaptomus coronatus*, with brachyuran and pagurid crab larvae. Carpenter et al. (1974a, b) noted that 70% of the copepods passing through Millstone Station Unit 1 were not returned to LIS at the quarry pond outlet. They believed that the mortality of copepods was almost entirely due to hydraulic or mechanical damage, rather than from temperature shock or chlorination. In addition, even live *A. tonsa* collected at the discharge sank 2.5 times faster than those found at the plant intakes, which increased concentrations in deeper water. Total annual copepod loss from entrainment was estmated as 4.253×10^{11}, which was calculated to be equivalent to the zooplankton production under 193×10^{3} m^2 of surface area of LIS. This was further estimated as 0.1 to 0.2% of the copepod production of eastern LIS. However, because of the relatively short generation time and rapid reproduction of holoplankton, the quick dilution of the Millstone Station thermal plume in Long Island Sound, and the small volume of water withdrawn by the station relative to its Niantic Bay source, it was concluded that the operation of Millstone Station did not have any adverse effects on the zooplankton community (NUSCO 1976, 1983b; USNRC 1984).

Brayton Point. Brayton Point Generating Station, located on Mount Hope Bay in Massachusetts, is the second-largest generating station in New England. MRI and NEPCO (1978) summarized a 5-year study of zooplankton that was designed to examine station operation under a maximum allowed discharge temperature of 35°C. Zooplankton abundance, number of species, and diversity were compared between observations at five control stations not exposed to the thermal plume and a test station which had maximum exposure. Dominant species were *A. clausi* (= *A. hudsonica*) in winter and spring and *A. tonsa* in summer and fall. *Oithona* spp., *Saphirella* spp., and *P. minutus* were also common. Additional studies were made to determine temperature tolerances within the 975-m long discharge channel by taking samples at three locations within the discharge channel, at the plant intake, and within the discharge plume. For the latter study, no significant differences in density were found for most taxa, except for adult *A. clausi* and *A. tonsa*, which declined in abundance from the upper to the lower end of the discharge channel. Further, there was a significant positive correlation between the plant reduction in zooplankton density in the discharge channel with absolute discharge water temperature, the greatest effect of which occurred in July and August. The large-scale studies, however, found no significant differences in the number of species, diversity, or densities among the stations sampled in Mount Hope and Narragansett Bays. MRI and NEPCO (1978) concluded that the zooplankton populations in Mount Hope Bay were not affected by station operation, except for some losses of adult *Acartia* spp. after plant passage during July and August. Apparently, these losses did not affect zooplankton standing stocks elsewhere in the bay. Also, no effects on higher trophic levels were expected to occur as a result of any changes to the zooplankton population.

Pilgrim. Toner (1984) summarized zooplankton studies completed in Cape Cod Bay during 1973-75 relating to Pilgrim Nuclear Power Station, located near Plymouth, Massachusetts on the northwestern shore of Cape Cod Bay. Peak densities of zooplankton were found in August with seasonal lows in December and January. The community was dominated by copepods, particularly *A clausi* (= *A. hudsonica*) and *A. tonsa*, with *Oithona similis*, *O. brevicornis*, and *P. minutus* also present. MRI (1976) presented results of zooplankton studies at Pilgrim Station,

including entrainment survival. Zooplankton (primarily copepods) entrained at the station appeared to survive plant passage with little (<10%) mortality under most operating conditions. High mortality only occurred when the plant chlorinated the cooling water at water temperatures of 29°C or greater. Although densities of zooplankton at the discharge were generally less than at the intake, on some occasions they were comparable or even higher. It was concluded that Pilgrim Station operation did not appreciably affect local holoplankton populations and, subsequently, studies were discontinued by the Pilgrim Station Technical-Advisory Committee (BECO 1976).

Maine Yankee. The Maine Yankee Nuclear Generating Station is located in Wiscasset, Maine on the western shore of Montsweag Bay, off the Gulf of Maine. The thermal effluent is discharged through a 13.4-m deep mid-channel diffuser in the bay. The two 152-m long diffuser pipes result in high speed jets (3.9 $m \cdot s^{-1}$) of heated water that rapidly entrain and mix with ambient water. Besides plant impacts, effects were also possible from the removal of a causeway that greatly increased water circulation in the bay, which allowed the plant to meet water quality temperature standards.

Lindsay et al. (1978) reported on a 5-year study of through-plant entrained microzooplankton. Samples taken at the plant intake and discharge had greatest densities each year from May through September, with lowest numbers collected during fall and winter. Copepods (species not differentiated), polychaete larvae, and rotifers made up over 95% of the microzooplankton. Bivalve larvae were only a minor component of the entrainment samples. Copepods had good (>80%) survival following plant passage until water temperature reached 30°C. Above this, survival of copepods decreased with temperature. Polychaete larvae generally had high survival even at high water temperatures, whereas rotifers did not survive well at any temperature examined, perhaps due to mechanical damage from plant passage.

McAlice et al. (1978) assessed the effect of the operation of Maine Yankee on species composition, abundance, life cycles, and spatial and temporal distribution of microzooplankton

populations at five stations located throughout Montsweag Bay. Twenty-seven taxonomic categories were chosen for statistical evaluation. They found that the bay was not warmed by the thermal discharge from the plant. The dominant holoplankton species, *A. tonsa*, did not show any significant changes in abundance throughout the study. They concluded that their sampling could not detect any direct plant effects (i.e., entrainment) on microzooplankton, although the causeway removal likely caused some changes, which were due to altered water circulation patterns alone.

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MARINE MACROBENTHOS

Summary of Proposed Monitoring Program After 5 Years of Plant Operation

The objective of the marine macrobenthos program after 5 years of plant operation is to monitor those habitats most likely to reflect effects of potential impacts from Seabrook Station (thermal plume effects and increased turbidity/sedimentation). While little or no evidence of impacts has been detected to date, this habitat merits continued monitoring at this time, given its ecological importance and the long-term cyclic nature of the benthic communities.

1. Focus will be on station pairs with nearfield stations closest to the source of impacts (Seabrook discharge), and with longest existing preoperational/operational period time-series. These stations are most likely to reflect impacts, if they occur.

    - **B17/B35** - Shallow subtidal zone is hard benthos habitat, most susceptible to thermal plume exposure, although no impacts have been shown after 5 years of plant operation.
    - **B19/B31** - Mid-depth zone would be most susceptible to potentially increased turbidity/sedimentation from the discharge, although no impacts have been demonstrated to date.

2. Sampling design and data analyses for these sites would remain almost identical to previous years, maintaining the historic time-series:

    - Destructive sampling
    - Non-destructive transects
    - General algae
    - Bottom panels (with new wooden panel attached); subsampling of panel would provide replication.
    - Study sample collection/processing for "incidental" parameters not analyzed in report would not be conducted (e.g., spirorbids, colonials, annual bottom panels).
    - Analysis of long-term trends for selected parameters will be evaluated.

3. Proposed stations:

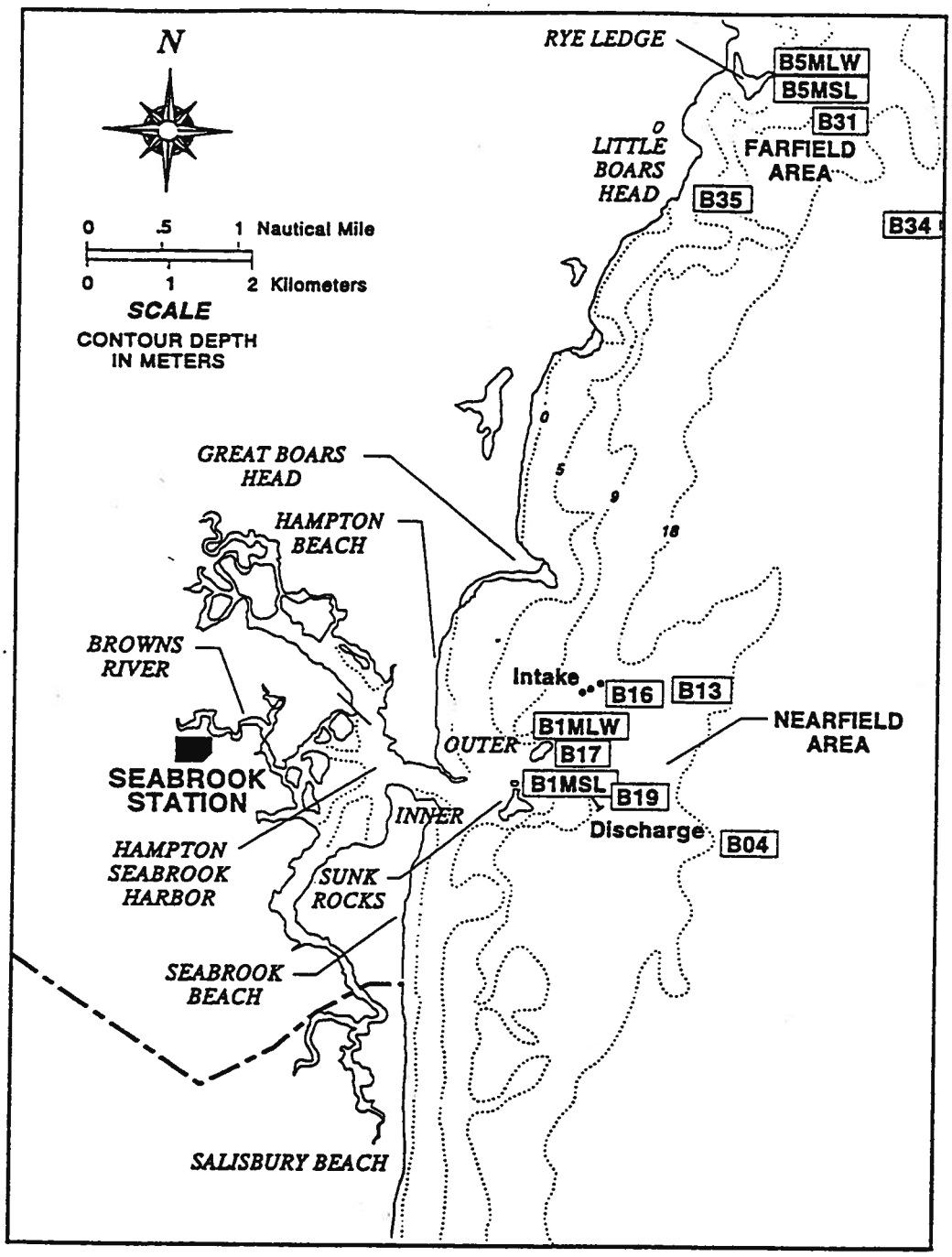
    - are most likely to be impacted (shallow subtidal/sunk rocks and mid-depth);
    - are historically most intensively studied (sampled 3X per year and include non-destructive study);
    - have a more extensive habitat (compared to intertidal stations) that is less vulnerable to impacts associated with destructive sampling.

MARINE MACROBENTHOS

PROPOSED PROGRAM	PAST PROGRAM
1) Destructive Sampling	
• **Stations/Sampling frequency:** B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW (Intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth) sampled 1X per year
• **Replicates:** 5	• **Replicates:** 5
• **Total samples/year:** 60	• **Total samples/year:** 110
• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa	• **Data collected:** Biomass and Density (total and for dominant taxa), No. of taxa, Spirorbid counts, length and/or reproductive status of some dominant fauna, colonial abundance
2) Non-Destructive Sampling	
• **Stations/Sampling frequency:** B17/B35 and B19/31 (Shallow subtidal and mid-depth) 3X per year	• **Stations/Sampling frequency:** B1/B5 (intertidal quads and transects), B17/B35 and B19/31 (Shallow subtidal and mid-depth) 3X per year
• **Replicates:** Subtidal transects-6	• **Replicates:** Intertidal quads-6 (2 each in 3 zones), Intertidal transects-3, Subtidal transects-6
• **Total samples/year:** 72	• **Total samples/year:** 126
• **Data collected:** % frequency of understory subtidal reds, kelp, urchin and *Modiolus* counts	• **Data collected:** % frequency/cover of intertidal dominants; % frequency of understory subtidal reds, kelp, urchin and *Modiolus* counts

MARINE MACROBENTHOS (continued)

PROPOSED PROGRAM	PAST PROGRAM
3) General Algae	
• **Stations/sampling frequency:** B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year	• **Stations/Sampling frequency:** B1MLW/B5MLW tidepools, B1MSL/B5MSL tidepools, B1MLW/B5MLW, B1MSL/B5MSL (Intertidal), B17/B35 (Shallow subtidal), B19/31 (Mid-depth) sampled 3X per year; B04/B34/B13 (Deep) and B16 (Mid-depth) sampled 1X per year
• **Replicates:** 1	• **Replicates:** 1
• **Total samples/year:** 12	• **Total samples/year:** 40
• **Data collected:** presence/absence of algal taxa	• **Data collected:** presence/absence of algal taxa
4) Bottom Panels	
• **Stations/Sampling frequency:** B19/31 (Mid-depth) triannual panels 3X/year	• **Stations/Sampling frequency:** B19/31 (Mid-depth), B04/B34(Deep); triannual panels 3X/year, annual panels 1X per year
• **Replicates:** 1 (4 subsamples)	• **Replicates:** 1
• **Total samples/year:** 24	• **Total samples/year:** 28
• **Data collected:** counts of selected dominant taxa, *Teredo* sp. counts in attached wooden panel	• **Data collected:** counts of selected dominant taxa



LEGEND

☐ = benthic samples

Fig. 1. Marine macrobenthos sampling stations. From NAI (1996).

WORKING DRAFT

EVALUATION OF SEABROOK STATION MARINE MACROBENTHOS PROGRAM AFTER FIVE YEARS OF PLANT OPERATION

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Evaluation of Seabrook Station Marine Macrobenthos Program After Five Years of Plant Operation

Introduction

The benthic habitat near Seabrook Station intake and discharge structures is primarily bedrock ledge and boulders. These rock substrata, as with similar habitats in the Gulf of Maine and other northern temperate coastal areas, support rich and diverse communities of attached plants and animals (macrobenthos), which are important and integral parts of coastal ecosystems. One of the most obvious and productive features of the shore and near-shore biota in the Gulf of Maine is an extensive canopy of brown macroalgae, e.g., rockweeds (fucoids) intertidally (Menge 1976; Topinka et al. 1981; Keser and Larson 1984), and kelps subtidally (Sebens 1986; Witman 1987). Generally, several understory layers occur beneath these canopies, and are comprised of secondary levels of foliose and filamentous algae and upright attached macroinvertebrates over a layer of encrusting algal and faunal species, which occupy much of the remaining primary rock surfaces (Menge 1976; Sebens 1985; Ojeda and Dearborn 1989). Also, many of the niches created in and around this attached biota are occupied by mobile predator and herbivore species such as fish, snails, sea urchins, starfish, and amphipods (Menge 1979, 1983; Ojeda and Dearborn 1991).

Because these coastal hard-bottom communities are ecologically important, are well documented as effective integrators of environmental conditions, and are potentially vulnerable to localized coastal anthropogenic impacts, studies of these communities have been and continue to be part of ecological monitoring programs associated with coastal nuclear power plants (Vadas et al. 1976; Wilce et al. 1978; Osman et al. 1981; Schroeter et al. 1993; BECO 1994; NUSCO 1996a). Seabrook Station marine macrobenthos studies were initiated in 1975 with the objective to determine whether differences that exist among benthic communities at sites in the Hampton-Seabrook area can be attributed to power plant construction and operation. One potential impact on the local macrobenthos from Seabrook Station operation is temperature-

related community alteration to areas directly exposed to the discharge thermal plume. Habitats in the upper portion of the water column (i.e., intertidal and shallow subtidal zones) are most susceptible to this impact. Thermal impacts are unlikely in deeper areas; however, increased turbidity in discharge water resulting from transport of suspended solids and entrained organisms could occur, increasing sedimentation rates and decreasing light transmission.

The purpose of this report is to evaluate the current marine macrobenthos program after over 20 years of monitoring that include, depending on the study, five or six years of Seabrook Station operation. This evaluation will first summarize what impacts to the local marine macrobenthos have been detected since the start-up of Seabrook Station in 1990. Second, based on this impact assessment, recommendations will be made for a monitoring program more focused on indicators (e.g., community parameters and dominant taxa population characteristics) and locations (nearfield/farfield) that have revealed impacts or have indicated that the potential for impact still exists.

Review of Current Methodology

Quantitative (destructive) macrofaunal and macroalgal samples were collected three times a year at six benthic stations (Fig. 1); three nearfield-farfield station pairs were established at lower intertidal (B1MLW, B5MLW), shallow subtidal (4-5 m; B17, B35) and mid-depth (9-12 m; B19, B31) locations. Four additional stations were sampled in August only: one mid-depth intake station (B16) and three deep water (18-21 m) stations (nearfield-B13 and B04, and farfield-B34). Epifauna and epiflora were removed by scraping from five randomly selected 0.0625 m^2 areas on horizontal rock surfaces.

Algal species from each sample were identified to the lowest practical taxon, dried and weighed. All faunal species collected in August samples were identified to the lowest possible taxon and enumerated. Only fauna previously designated as selected species were identified and counted from May and November macrofaunal samples. In addition, abundance of spirorbid polychaetes

at subtidal Stations B19 and B31 was estimated from five subsamples of the algal complex *Phyllophora/Coccotylus spp.* Also, life history information (length measurement, and sex and reproductive status determination) was obtained for nine macrofaunal taxa at paired nearfield-farfield stations where they were most abundant in destructive samples.

A comprehensive collection of all visible algal species ("general algae") was made in conjunction with destructive sampling at each sampling station. In addition, collections were taken from the mean low water and mean sea level areas (including tide pools) in the intertidal zone. Macroalgae from general collections were identified to the lowest practical taxon. The complete macroalgal species list was compiled from both general and destructive collections and included crustose coralline algae, collected only in August.

Beginning in 1982, two intertidal stations (B1MSL and B5MSL; Fig. 1) were evaluated nondestructively during April, July and December. Observations were made at permanently marked 0.25 m^2 quadrats at three intertidal levels. Percent cover of fucoid algae and percent frequency of occurrence for other algae and fauna from an established species list were estimated and recorded. Frequency of occurrence of fucoid algae was also recorded along a 9.5 m transect line.

Subtidal transects were established in 1978 to monitor larger macroinvertebrates and macroalgae that were not adequately represented in destructive samples. Six randomly placed replicate 1 m x 7 m band-transects were surveyed at nearfield-farfield station pairs in the shallow subtidal (B17, B35) and mid-depth (B19, B31) zones in April, July and October. Percent frequency of occurrence was recorded for dominant "understory" macroalgae , as well as counts of *Modiolus modiolus, Strongylocentotus droebachiensis* and all kelp species.

Information on patterns of recruitment and settlement of sessile benthic organisms was obtained from the bottom panels program. Bluestone panels (60 cm x 60 cm) were placed 0.5 m off the bottom at Stations B19 and B31, beginning in 1982. Short-term bottom panels were exposed for four months during three exposure periods: December-April, April-August, and August-

December. Long-term bottom panels were exposed for one year, deployed in August and collected in August of the following year. All undisturbed bottom panel faces were first analyzed for *Balanus* spp. and Spirorbidae, and then scraped to remove sessile bivalves and solitary chordates for identification and enumeration. Hydrozoa, Bryozoa and any abundant algal species were analyzed only on long-term panels.

Macroalgal and macrofaunal data analyses included analysis of variance (ANOVA) and numerical classification analysis. A fixed-effects ANOVA model was used to test the null hypothesis that spatial and temporal differences in specific parameters were not significant. The data collected for the ANOVAs met the criteria of a Before-After/Control-Impact (BACI) sampling design discussed by Stewart-Oaten et al. (1986), where sampling was conducted prior to and during plant operation, and sampling locations included both potentially impacted and non-impacted sites. The main effects were period (Preop-Op) and station (Station); the interaction term (Preop-Op X Station) was also included in the model. Further details on the ANOVA model are provided in NAI (1996). A comparison of macroalgal and macrofaunal community composition during operational and preoperational periods was carried out using numerical classification methods (Boesch 1977). Bray-Curtis similarity indices were computed for the annual August log-transformed average densities(macrofauna) and square-root transformed average biomass (macroalgae). The group average method method (Boesch 1977) was used to classify the station-year collections into groups or clusters.

Summary of Monitoring Results After 5 Years of Plant Operation

A considerable physical and biological database has been established during the over 20 years of study to characterize natural variability in the benthic community, and during the operational period, to assess the extent to which Seabrook Station operation may have affected the local marine macrobenthos. The type of impact a community is vulnerable to is dependent upon its relative position in the water column (i.e., temperature effects for shallow water sites, turbidity effects at deeper water sites); potential impacts associated with construction and operation of

Seabrook Station on communities in each of these depth zones will be examined separately and discussed below.

Thermal Plume Effects.

Nearfield sampling sites used for the Seabrook intertidal and shallow subtidal macrobenthos studies were selected because they occur within, and best represent, the shallow water communities that are most susceptible to incursion by the Seabrook Station discharge thermal plume. Hydrodynamic modeling, conducted prior to plant start-up to predict the areal extent of the thermal plume under various meteorological and current regimes, indicated that thermal incursion to these sites would be minimal, with temperature increases of <1°C (Teyssandier et al. 1974). Subsequent field studies, conducted after Seabrook began commercial operation, verified these predictions by measuring no temperature increases at the intertidal sampling site, and increases of <1°C at the shallow subtidal site (Padmanabhan and Hecker 1991).

The results from marine macrobenthos studies at study sites potentially exposed to the thermal plume after 5 years of Seabrook operation are consistent with the physical assessment of environmental conditions at these sites from hydrothermal studies. Specifically, there is no evidence that intertidal and shallow subtidal benthic communities nearest to the discharge have been affected by the Seabrook thermal plume. In the intertidal and shallow subtidal depth zones, nearfield/farfield differences that were not consistent between preoperational and operational periods (resulting in significant Preop-Op X Station interaction in the ANOVA model) were noted for several community parameters (Table 1) and selected benthic taxa (Table 2). However, in nearly all cases, further examination and analysis of these parameters indicated that the changes observed were not consistent with a power plant impact (NAI 1996). This conclusion was also supported by numerical classification analyses, which revealed no changes to macroalgal or macrofaunal communities in the nearfield intertidal and shallow subtidal areas after the start-up of Seabrook Station. One trend that has been monitoried closely during the operational period is the apparent decline in abundance of the kelp *Laminaria digitata* in the nearfield shallow subtidal area (Fig. 2). Densities began to decline at nearfield B17 in 1990, and this trend continued through 1992, while no change in abundance was observed at the farfield

station (B35). The difference in abundance between nearfield and farfield stations has steadily decreased since that time, with little difference noted in 1995, so factors other than power plant impact may be responsible for this change.

Thermal impacts are well-documented for intertidal and shallow subtidal communities during monitoring studies for coastal nuclear power plants elsewhere in New England, and include elimination or reduced abundance of cold-water species, and increased abundance of warm-water tolerant and/or opportunistic species, leading to the development of communities distinct from those seen prior to thermal incursion and from those on nearby unaffected coasts (Vadas et al. 1976; Wilce et al. 1976; BECO 1994; NUSCO 1996a). For each of these studies, temperature increases on the order of >5° C were required to bring about detectable community change, and therefore, impacts were restricted to those communities in the immediate vicinity of the discharge (typically within a few hundred meters). Furthermore, these thermal impacts to nearby communities were observed shortly after (within months) thermal plume incursion began. No similar community changes have been observed for macrobenthos communities nearest the Seabrook discharge after 5 years of plant operation, and with maximum temperature increases at the nearest hard benthos communities from the Seabrook thermal plume of <1° C, such changes are highly unlikely .

Turbidity/Sedimentation Effects.

Another possible impact resulting from coastal nuclear power plants is related more to altered water circulation patterns than to thermal incursion. Specifically, the introduction (discharge) of turbid water to an area of historically lower levels of turbidity can decrease light penetration and increase sedimentation rates. Possible sources of this turbidity include suspended inorganic and organic particles if intakes are located in more turbid waters, and potentially, increased detrital deposition resulting from settlement of entrained organisms. Nearfield mid-depth and deep study sites represent macrobenthic communities in closest proximity to the Seabrook Station discharge, and are therefore potentially most susceptable to these types of impact. Higher sedimentation rates (and impacts to nearby macrobenthic communities) associated with a thermal effluent have been documented for a nuclear power plant in California (Osman et al.

1981; Schroeter et al. 1993), with the major source of turbidity being fine inorganic sediments transported from inshore waters where intakes for the plant were located. The organic component of these sediments contributed little to the overall flux of sediments, and organic enrichment was not observed at sites near the discharge.

The Seabrook intake is located about one mile offshore, 5 meters above the seafloor, and thus draws in relatively low turbidity water, similar to that near the discharge. Therefore, transport of fine inorganic particles is unlikely and any increase in sedimentation would be the result of settlement of organic material from entrained organisms. However, plankton densities are generally lower in deeper offshore waters, such as those near the intake structure, compared to densities in more productive inshore waters. Thus, it is unlikely that any increased organic loading to benthic habitats near the Seabrook discharge is occurring.

Similarly, results of marine macrobenthos monitoring at deeper water sites near the discharge reveal little change that would indicate an increase in turbidity or sedimentation in the nearfield area. Numerical classification analysis for macroalgae and macrofauna both indicated no nearfield-farfield or temporal changes have resulted from the operation of Seabrook Station. Similarly, bottom panel studies demonstrated no changes to settlement and early development of dominant benthic taxa populations after the plant began operation. Significant interactions terms based on ANOVA were noted for six of the seventeen community and selected taxa parameters monitored for mid-depth and deep communities (Tables 3 and 4). However, as was the case with stations monitored for thermal plume effects, further examination and analysis revealed that most of the observed differences responsible for the significant interaction terms were not consistent with a power plant impact. A similar operational period nearfield area decline of the kelp *Laminaria digitata* noted in the shallow subtidal zone was also apparent in the mid-depth zone. Specifically, nearfield abundances of *L. digitata* (Fig. 3) have declined during the operational period, relative to those at the farfield station. *L. digitata* abundunce has also declined at the farfield station in recent years. While the mechanisms causing these declines are unclear, monitoring of nearfield kelp communities should continue given that some of the observed declines coincided with Seabrook start-up.

Documented turbidity effects detrimental to macrobenthic plants and animals include shading or burial, and an increased community dominance by suspension-feeding organisms and organisms more tolerant of higher sedimentation rates (Hiscock and Mitchell 1980; Osman et al. 1981; NUSCO 1988; Schroeter et al. 1993). In the vicintiy of Seabrook Station discharge, no evidence of community change has been noted for nearfield macrobenthic communities after 5 years of plant operation.

Recommendations

Over 20 years of marine macrobenthos studies, including five full years during Seabrook operation, have provided the long-term database which has documented that balanced indigenous macrobenthic communities continue to occupy intertidal and subtidal rocky habitats in the vicinity of the Seabrook discharge, with little change beyond that expected from natural variability. A nearfield area change (e.g., decline in *Laminaria digitata* abundance) has coincided with plant start-up and continues to be apparent through 1995. However, there was no evidence for thermal impacts or impacts associated with increased organic loading on the local macrobenthos since the start-up of Seabrook Station in 1990.

While no impacts to macrobenthos from Seabrook have been detected after 5 years of plant operation, this habitat merits some continued monitoring at this time given the documented long-term cyclical nature of many benthic species (Hiscock and Mitchell 1980; Witman 1985, 1987; Johnson and Mann 1988; Elner and Vadas 1990) and its overall importance to the local coastal ecosystem. However, the scope of the study should be focused on station pairs with nearfield sites nearest to the source of potential impacts (Seabrook discharge), and on study parameters that have proven useful for impact assessment historically at Seabrook and in studies at other power plants.

Proposed Sampling Stations

The proposed sampling stations for continued monitoring of marine macrobenthos for Seabrook Station thermal plume effects are the shallow subtidal nearfield/farfield pair B17/B35 (Fig. 1). Hydrodynamic modeling and thermal plume studies all indicate that the shallow subtidal zone near the Outer Sunk Rocks would be most susceptible to thermal plume incursion, and that the nearest intertidal zone (nearfield station B1) has been totally unaffected by the thermal plume. If impacts from Seabrook's thermal plume were ever to occur, they would be detected at shallow subtidal B17 rather than at any intertidal site. Therefore, continued monitoring at B17/B35 alone would provide the necessary information for assessment of potential thermal plume effects. Furthermore, focus on the shallow subtidal zone avoids additional destructive sampling in the intertidal zone, which has decimated much of the habitat at sampling stations.

Although not likely, increased turbidity and sedimentation organic loading still is a potential impact associated with Seabrook's discharge, and would most likely impact deeper subtidal communities nearest to the discharge structures. The mid-depth station pair B19/B31 has the historically monitored nearfield station closest to the discharge (Fig. 1), and as with the shallow subtidal stations for thermal plume effects, would more likely reflect impacts from increased turbidity/sedimentation than the more distant deep stations.

Proposed Sampling Methodology

Sampling design and data analyses for the proposed sampling sites would remain almost unchanged, allowing continuity with the historical databases. This proposed new study would also allow for improvements to data analyses that would increase their sensitivity to detect power plant impacts.

The destructive program field sampling and laboratory processing for the four proposed stations would remain almost identical to the current program, and would provide the necessary data to support analyses currently presented in annual environmental reports. Five replicate quadrats would be destructively sampled at each station three times a year (May, August and November) as they have in the past. Laboratory sample processing would be similar to that done in the past,

with the following exceptions; spirorbid counts, assessment of colonial macrofauna abundance, and life history studies of dominant macrofauna would no longer be conducted. These aspects of the overall program have either not been used for impact assessment (spirorbids and colonials), or have revealed no impacts to date (life history studies). All necessary data to continue impact assessment with the ANOVA model and numerical classification analysis would be collected in a manner consistent with current practice. Furthermore, samples would be available for life history analysis of colonial identification, should it be necessary.

General algal collections will continue to be conducted concurrently with destructive samples (three times per year) at the four proposed sampling stations, as they have in previous years.

The shallow subtidal and mid-depth non-destructive transect study (used to monitor *Laminaria digitata* and other larger subtidal species) would continue unchanged in the proposed study program. Six randomly placed 1 m x 7 m subtidal transects sampled three times a year in April, July and October for the same dominant taxa described above for the current program.

Some modifications to the bottom panels program are recommended for the proposed study program. Triannual panels would continue to be sampled at the mid-depth station pair. Annual environmental reports historically include data collected from these stations. To improve the sensitivity of the program to detect changes, triannual panels would be subsampled to provide four replicates and allow the estimation of variability. Annual panels would no longer be sampled, as data from these panels have not been analyzed or presented in operational monitoring reports.

Another enhancement to this study would be the addition of a wooden panel, attached to each bottom panel, to monitor marine woodborers. *Teredo* sp. individuals were collected on surface wooden panels in 1995 for the first time in many years. The overall proposed monitoring program after 5 years of Seabrook operation does not include a surface panels study (see NUSCO 1996b); monitoring of woodborer occurrence in nearfield and farfield areas following this recent event would be continued as part of the bottom panels program. This change in

methodology would actually improve our ability to monitor *Teredo* sp., because larval settlement is much higher in near-bottom waters than near the surface (Grave 1928; Scheltema and Truitt 1956; NUSCO 1996c).

Data Analysis

Data collected under the proposed monitoring program will be consistent with all critical time-series currently used for impact assessment, and therefore amenable to all analyses presently used (e.g., ANOVA, numerical classification). Improvement of analyses would continue, however, based always on appropriate proven methodology described in the scientific literature. Refocusing effort to sites closest to the discharge would improve the sensitivity of the program to detect impact. For example, many ANOVAs for the mid-depth station group include a nearfield (but distant) intake station (B16), which, after 5 years of operational studies, clearly shows no evidence for impact. ANOVAs on data from only the proposed nearfield/farfield pair (B19/B31) would improve the sensitivity of tests to detect impact because the statistical evidence would not be "diluted" by data collected at sites such as B16 where no impact is expected.

Numerical classification analysis would continue to compare macroalgal and macrofaunal communities at the proposed four sampling stations, and would simplify a more detailed comparison of individual station/year collections. To demonstrate this, clustering dendrograms base on annual macroalgal (Fig. 4) and macrofaunal (Fig. 5) collections were generated using the same analytical technique discussed above for the current program, but for only the four proposed sampling stations. Conclusions from these analyses are entirely consistent with those drawn from analyses using all stations under the current program presented in NAI (1996). Namely, annual collections (for both macroalgae and macrofauna) made at stations located in the same depth strata (i.e., shallow subtidal, mid-depth, etc.) formed distinct groupings. Within those groupings, collections made during operational years (1990-1995) at each station often grouped closely with collections made during preoperational years, with no separation of preoperational and operational periods. These analyses indicate that no spatial (nearfield-

farfield) or temporal (preoperational period-operational period) changes to macroalgal and macrofaunal communities have resulted from Seabrook Station operation.

Conclusions

The proposed marine macrobenthos monitoring program after 5 years of Seabrook operation will focus effort on nearfield study sites and their respective farfield counterparts most likely to reflect power plant impacts. These proposed station pairs (shallow subtidal B17/B35 and mid-depth B19/B31) were selected because they are within benthic habitats closest to the source of impacts from Seabrook station (condenser cooling water discharge). Sampling design and data analyses for these sites would remain almost unchanged, and would maintain the historic time-series used for impact assessment. Suspension of sampling at sites more distant from the discharge (intertidal, deep and intake stations) is appropriate because no evidence of power plant impact to local macrobenthic communities (related to thermal plume or turbidity/sedimentation) has been detected after 5 years of Seabrook operation, even at the study sites nearest the discharge where continued monitoring is proposed. And the apparent population decline of *Laminaria digitata* in the nearfield area during the operational period would be closely monitored since the non-destructive subtidal transect study that is used to monitor this species would continue unchanged as part of the proposed monitoring program.

Along with the low potential for impacts, many of the more distant stations have not been as intensively monitored historically; all deep stations and the mid-depth intake station are only destructively sampled one time per year, and are not sampled at all non-destructively. Furthermore, the less extensive habitat at intertidal stations (compared to deeper habitats) makes them more vulnerable to impacts associated with destructive sampling; evidence of sampling impacts have been noted at Seabrook intertidal sampling sites (NAI 1994).

In conclusion, based on thorough evaluation, the proposed marine macrobenthos program after 5 years of Seabrook operation is expected to continue to characterize the communities of attached

plants and animals in the vicinity of Seabrook Station, and to detect impacts to these communities, if they occur.

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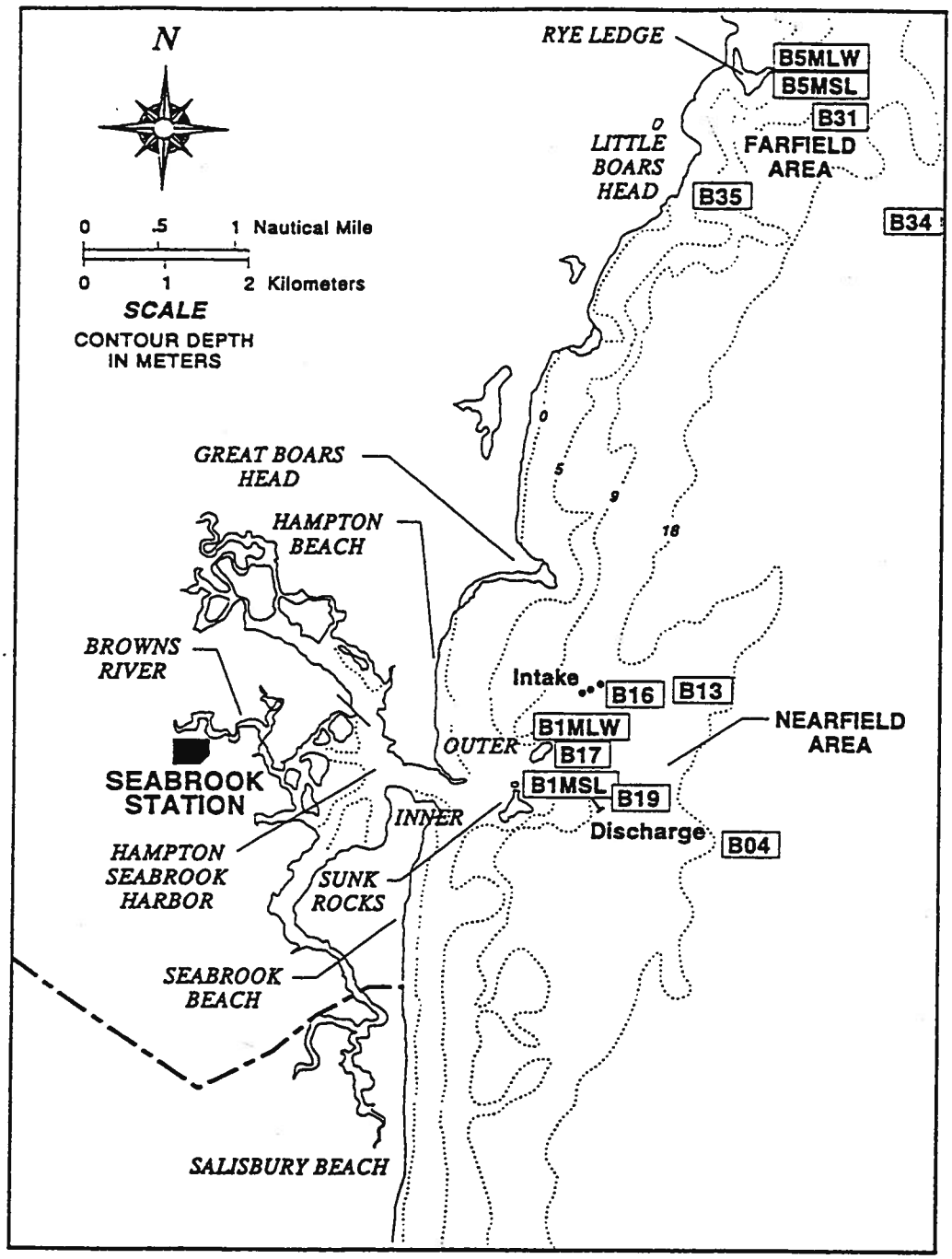


LEGEND

☐ = benthic samples

Fig. 1. Marine macrobenthos sampling stations. From NAI (1996).

Shallow Subtidal Zone: *Laminaria digitata*

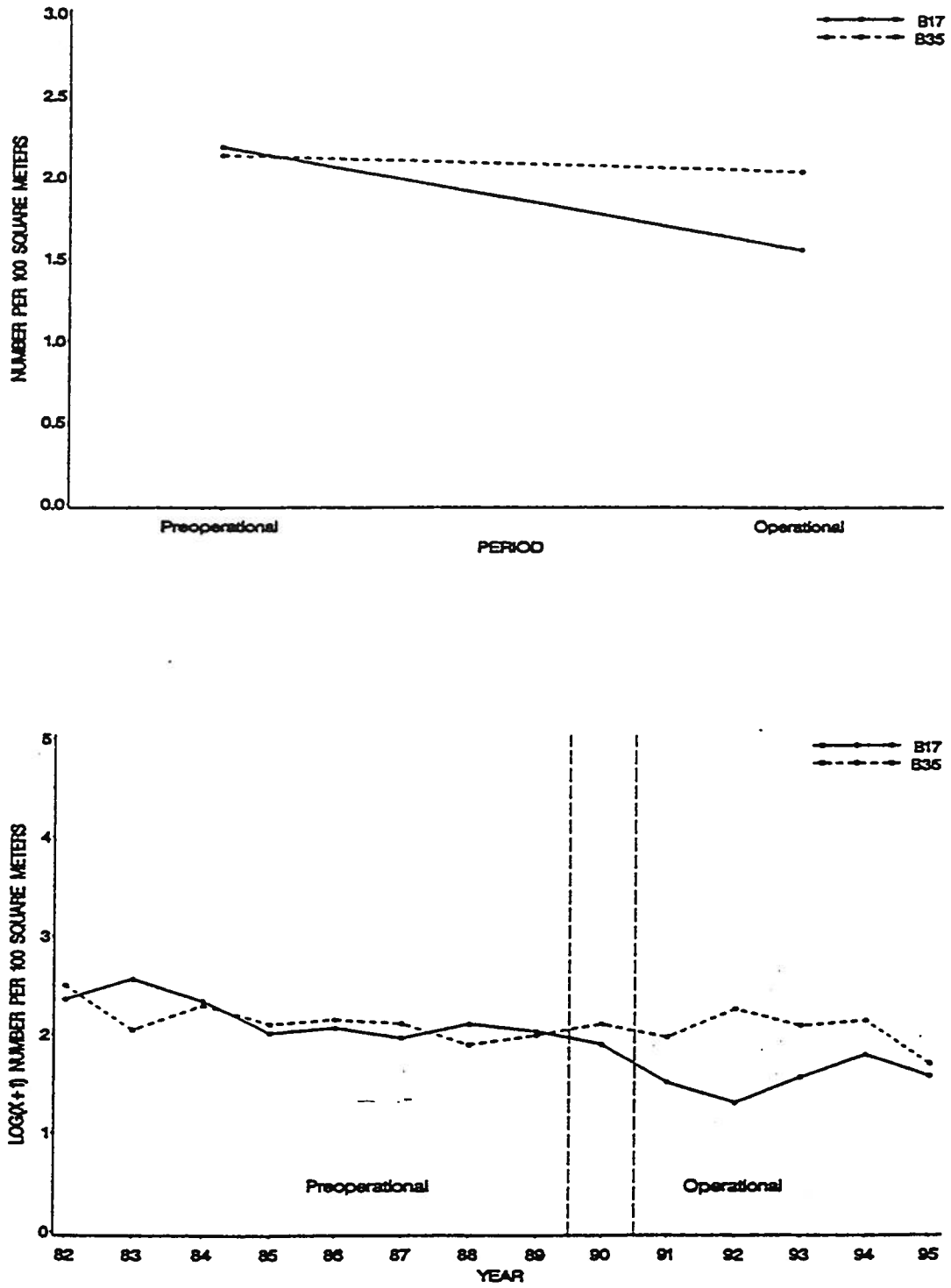
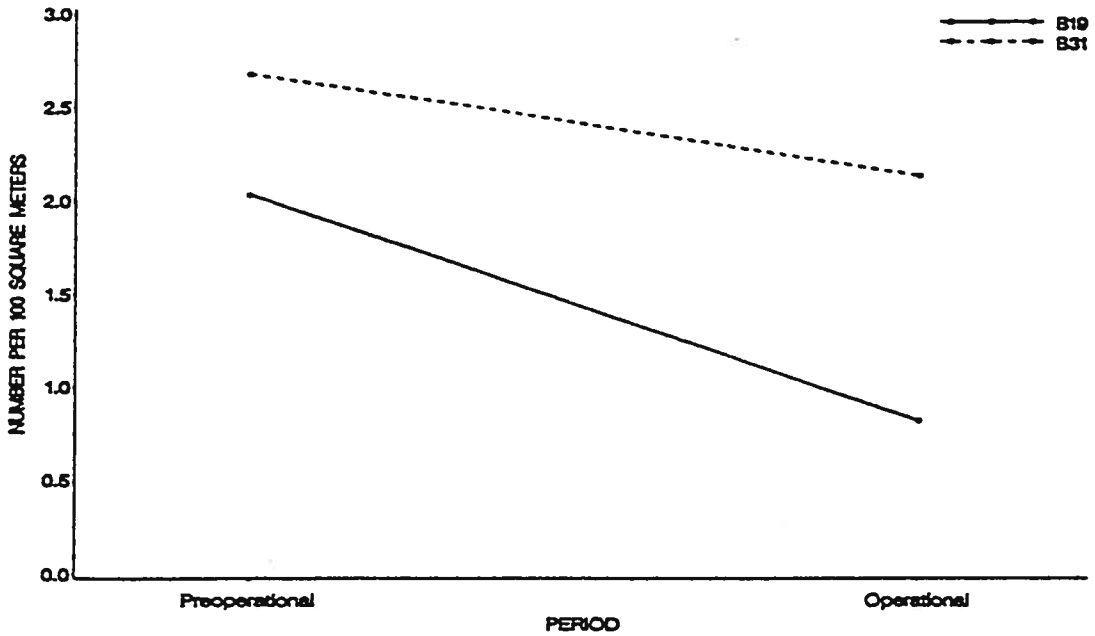


Fig. 2. Comparison between stations of mean number of holdfasts/100m^2 of the kelp *Laminaria digitata* in the shallow subtidal zone during the preoperational (1982-1989) and operational (1991-1995) periods for the significant interaction term (Preop-Op X Station) of the ANOVAmodel (data between the two dashed lines excluded from the ANOVA model). From NAI (1996).

Mid-depth Subtidal Zone: *Laminaria digitata*



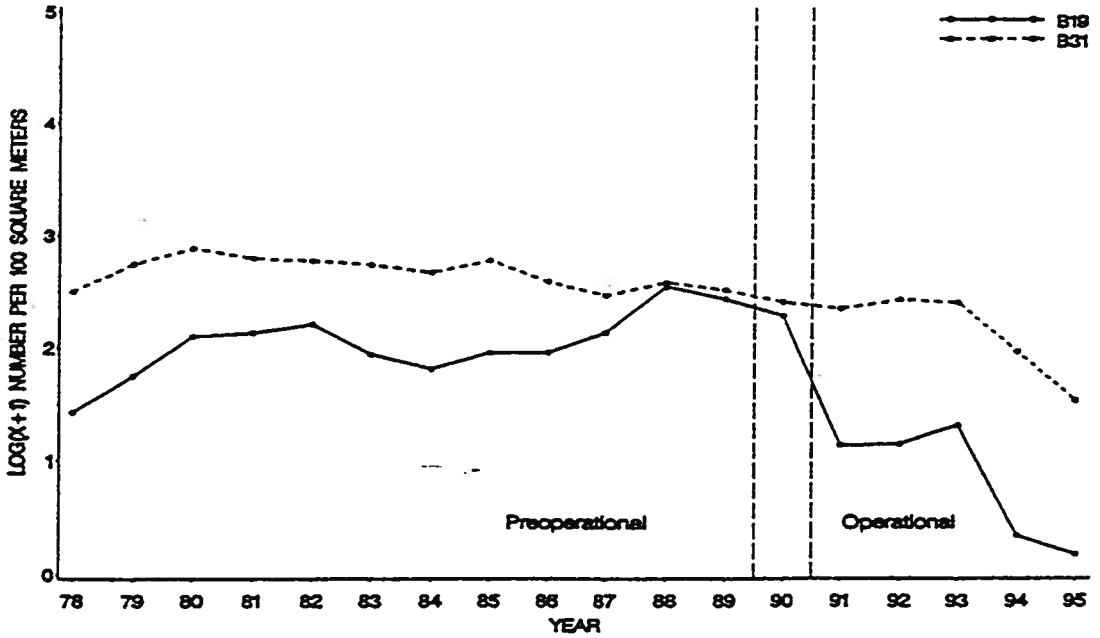


Fig. 3. Comparison between stations of mean number of holdfasts/100m^2 of the kelp *Laminaria digitata* in the mid-depth subtidal zone during the preoperational (1982-1989) and operational (1991-1995) periods for the significant interaction term (Preop-Op X Station) of the ANOVA model (data between the two dashed lines excluded from the ANOVA model). From NAI (1996).

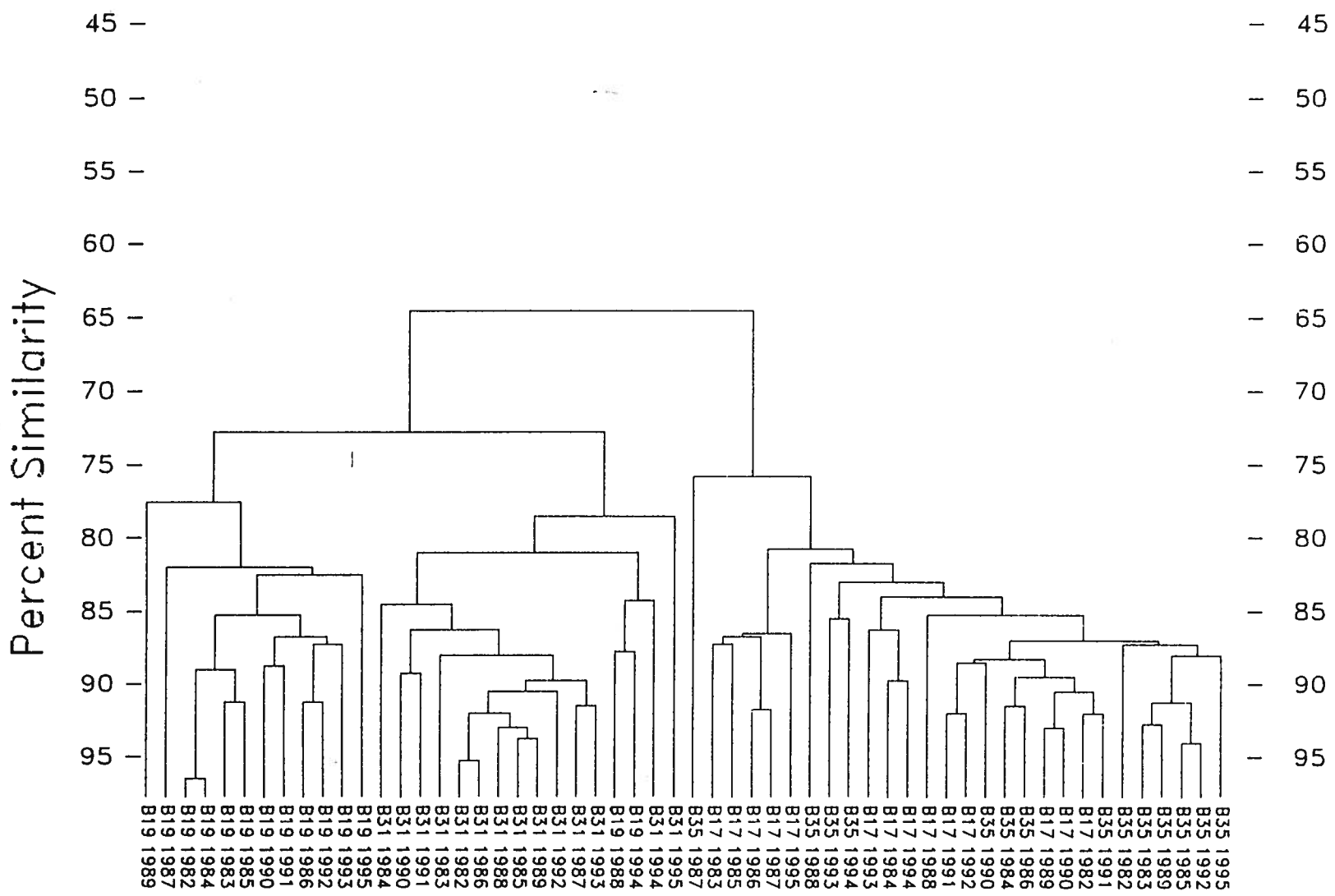


Fig. 4. Clustering dendrogram of percent similarity of macroalgal communities based on annual collections at shallow subtidal and mid-depth stations.

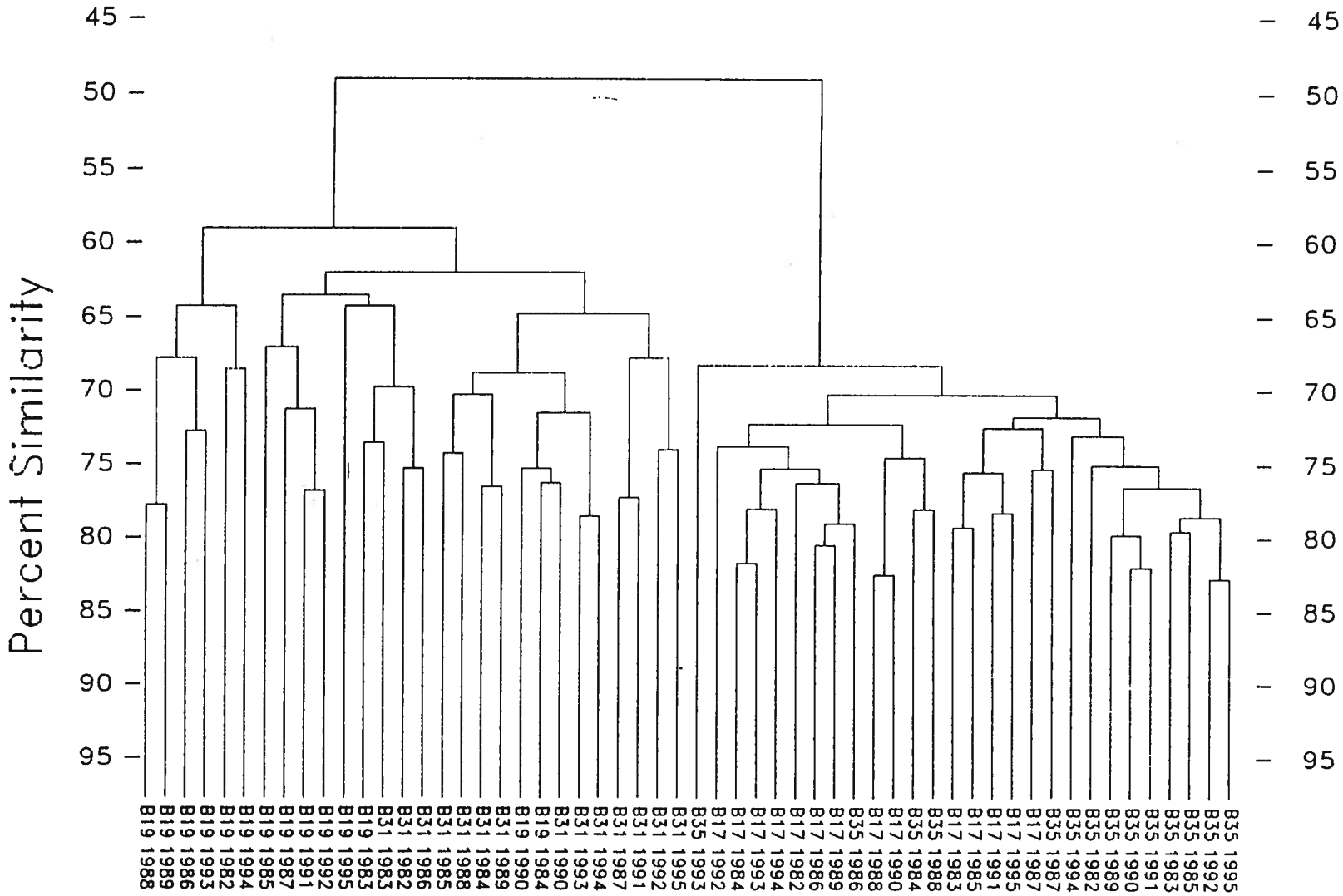


Fig. 5. Clustering dendrogram of percent similarity of macrofaunal communities based on annual collections at shallow subtidal and mid-depth stations.

TABLE 1. SUMMARY OF EVALUATION OF POTENTIAL THERMAL PLUME EFFECTS ON BENTHIC COMMUNITIES IN VICINITY OF SEABROOK STATION. FROM NAI (1996).

COMMUNITY	AREA/DEPTH ZONE	PARAMETER[a]	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS?[b]	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[c]
Macroalgae	Intertidal	No. of taxa	No	NF: Op<Preop FF: Op<<Preop
		Total biomass	No	NF: Op<Preop FF: Op=Preop
		Community structure	Yes	Yes
	Shallow subtidal	No. of taxa	Yes	Yes
		Total biomass	Yes	Yes
		Community structure	Yes	Yes
Macrofauna	Intertidal	No. of taxa	No	NF: Op<<Preop FF: Op<Preop
		Total density	Yes	Yes
		Community structure	Yes	Yes
	Shallow subtidal	No. of taxa	No	NF: Op>Preop FF: Op=Preop
		Total density	Yes	Yes
		Community structure	Yes	Yes

[a]Abundance, no. of taxa, biomass, total density, evaluated using ANOVA; community structure evaluated using numerical classification by year and station.
[b]Operational period = 1990-1995 (August only)
[c]NF = nearfield; FF = farfield

TABLE 2. SUMMARY OF EVALUATION OF POTENTIAL THERMAL PLUME EFFECTS ON REPRESENTATIVE IMPORTANT BENTHIC TAXA IN VICINITY OF SEABROOK STATION. FROM NAI (1996).

COMMUNITY	AREA/DEPTH ZONE	SELECTED TAXON	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS?[a]	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[b]
Macroalgae	Intertidal	*Chondrus crispus*	Yes	NF: Op<Preop FF: Op=Preop
		Ascophyllum nodosum	Yes	NF: Op>Preop FF: Op=Preop
		Fucus vesiculosus	No	NF: Op<<Preop FF: Op<Preop
		Fucus spp. (juveniles)	No	Yes
	Shallow Subtidal	*Chondrus crispus*	Yes	Yes
		Laminaria saccharina	Yes	Yes
		Laminaria digitata	No	NF: Op<Preop FF: Op=Preop
Macrofauna	Intertidal	*Ampithoe rubricata*	No	NF: Op=Preop FF: Op>Preop
		Nucella lapillus	Yes	Yes
		Mytilidae	Yes	Yes
	Shallow Subtidal	*Jassa marmorata*	Yes	Yes
		Asteriidae	Yes	Yes
		Mytilidae	Yes	Yes

[a]Conclusions derived from ANOVA.
[b]NF = nearfield; FF = farfield.

TABLE 3. SUMMARY OF EVALUATION OF POTENTIAL TURBIDITY EFFECTS ON THE BALANCED INDIGENOUS BENTHIC COMMUNITIES IN VICINITY OF SEABROOK STATION. FROM NAI (1996).

COMMUNITY	AREA/DEPTH ZONE	PARAMETER[a]	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS?[b]	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[c]
Macroalgae	Mid-depth	No. of taxa	Yes	B16: Op>Preop B19: Op<Preop B31: Op=Preop
		Total biomass	No	Yes
		Community structure	Yes	Yes
	Deep	No. of taxa	Yes	Yes
		Total biomass	No	Yes
		Community structure	Yes	Yes
Macrofauna	Mid-depth	No. of taxa	Yes	Yes
		Total density	No	B16: Op<Preop B19, B31: Op=Preop
		Community structure	Yes	Yes
	Deep	No. of taxa	Yes	Yes
		Total density	No	B04: Op=Preop B13: Op>Preop B34: Op=Preop
		Community structure	Yes	Yes

[a]Abundance, no. of taxa, biomass, total density, evaluated using ANOVA; community structure evaluated using numerical classification by year and station.
[b]Operational period = 1990-1995 (August only)
[c]NF = nearfield; FF = farfield

TABLE 4. SUMMARY OF EVALUATION OF POTENTIAL TURBIDITY EFFECTS ON REPRESENTATIVE IMPORTANT BENTHIC TAXA IN THE VICINITY OF SEABROOK STATION. FROM NAI (1996).

COMMUNITY	AREA/DEPTH ZONE	SELECTED TAXON	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS?[a]	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[b]
Macroalgae	Mid-depth	*Laminaria digitata*	No	NF: Op<<Preop FF: Op<Preop
		Laminaria saccharina	No	NF: Op<Preop FF: Op=Preop
Macrofauna	Mid-depth	*Pontogeneia inermis*	Yes	Yes
		Modiolus modiolus	Yes	Yes
		Mytilidae	Yes	Yes
		Strongylocentrotus droebachensis	Yes	Yes

[a]Conclusions derived from ANOVA.
[b]NF = nearfield; FF = farfield

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EPIBENTHIC CRUSTACEA

Summary of the Proposed Monitoring Program After 5 Years of Plant Operation

The objective of the epibenthic crustacea monitoring program is to assess potential entrainment effects on larval crabs and lobsters, and discharge-related effects on juvenile and adult forms. This objective has been successfully met, so the proposed program would remain essentially the same as in previous years, due to these species' recreational importance and high profile with the public and regulators. Proposed changes would still maintain continuity with historically reported data.

1. Adult Lobster/Crab Survey would continue unchanged.

2. Lobster/crab larvae sampling design and data analyses for these sites would remain almost identical to previous years, maintaining the historic time-series presented in reports:

    - As with other plankton programs, P2 would be sufficient to characterize the nearfield area, with P7 as its farfield counterpart.

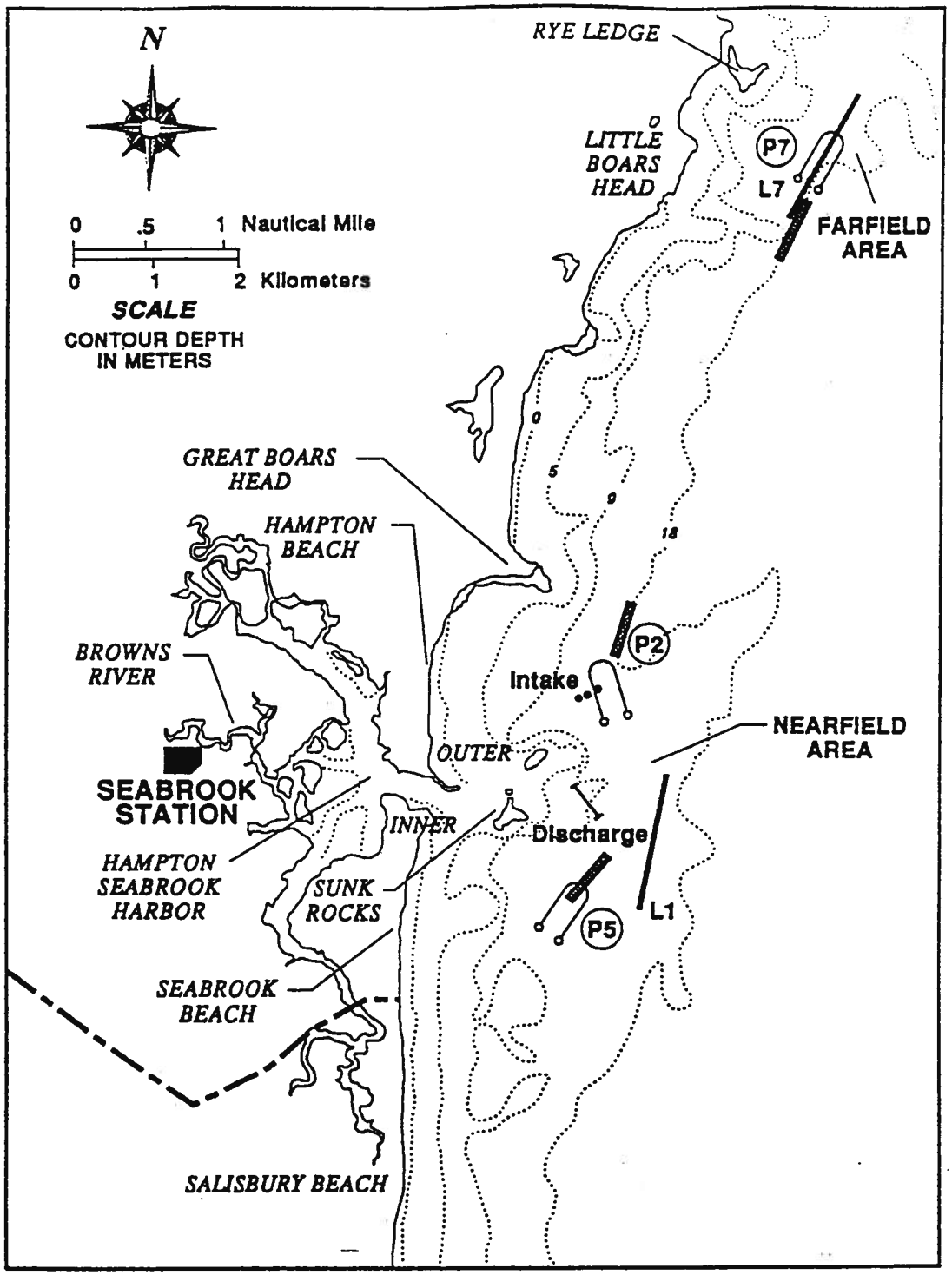
    - The first 4 and last 2 weeks of lobster larvae neuston sampling would be discontinued because of low densities and high variability. Analysis demonstrated improved ability of the proposed program to detect plant operational impacts.

    - *Cancer* spp. larvae sample replicates would be reduced from 3 to 1 (through the macrozooplankton program); analysis indicated that the ability to detect impacts is not affected.

    - *Cancer* crabs will be enumerated in impingement samples.

EPIBENTHIC CRUSTACEA

PROPOSED PROGRAM	PAST PROGRAM
1) Adult Lobster/Rock Crab (No changes proposed)	
• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.	• **Stations/Sampling frequency:** L1/L7; 3X per week, Jun.-Nov.
• **Replicates:** 1 (30 traps)	• **Replicates:** 1 (30 traps)
• **Total samples/year:** 156	• **Total samples/year:** 156
• **Data collected:** Lobster/crab abundance, carapace length (mm), sex determination	• **Data collected:** Lobster/crab abundance, carapace length (1/8"), sex determination
3) Lobster Larvae Neuston	
• **Stations/Sampling frequency:** P2/P7; 1X per week from mid-June through September.	• **Stations/Sampling frequency:** P2, P5 and P7; 1X per week from mid-May to mid-Oct.
• **Replicates:** 1	• **Replicates:** 1
• **Total samples/year:** 30	• **Total samples/year:** 63
• **Data collected:** lobster larvae density	• **Data collected:** lobster larvae density
4) *Cancer* spp. larvae (macrozooplankton sampling)	
• **Stations/Sampling frequency:** Station P2 and P7 sampled twice per month	• **Stations/Sampling frequency:** Stations P2, P5, and P7 sampled twice per month
• **Replicates:** 1 sample	• **Replicates:** 4 replicates collected; 3 replicates processed
• **Total samples/year:** 48	• **Total samples/year:** 288 collected; 216 processed
• **Data collected:** Density per $1000m^3$	• **Data collected:** Density per $1000m^3$



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= Lobster larvae (neuston)

P = Jonah and rock crab larvae (macrozooplankton)

L = Lobster traps (15 traps)

Figure 1. Epibenthic crustacea (American lobster, Jonah and rock crabs) sampling stations. Seabrook Operational Report, 1995.

WORKING DRAFT

EVALUATION OF SEABROOK STATION EPIBENTHIC CRUSTACEAN SAMPLING PROGRAM AFTER FIVE YEARS OF PLANT OPERATION

Prepared for

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August 1996

Evaluation of Seabrook Station Epibenthic Crustacea Sampling Program After Five Years of Plant Operation

Introduction

The American lobster (*Homarus americanus*) is the most valuable fishery resource in the northeastern United States. Since 1979, annual landings in the Gulf of Maine have ranged between 11,000 and 25,000 metric tons, which represents 65% of the total landings in the U.S. (NMFS 1993). Because of the economic importance of lobsters, detailed studies have been conducted in the vicinity of Seabrook Station since 1975 to assess the potential impact of power plant operations on the local lobster resource. Potential impacts of Seabrook Station operation on local lobsters include entrainment of larvae and impingement of adults in the cooling-water system, and possible effects related to the discharge of cooling water, such as increased temperature and turbidity. Other commercially important crustacean species, rock crabs (*Cancer irroratus*) and Jonah crabs (*C. borealis*) have also been monitored as part of the Seabrook Station epibenthic crustacean monitoring program. Like lobsters, the planktonic and adult life stages of these crab species are also potentially susceptible to power plant impacts. The objectives of the epibenthic crustacean monitoring program have been to determine the seasonal, spatial, and annual trends in larval density and catch-per-unit-effort (CPUE) for juvenile and adult stages of these commercially important crustaceans and most importantly, to determine whether Seabrook Station operation had any measurable effect on them.

The purpose of this evaluation was to examine the findings of the epibenthic crustacean monitoring programs after 5 years of Seabrook Station operation. The effectiveness of each aspect of this program in providing data for determining Station impact will be assessed. Recommendations will be made to either maintain current work or to modify sampling where necessary to enhance the collection of information needed for impact assessment.

Summary of Current Methodology

American lobster, Jonah crab, and rock crab have been collected at nearfield (L1) and farfield (L7) stations since 1975 and 1982, respectively (Fig. 1). Fifteen wire mesh 2.5 cm (1 in) lobster traps without escape vents were hauled at two-day intervals from June through November. The following data were recorded for each lobster, rock crab, and Jonah crab: sex, presence of eggs, and carapace length of lobsters or width of crabs.

The distribution and abundance of lobster larvae have been monitored at two nearfield stations since 1978 and 1982, intake (P2) and discharge (P5), respectively, and at one farfield station (P7) since 1988 (Fig. 1). Surface neuston samples were collected once a week during daylight hours from May through October using a 1-m deep x 2-m wide x 4.5-m long net (1 mm mesh) fitted with a flowmeter and a 40 lb depressor. Thirty-minute horseshoe-shaped tows (800 m along each side) were taken with the bottom of the net mouth approximately 0.5 m below the surface; each tow sampled an average of about 3700 m^2 of surface water. Lobster larvae samples were processed in the laboratory shortly after collection; larvae were enumerated and classified by stage and live larvae were returned to Hampton Harbor.

The distribution and abundance of the larval stages of rock and Jonah crabs have been monitored at the same stations as lobster larvae as part of the macrozooplankton monitoring program. Macrozooplankton samples have been collected at least two times per month from January to December since 1978 at P2, January 1982 at P7 and during 1978-81, July-December 1986, and 1987 to the present at P5. No macrozooplankton samples were collected in 1985 at any station. On each sampling day, four replicate (two paired-sequential) oblique tows were made at night with a 1-m diameter 0.505-mm mesh net fitted with a flowmeter. Contents of each sample were preserved in 5-10% buffered formalin for later processing. Since the characteristics of the larval stages of both rock and Jonah crabs are similar, larval abundance and distribution data were pooled for both species as *Cancer* spp. larvae. In the laboratory, three of the four replicate samples collected at each station were processed for *Cancer* spp. larvae.

Monthly arithmetic mean CPUE (no. per 15 traps) was calculated for juvenile and adult lobsters and crabs for the preoperational (1982-89) and operational (1991-95) periods. An analysis of variance (ANOVA; SAS 1985) was applied to annual mean lobster and crab CPUE data to determine differences between the preoperational and operational periods at the nearfield and farfield stations. Monthly geometric means were calculated for lobster and *Cancer* spp. larvae. The ANOVA was applied to log (x+1) transformed densities of lobster and *Cancer* spp. larvae to determine differences between the average abundances for the preoperational (1988-89) and operational (1991-95) periods at the nearfield and farfield stations. The juvenile and adult lobster and crab data collected since 1982 and larval data collected since 1988 were used for impact assessment because the collections met the requirements for the Before-After/Control-Impact (BACI) sampling design (Stewart-Oaten et al. 1986), when all stations were sampled concurrently, and were amenable to statistical testing based on ANOVA models.

Summary of Monitoring Results After 5 Years of Operation

Juveniles and Adults Lobster catches (all sizes) were typically highest from August through November during both preoperational and operational periods. The catchability of lobsters is directly influenced by water temperature; when water temperature rises above 10°C, lobster activity (e.g., feeding, movement, and molting) increases (McLeese and Wilder 1958; Dow 1966, 1969, 1976; Flowers and Saila 1972). Means of total lobster CPUE at the nearfield station during the preoperational and operational periods were not significantly different, but CPUE at the farfield station showed a significant decrease (Table 1). The CPUE of legal-sized lobsters was significantly lower during the operational period than during the preoperational period due, in part, to increases in the minimum legal size limit and to overfishing throughout the range of lobsters. Size characteristics of lobsters and the proportion of egg-bearing females collected at the nearfield and farfield stations were similar during both the preoperational and operational study periods (NAI 1996) and typical of New Hampshire coastal waters (Grout et al. 1989; NHFG 1993). A total of 87 lobsters have been impinged in the cooling water system since

Seabrook Station began operating in 1990 (annual range=1 to 31); this level of impingement is small when compared to two other coastal nuclear power plants in New England, Pilgrim and Millstone Stations (annual ranges=261 to 1,167; NUSCO 1982, 1988; BECO 1994). Although crabs are not currently enumerated in impingement samples, we propose to add this component to the monitoring study.

There is no evidence of an effect by Seabrook Station operation on the local population of lobsters. Impingement of adults has been minimal. The distribution of legal lobsters has been consistent among stations between the preoperational and operational periods. Although total lobster CPUE decreased at the farfield station during the operational period, there was no change at the nearfield station. This change can not be attributable to the operation of Seabrook Station because the decrease occurred only at the farfield station.

Like lobsters, Jonah crab CPUE showed no significant difference at the nearfield station between the preoperational and operational period, but declined significantly at the farfield station (Table 1). However, this decline began during the preoperational period and was not due to the operation of Seabrook Station. Since the study began, rock crab catches have been consistently lower than the catch of Jonah crabs. During the operational period, rock crab CPUEs at both the nearfield and farfield stations were significantly higher than during the preoperational period. There is no evidence of an effect of Seabrook Station operations on local Jonah or rock crab populations.

Larvae Historically, lobster larvae have been rare in the study area, averaging less than 1 per 1000 m^2. Although sampling has been conducted from May through October, peak abundances have typically occurred in July and August; other lobster larvae studies conducted in New England also indicated peak densities in July and August (Fogarty and Lawton 1983; Grabe et al. 1983, NUSCO 1996). Stage IV lobster larvae predominated in collections made during both the preoperational and operational study periods, followed by Stage I larvae; very few Stage II and III larvae were collected. Other researchers working in New England waters have found similar

high variability in the number and stage composition of larvae collected (Bibb et al. 1983; Fogarty 1983; Lux et al. 1983).

The average densities of both lobster and *Cancer* spp. larvae were significantly higher during the operational period than during the preoperational period (Table 1). However, since the increases occurred at both the nearfield and farfield stations, it reflects an area-wide increase. Furthermore, the interaction terms (Preop-Op X Station) for both lobster and *Cancer* spp. larvae were not significant, indicating that the increases observed between the preoperational and operational periods were consistent among stations and were not due to plant operation.

Evaluation of Present Epibenthic Crustacea Sampling Program with Recommendations for Future Studies

Juvenile and Adult Lobsters; Jonah and Rock Crabs Evaluation of Epibenthic Crustacea monitoring program results following 5 years of Seabrook operation show that no changes are recommended in the scope and design of the juvenile and adult lobster, rock, and Jonah crab sampling programs. Because lobsters require several years of growth to reach legal size, there is a lag of about 6-7 years between the time of a potential impact on larvae and the time at which an impact can be detected. For this reason, and the fact that Seabrook Station has only been operating for 5 years, monitoring of juvenile and adult epibenthic crustacea should continue at the current level of effort.

Larvae The lobster larvae sampling program was evaluated to determine whether restricting the sampling period to mid-June through September would affect the ability to detect plant operational impacts on the abundance of local lobster larvae. When the lobster larvae sampling program was initially designed, adequate sampling during the lobster larvae hatching season was necessary to better define the timing of annual hatches and peak abundance of lobster larvae in the Seabrook area. Data collected since 1978 indicate that the abundance of lobster larvae peaks in July or August. The rationale for reducing the sampling period is based on the lack of lobster

larvae found in samples collected at the beginning (May) and end (October) of the present sampling program. These sparse catches contribute only variability without adding to the description of annual abundance. Therefore, an analysis was made to determine if the current sampling period could be changed to mid-June through September without loss of information critical to impact assessment.

Data for *Cancer* spp. larvae originates from the macrozooplankton monitoring program; this program was evaluated separately to determine whether data collected and statistical analyses conducted would become biased if only one sample of the three replicates at each station was processed to determine *Cancer* spp. larval densities. Finally, there are two nearfield stations (P2 and P5) where lobster and *Cancer* spp. larvae have been sampled; discontinuing the larval collections at one of these stations (P5) was evaluated to determine whether the sampling design change would result in an appreciable loss in precision to detect possible operational impacts.

The effect of reducing the sampling period for lobster larvae was simulated by computing annual geometric means for each station and comparing the results of ANOVA tests using data from all samples collected with those obtained by using only samples collected during the mid-June through September period. The same technique was used to assess the effects of using only one sample per date to determine *Cancer* spp. larval density and reducing the number of nearfield stations sampled for both lobster and *Cancer* spp. larvae. Recommendations for program changes were based on whether there was a loss in precision in estimating annual abundance and whether ANOVA results were similar for the current data base and for two simulated databases (3 stations and 2 stations sampled from mid-June through September). Of particular concern were the results from testing the Preop-Op X Station interaction, critical for impact assessment, and whether the mean squares for the actual and simulated databases were similar. The significance of this interaction was tested with separate F-tests.

A total of 510 lobster larvae samples were collected at the three stations from 1988 through 1995, but only 250 contained lobster larvae (less than 50% of the samples). Smith et al. (1993) stated

that databases with excessive zeros used in a BACI design could result in unreliable statistical tests. Examination of the distribution of sample densities during the mid-May through mid-October collection period indicated that many of the samples with no larvae were collected from May through mid-June and in October. In addition, the geometric mean density of lobster larvae was lowest during these two periods (Fig. 2). When these samples were eliminated (a reduction of about 30% of the total samples), the percentage of non-zero sample densities increased to about 65%.

The annual geometric means for each of the three stations computed from the simulated reduced database (mid-June through September samples) were consistently greater than those using the complete database (mid-May through mid-October), due primarily to the reduction in the number of zero density samples (Table 2). The increases in annual abundance estimates using the reduced sampling period did not alter the general ranking or magnitude of differences among stations within a year nor among years at each station when compared to the estimates using the complete database. Of greater importance, there was a consistent increase in the precision of the annual abundance estimates using data from the reduced sampling period, based on inspection of the standard errors expressed as a percentage of the geometric means (Table 2).

The abundance of lobster larvae at the two nearfield stations (P2 and P5) was compared with the Wilcoxon's signed ranks test for paired comparisons (Sokal and Rohlf 1969). Paired samples containing lobster larvae at either P2 or P5 were collected on the same date a total of 95 days from 1988 to 1995. No significant ($p = 0.672$) difference in abundance between stations was detected. Furthermore, comparison of the F-tests from ANOVA analyses of the complete and reduced databases showed similar results (Table 3). The Preop-Op, Year(Preop-Op), and Week(Year) terms were significant ($p \leq 0.05$) and the Station and Preop-Op X Station terms were not significant (Table 3). The critical interaction (Preop-Op X Station) term for assessing plant impact was not significant in either the reduced sampling scenario (as with the actual data base) and the F-value of 1.57 for three stations was well below the point of rejection of $F_{0.05} = 3.04$; the F-value of 1.21 for two stations with reduced sampling period was also below the point

of rejection of $F_{0.05} = 3.98$. In addition, there was no significant difference detected with F-tests between the interaction mean squares from the actual database and those from the two reduced databases for three stations ($p = 0.431$) and two stations ($p = 0.565$).

Comparison of the three ANOVAs (three replicates versus one sample per sampling date for three stations and two stations) for *Cancer* spp. showed similar results in assessing potential plant impact (Table 4) and suggests that current sample replication is redundant. The interaction (Preop-Op X Station) term, critical for impact assessment, was not significant in either reduced sampling scenario, as with the actual data base. The F-values of 0.04 for three stations and of 0.06 for two stations were well below the point of rejection of $F_{0.05} = 2.95$ and 3.76 for three stations and two stations, respectively. In addition, there was no significant difference detected with F-tests between the interaction mean squares from the actual database and those from the two reduced databases for three stations ($p = 0.207$) and two stations ($p = 0.427$). Similar results were demonstrated in an ongoing evaluation of the macrozooplankton monitoring program for other selected species, including *Calanus finmarchicus, Carcinus maenas, Crangon septemspinosa,* and *Neomysis americana.*

Conclusions

No changes are recommended in the scope and design of the juvenile and adult lobster, rock, and Jonah crab sampling programs; these monitoring programs should continue at the current level of effort. The timing of annual lobster larvae hatches and peaks in abundance have been well documented for the Seabrook area and since lobster larvae have been rarely collected at the beginning or end of the present sampling period, restricting this sampling period from mid-June through September would not cause a loss in the ability to detect possible Seabrook Station operational impacts. The shorter sampling period also will improve the precision of mean estimates. As was demonstrated for other macrozooplankton, a reduction in replicates for estimating *Cancer* spp. larval densities was indicated as no significant differences were found between the mean of three replicates and one sample. Further, even with discontinued sampling

of lobster and *Cancer* spp. larvae at station P5, the BACI sampling design will be maintained with stations P2 and P7 and with no appreciable loss in model sensitivity. The estimated variances for the critical interaction terms were similar for the present and proposed sampling programs. Therefore, it is proposed that the collection of lobster larvae samples be restricted to the period from mid-June through September at stations P2 and P7. It is also recommended that *Cancer* spp. larval collections be reduced from three to one sample per sampling date at stations P2 and P7. These modifications should not reduce the sensitivity of the monitoring programs to detect plant operational impacts, if any, nor affect annual and spatial abundance comparisons.

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Table 1. Summary of potential plant effects on abundance of epibenthic crustacea. Seabrook Operational Report, 1995.[a]

PARAMETER MEASURED	OPERATIONAL PERIOD SIMILAR TO PREOPERATIONAL PERIOD[b]	DIFFERENCES BETWEEN PREOPERATIONAL AND OPERATIONAL PERIODS CONSISTENT AMONG STATIONS[c]
Lobster: Larvae	Op>Preop	Yes
Lobster: Total Catch	Op<Preop	nearfield: Op=Preop farfield: Op<Preop
Lobster: Legal-Sized Catch	Op<Preop	Yes
Cancer spp.: Larvae	Op>Preop	Yes
Jonah Crab: Total Catch	Op<Preop	nearfield: Op=Preop farfield: Op<Preop
Rock Crab: Total Catch	Op>Preop	Yes

[a] From NAI (1996).
[b] based on Preop-Op term of ANOVA model (Table 8-2 in NAI 1996).
[c] based on the interaction term (Preop-Op X Station) of the ANOVA model and multiple comparison test at $\alpha \leq 0.05$ (Table 8-2 in NAI 1996).

Table 2. Comparison of annual lobster larvae geometric means (number per 1000 m^2) and standard errors (SE), expressed as a percentage of the mean, for each station computed using the actual (mid-May through mid-October) and reduced (mid-June through September) databases, 1988-95.

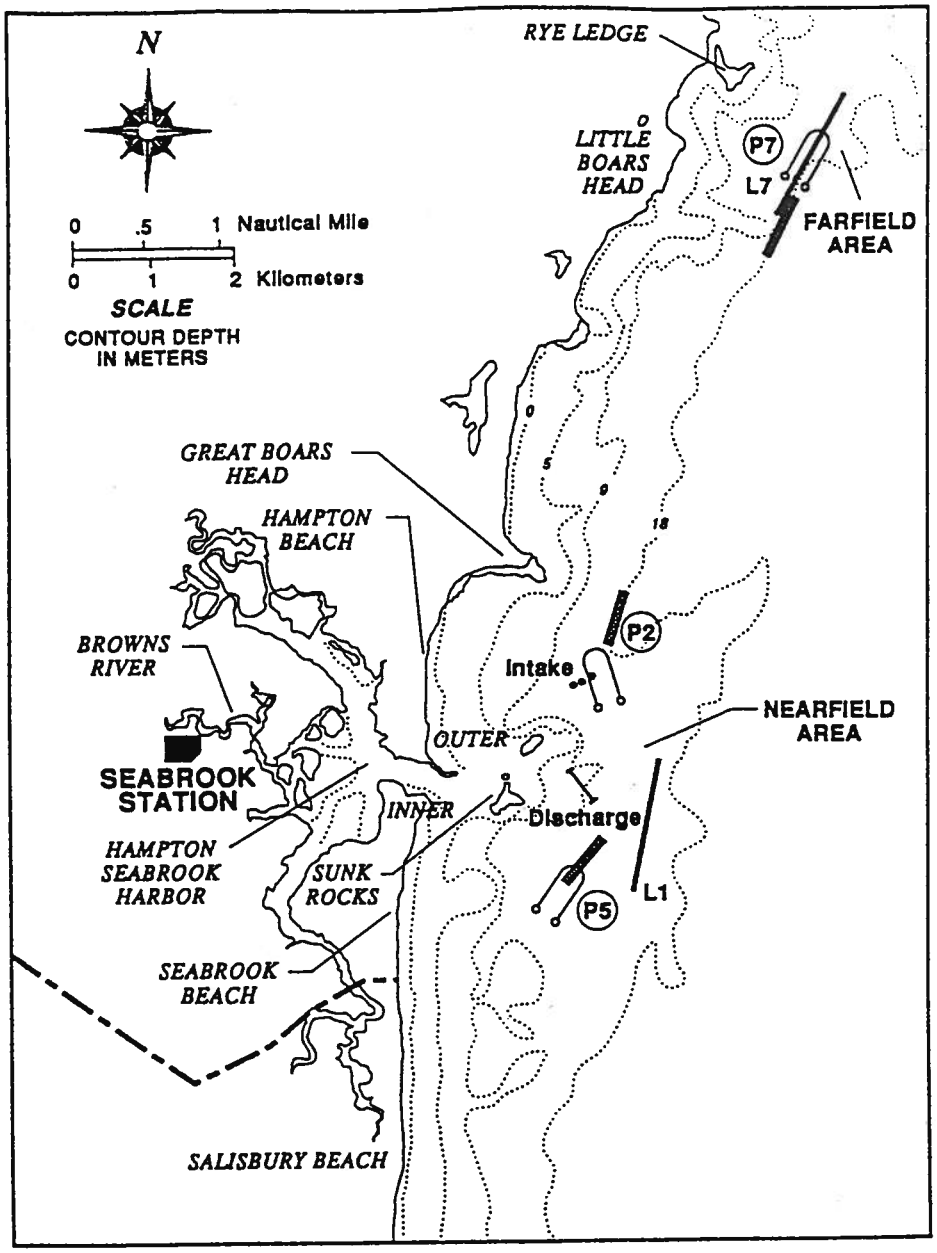
		Actual		Reduced	
Year	Station	Mean	SE as % of mean	Mean	SE as % of mean
1988	P2	0.4	35.7	0.7	32.8
	P5	0.6	35.5	0.9	32.5
	P7	0.4	32.6	0.6	30.8
1989	P2	0.4	36.5	0.7	33.6
	P5	0.5	51.0	0.7	38.5
	P7	0.4	40.9	0.7	38.5
1990	P2	1.0	37.9	1.6	35.9
	P5	0.9	39.4	1.3	39.1
	P7	1.1	36.9	1.5	37.7
1991	P2	0.9	31.7	1.4	28.6
	P5	0.9	35.3	1.5	32.7
	P7	1.1	24.7	1.8	21.1
1992	P2	1.3	27.2	2.2	25.1
	P5	1.1	27.9	1.9	24.6
	P7	1.5	21.8	2.4	20.4
1993	P2	0.7	29.9	1.2	26.2
	P5	0.6	28.2	1.0	24.2
	P7	0.7	30.2	1.1	26.5
1994	P2	0.7	32.1	1.2	29.1
	P5	0.5	34.2	0.8	31.5
	P7	1.5	28.6	2.7	25.1
1995	P2	0.7	30.7	1.0	28.1
	P5	0.8	31.6	1.2	31.9
	P7	0.8	26.6	1.2	24.3

Table 3. Comparison of lobster larvae results for ANOVA tests computed using the actual (mid-May through mid-October) and two reduced database scenarios of mid-June through September with the present three stations and mid-June through September with only stations P2 and P7, 1988-95

Source of variation	df	MS	F-value	P
		Actual		
Preop-Op	1	1.79	42.59	0.001
Year (Preop-Op)	5	0.17	3.96	0.002
Week (Year)	129	0.32	7.68	0.001
Station	2	0.02	0.48	0.621
Preop-Op X Station	2	0.07	1.69	0.187
Error	310	0.04		
		Stations P2, P5 and P7 with reduced sampling period		
Preop-Op	1	2.30	38.56	0.001
Year (Preop-Op)	5	0.20	3.34	0.006
Week (Year)	87	0.35	5.90	0.001
Station	2	0.02	0.31	0.733
Preop-Op X Station	`2	0.09	1.57	0.211
Error	214	0.06		
		Stations P2 and P7 with reduced sampling period		
Preop-Op	1	1.91	30.54	0.001
Year (Preop-Op)	5	0.16	2.50	0.035
Week (Year)	87	0.24	3.78	0.001
Station	1	0.03	0.48	0.489
Preop-Op X Station	1	0.08	1.21	0.274
Error	112	0.06		

Table 4. Comparison of *Cancer* spp. larvae results for ANOVA tests computed using the actual (three stations with three replicate samples) and two reduced database scenarios of three stations and one sample and two stations and one sample, May through September 1987-95.

Source of variation	df	MS	F-value	P
		Actual		
Preop-Op	1	3.52	4.89	0.028
Year (Preop-Op)	6	2.11	2.94	0.009
Month (Year)	32	7.15	9.94	0.001
Station	2	0.76	1.05	0.351
Preop-Op X Station	2	0.12	0.16	0.851
Error	193	0.72		
		Stations P2, P5 and P7 - One sample		
Preop-Op	1	4.45	5.57	0.019
Year (Preop-Op)	6	2.06	2.58	0.020
Month (Year)	32	7.36	9.23	0.001
Station	2	0.66	0.82	0.440
Preop-Op X Station	2	0.03	0.04	0.963
Error	193	0.80		
		Stations P2 and P7 - One sample		
Preop-Op	1	3.07	3.52	0.063
Year (Preop-Op)	6	1.37	1.57	0.163
Month (Year)	32	5.42	6.21	0.001
Station	1	1.05	1.21	0.274
Preop-Op X Station	1	0.05	0.06	0.808
Error	116	0.87		



LEGEND

= Lobster larvae (neuston)

P = Jonah and rock crab larvae (macrozooplankton)

L = Lobster traps (15 traps)

Figure 1. A map of the Seabrook-Hampton area showing the location of the epibenthic crustacea (American lobster, Jonah and rock crabs) sampling stations.

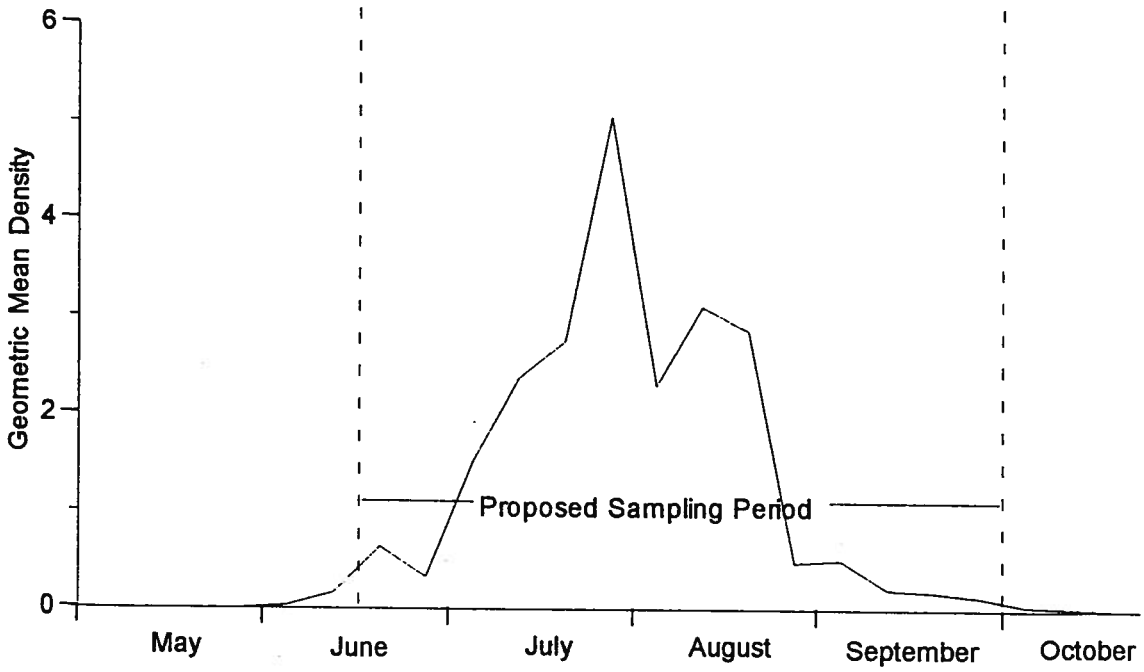


Figure 2. Weekly geometric mean density (number per 1000 m^2) of lobster larvae at stations P2, P5, and P7 combined, 1988-95.

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MYA ARENARIA

Summary of the Proposed Monitoring Program After 5 Years of Plant Operation

The objectives of the proposed Mya arenaria program are to ensure the continuity of the current database on the soft-shell clam and its predators, and to make available information needed to explain to the public major changes in clam abundance which may occur in the future. The proposed *Mya arenaria* monitoring program would have three main components: 1) The Hampton Harbor Population Surveys; 2) the Near/Farfield Study; and 3) The Predator Surveys. Because of this species' recreational importance and high profile with the public and regulators it is important to maintain continuity with historically reported data.

1. Hampton Harbor Survey would focus on Flats 1,2, and 4; data from Flats 3 and 5 have not been used in analyses in the past due to low densities of clams >25 mm. Surveys at Hampton Harbor Flats 2 and 4 should be maintained because they are also used in the Near/Farfield Study. The monthly survey of green crabs on Flat 2 would continue unchanged.

    - Sampling design and data analyses for the Population Survey should change to reflect the fact that larval abundance and annual clam set are totally unrelated (see supporting regression analysis attached). Thus, plant effects via larval entrainment can be dismissed. Since incursions of warm water into the estuary from the thermal plume have not occurred, the focus of the program should change from "impact assessment" to "Annual Abundance Survey". This new focus, with similar monitoring effort, would serve better the interest of NH State and the public by monitoring the availability of soft-shell clams for recreational fishing.

    - Redesign the sampling program and allocate similar effort to improve accuracy of annual estimates by size classes; annual means and stratified random design will be useful for this purpose.

2. The Nearfield/Farfield Study would be the same as in the past program because it is the only study that actually provides valid data for statistically testing whether future clam abundance declines, mass mortalities, etc. can be attributed to plant operation.

3. The green crab surveys would continue unchanged. Clam digger counts should be discontinued if recreational license data is acceptable to quantify harvesting effort; otherwise restrict sampling to Flats 1, 2, an 4 for consistency with the random surveys of adult clams in the fall.

MYA ARENARIA

PROPOSED PROGRAM	PAST PROGRAM
1) Random survey - Hampton Harbor	
• **Stations/Sampling frequency:** Reallocate similar sampling effort to *Mya* adults and spat in the historically most productive two or three flats using stratified random design.	• **Stations/Sampling frequency:** *Mya* adults - flats 1,2,4 / *Mya* spat - flats 1-5; once per year in the fall.
• **Replicates:** determined by historical variability	• **Replicates:** varies
• **Data collected:** Density by size class starting at 1 mm	• **Data collected:** Density by size class
2) Nearfield/Farfield Study - no changes proposed	
• **Stations/Sampling frequency:** 10 stations each in Hampton Harbor and Plum Island Sound, once per year in the fall.	• **Stations/Sampling frequency:** 10 stations each in Hampton Harbor and Plum Island Sound, once per year in the fall.
• **Replicates:** 3	• **Replicates:** 3
• **Total samples/year:** 60	• **Total samples/year:** 60
• **Data collected:** Seed clam (1-12 mm) density	• **Data collected:** Seed clam (1-12 mm) density

MYA ARENARIA

PROPOSED PROGRAM	PAST PROGRAM
3) Predator Surveys	
a) Clam digger counts **Replace with recreational license data (currently used);** or consider sampling only at monitoring stations as outlined below. • **Stations/Sampling frequency:** Stations 1,2 and 4; once per week except from June through August • **Replicates:** 1 • **Total samples/year:** 76 • **Data collected:** Number of diggers per flat.	**a) Clam digger counts** • **Stations/Sampling frequency:** Stations 1,2,3,4 and 5: once per week except from June through August • **Replicates:** 1 • **Total samples/year:** 190 • **Data collected:** Number of diggers per flat.
b) Green Crabs - no changes proposed • **Stations/Sampling frequency:** Stations 1-4 within *Mya* Flat 2 in Hampton Harbor; twice monthly except Feb. and Mar. • **Replicates:** 2 • **Total samples/year:** 160 • **Data collected:** Monthly CPUE	**b) Green Crabs** • **Stations/Sampling frequency:** Stations 1-4 within *Mya* Flat 2 in Hampton Harbor; twice monthly except Feb. and Mar. • **Replicates:** 2 • **Total samples/year:** 160 • **Data collected:** Monthly CPUE

4) Bivalve Larvae: discussed with zooplankton evaluation

WORKING DRAFT

EVALUATION OF SEABROOK STATION
SOFT-SHELL CLAM (*Mya arenaria*) PROGRAMS
AFTER FIVE YEARS OF PLANT OPERATION

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Evaluation of Seabrook Station Soft-shell Clam (*Mya arenaria*) Program After Five Years of Plant Operation

Introduction

The range of the soft-shelled clam *Mya arenaria* on the East Coast extends from Labrador to North Carolina (Abbott 1954); in New England *Mya arenaria* is especially abundant in Maine, New Hampshire and parts of Massachusetts, where it tends to be associated with silty-sand sediments (Whitlatch 1982). This clam is typically thought of as an intertidal bivalve because it is harvested from mud flats when exposed at low tide; the species, however, does occur below the water mark. The soft-shell clam is a widely occurring species in coastal mud flats throughout the Gulf of Maine (Larsen and Doggett 1991) where it has great economic importance due to his high recreational and commercial value; in the vicinity of Seabrook Power Station the tidal flats in the Hampton-Seabrook estuary contain the majority of New Hampshire's stock of soft-shell clam. Potential impacts of Seabrook Station operation on this local soft-shell clam were expected to be negligible (YAEC 1982) and they appeared limited to entrainment of planktonic *Mya arenaria* larvae in the cooling-water system, and to possible effects associated with the station discharge of cooling water such as increased water temperatures in the thermal plume path and increased turbidity near the discharge site from resuspension of organic sediments. Although unlikely, given the predicted path and extent of the thermal plume (Teyssandier et al. 1974), there was also the possibility of Seabrook plume being carried by tidal currents into the Hampton-Seabrook estuary. For all these reasons and also because the soft-shell clam is the most economically important species inhabiting the estuary (Sullivan and Sawyer 1966), the collection of baseline data on *Mya arenaria* in the tidal flats of Hampton Harbor started in 1971 in preparation for the planned construction of Seabrook Station. This database has been incremented annually to the present, essentially keeping the original sampling locations at five selected flats (Fig. 1). A control site at Plum Island Sound (Fig. 1) has also been sampled annually since 1976, sampling programs for green

crabs (Fig. 1) and for bivalve larvae (Fig. 2) were started in 1978, and surveys of clam diggers started in 1980. The objectives of these monitoring programs have been to describe the spatial and temporal distribution of various life stages of soft-shell clams in the Hampton-Seabrook estuary, to compare their abundance to that of the same clam species monitored in Plum Island Sound since 1976 and, most importantly, to assess whether the operation of Seabrook Station has had a significant adverse effect on the abundance and distribution of soft-shell clams in the Hampton-Seabrook estuary.

The purpose of this evaluation is to review results to date of the *Mya arenaria* monitoring program, after more than 20 years of study that include the first 5 years (1991-1995) of Seabrook plant operation, and to assess how well program objectives have been met. The effectiveness of each component of the program in assessing plant operation effects on soft-shell clams will be examined and what has been learned since the inception of the program will form the basis for recommending program changes where needed. Finally, an improved and more focused *Mya arenaria* program to be implemented after 1996 is proposed.

Summary of Current Program

The current soft-shell clam monitoring program at Seabrook consists of four separated but related studies: the annual population survey at Hampton Harbor, the nearfield/farfield study, the predator surveys, and the larval study. The latter is only a part of a larger bivalve larvae program (see Evaluation of the Zooplankton Program) that arose from the need to monitor abundance of *Mya arenaria* larvae. A succinct review of each of these programs databases and methodology follows; more detailed descriptions have been provided by Normandeau Associates Inc. in their annual reports of the Seabrook Station Environmental Studies, the most relevant being NAI (1990) for the pre-operational period and NAI (1996) for the operational years.

Hampton Harbor Population Survey.

The first survey of soft-shell clams in the Hampton-Seabrook estuary was conducted in the Summer of 1969 as a part of a two-year preliminary Seabrook ecological study (Normandeau et al. 1971), which yielded an estimated standing crop of 21,769 bushels of legal size clams from the total of 174 acres among the ten productive clam flats surveyed. These flats were the same ten flats used by Ayer (1968) in his study for the NH Fish and Game Dept. Among them, Flats nos. 1, 2, and 4 were the most productive with 11,775., 2,972., and 2,492. bushels, respectively; except for Flats nos. 3 and 5 (over 1000 bushels each), all the other flats were only marginally productive (less than 500 bushels each). These data were the basis to later select the five most productive flats for the annual surveys started in 1971.

Flats nos. 1 through 5 in the Hampton-Seabrook estuary (Fig. 1) have been surveyed in the late fall from 1971 through 1995 to estimate densities of clams measuring at least 1 mm. Sampling sites in each flat were chosen randomly and their number was proportional to the variance in density observed in each flat historically (NAI 1996). Flats nos. 3 and 5 were not sampled for clams larger than 25 mm in length after 1984 because their density had been historically low (Table 1). Samples for Young-of-Year (YOY) and spat (1-25 mm) consisted of three cores (10.2 cm diameter and 10.2 cm deep) taken within a 30 x 61 cm quadrat (1 x 2 ft). Samples were sieved (1 mm mesh) and clams were enumerated, measured and released. Samples for clams > 25 mm consisted of the same quadrat as before but dug to a depth of 45 cm with a clam fork; large clams were removed from the sediment, enumerated, measured, and released. The clam counts were classified into four size-classes: YOY (1-5 mm), Spat (6-25 mm), Juvenile (26-50 mm), and Adult (legal size) clams > 50 mm (NAI 1996).

The parameters reported have been annual means corresponding to numbers of clams per square foot at each of the flats sampled during the preoperational period (Table 3.3.7-1, NAI 1990), and annual geometric means and coefficients of variability for combined densities of all flats sampled annually both during the preoperational and the operational periods (NAI 1996). These geometric means were based on a sample size equal to the number of years sampled in each period, and on a sample size equal to the number of samples for any given year (NAI

1996). A fixed effects analysis of variance (ANOVA) model was used on log(x+1) transformed mean densities (n=number of samples) to test for differences in the following main effects: spatial differences (among areas or flats), temporal differences (among years), and differences between periods (preoperational and operational). Although this model had also and interaction term (Preop-OP x areas), the test had no interpretation because flats could not be assigned rationally to "nearfield" and "farfield" groups to meet the requirements of the BACI sampling design on which the ANOVA model was based (Green 1979; Underwood 1994).

Nearfield/Farfield Study.

This study started in 1976 to compare seed clam (1-12 mm) densities between Hampton Harbor and Plum Island Sound, Ipswich, Massachusetts. The surveys were conducted once a year in the fall at ten sites in each location, Hampton Harbor (Flats 2 and 4) and Plum Island Sound (Fig. 1). Three cores were taken per site and processed in the same manner as in the Hampton Harbor population survey described above. Sampling sites were fixed in the above mentioned locations and the specific sampling areas were selected according to where the abundance of clams had been high historically (NAI 1996). The parameters reported have been annual geometric means and coefficients of variability of densities of seed clams (1-12 mm) at Hampton Harbor and Plum Island Sound, and "preoperational" and "operational" geometric means. These means were based on the number of samples for any given annual mean and in the number of years sampled for the means of preoperational and operational periods. The same fixed ANOVA model used in the Hampton Harbor surveys was applied to the annual means of this study to determine whether there was a Seabrook Station effect when the interaction term (Preo-Op x Location) was significant. Because Hampton Harbor qualifies as "nearfield" and Plum Island Sound as "farfield", the BACI sampling design requirements were met and the interpretation of the interaction term was straightforward.

Predator Surveys.

Clam digger counts. Beginning in the spring of 1980 the numbers of diggers in flats 1, 2, 3, 4, and 5 have been counted weekly, except for the summer months (Memorial Day through

Labor Day). The parameter reported has been the estimated total number of digger trips per flat (see note [a] in Table 3 for more details). These data was summarized by flat, as percentages of the total, and by either spring or fall, since the spring of 1980 through the Spring of 1989 (NAI 1990). Hampton Harbor flats were closed to clam digging from April 1989 through September 1994 and the Spring of 1995, depending on the flats, by the NH Dept. of Health and Human Services due to coliform contamination.

Green crab (*Carcinus maenas*). Beginning in the Fall of 1977, *C. maenas* crabs were trapped at four stations around the perimeter of Flat # 2 (Fig. 1). The traps were set twice a month except for February and March when historically no crabs were found; two baited "box" traps (13-mm mesh) were set at each station so that they were awash at mean low tide. After fishing for 24 h traps were retrieved and catch was sized and sexed. Reported parameters have been monthly catch per unit effort (CPUE) during both preoperational and operational years. The only estimates based on these data were the monthly geometric means for individual years and the monthly geometric means for the entire preoperational and operational periods. The data were log(x+1) transformed prior to any calculations (NAI 1996).

Bivalve larvae.

The spatial and temporal distribution of 12 species of bivalve larvae, including *Mya arenaria*, have been monitored since July 1976 at station P2 (intakes), during July-December 1986 and since April 1988 to the present at station P5 (discharge), since July 1982 at station P7 (farfield control), and since July 1986 at P1 (Hampton Harbor) (Fig. 1). Samples were collected weekly from mid-April through October at all stations; two simultaneous two-minute oblique tows were taken at each station and preserved (NAI 1996). A more detailed description of methods, including laboratory processing, can be found in NAI (1991). Samples of the same 12 species of bivalve larvae entrained at Seabrook Station have been collected weekly since 1990 (see Zooplankton Programs and their Evaluation report for an account). Parameters reported from the *Mya arenaria* larval collections at the plankton stations have been log(x+1) numbers per cubic meter, and the geometric mean of individual years and for the entire preoperational and operational periods. The same ANOVA model described earlier was used

to analyze the larval data with the BACI sampling design where station P7 was the control station or farfield and P2 and P5 were the nearfield stations.

Summary of Results
After 5 Years of Seabrook Plant Operation

Population survey.

Densities of all sizes of soft-shell clams at Hampton Harbor have been highly variable during both preoperational and operational periods NAI (1996). The YOY (1-5 mm) size class has historically undergone periodic fluctuations in abundance approximately every three years. This typical periodicity was apparent in both preoperational and operational periods, and differences among flats just added to the noise without providing any insight into the overall trend (Fig. 3). Although the operational period mean for all the flats was lower (Table 2), none of the statistical tests could relate this differences to Seabrook Station operation (NAI 1996). The spat (6-25 mm) and juvenile (25-50 mm) size classes generally reflect the recruitment success of the previous one and two years' spat falls, but this success is modulated by predators' activities (both green grabs and clam diggers disturbing the flats and exposing small clams to predation). Densities of spat reached a low in 1984 and seem to be increasing now (Fig. 4); the peaks in 1990 and 1994 were preceded by good sets of YOY in 1989 and 1993 (Fig. 3). Differences among flats are widespread and the overall mean is lower during the operational period (Table 2). For juvenile clams the lowest density was observed in 1986 (one year after the "low" for spat), then increased up to 1990, decreased to a secondary low in 1993 and increased at all flats in 1994 and 1995 (Fig. 5). The mean for all flats in 1995 was higher than either the preoperational or the operational means (Table 2), and again, none of these changes could be related to the operation of Seabrook Station (NAI 1996). Finally, legal size clams (>50 mm) were more abundant in 1995 than in an average year of either the preoperational or operational periods and specially so for Flat # 4 (Table 2); however abundances have been generally higher every year since 1989 at all flats (Fig. 6). With Hampton Harbor closed to recreational clamming from April 1989 through September 1994,

and April 1995 depending on the flat, the number of legal clams on Flat # 4 greatly increased from 1989 to 1990 and remained fairly high from 1991 through 1995; the largest number reported in the entire study occurred in 1992 for Flat # 4 (Fig. 6). Another factor that could have some effect in the peak abundance of legal clams at Flat # 4 was the disease sarcomatous neoplasia, a lethal form of blood cancer. Neoplasia was present in 1986 and 1987 in flats 1 and 2 but it was absent in Flat # 4, the best performing flat during the operational (NAI 1996).

Nearfield/Farfield study.

The ANOVA model results indicated that there was not a significant difference between the mean densities of seed clams (1-12 mm) in Flats 2 and 4 at Hampton Harbor during the preoperational and operational periods. Although there was a significant difference between preoperational and operational periods at Plum Island Sound, both areas showed the same trend as demonstrated by the clearly non-significant interaction term "Preop-Op x Area" (NAI 1996). Actual means by period and area are listed in Table 2. This has been a very straightforward study that still provides reliable results on whether the operation of Seabrook Station has any effect on the recruitment success of soft-shell clams in the tidal flats of Hampton Harbor.

Predator Surveys.

Clam digger counts. Recreational digging on the Hampton Harbor flats has been a significant source of mortality for legal size clams and also for spat and juvenile clams due to disturbance (NAI 1990). Census figures indicate that digging activity tripled from 1980 to 1981; effort remained high through 1982 and begun a slow decline in 1983 that continued through 1989 (Table 3) when Hampton Harbor was closed to recreational clamming. Among the five flats surveyed in Hampton Harbor, Flat # 4 was consistently the preferred flat by local diggers except for a brief period (Spring 1985 through Fall 1985) when diggers attention turned to Flat # 1 (NAI 1990).

Green crab (*Carcinus maenas*). Soft-shell spat and juvenile clams are a major source of food for green crabs, especially in the fall (Ropes 1969). Mean monthly CPUEs of green crabs

collected in Hampton Harbor during the preoperational and operational periods appear to follow similar seasonal trends, although in general, monthly CPUEs were lower during the operational period (Fig. 7). The abundance of the green crab in the Gulf of Maine appears driven by winter water temperatures (Welch 1969; Dow 1972; Welch and Churchill 1983); this was loosely supported by temperature data and mean green crab CPUE from Hampton Harbor from the last 15 years (Fig. 8). These data also show that there is no relationship between green crab abundance and the start of Seabrook Station operation in 1990.

Soft-shell Clam Larvae.

Mya arenaria larvae has been historically one the least abundant species among the twelve bivalve larval species collected at stations P2, P5, and P7; from 1988 through 1995 it accounted for only 0.4 percent of the total collections (Table 4). Soft-shell clam larvae generally occurred in plankton samples May through October every year since 1978 at station P2 (intakes). Peak densities were typically recorded in late summer or early fall, but a secondary peak usually occurred in early summer (Fig. 9). This alone represents strong evidence that the pool of pelagic Mya arenaria larvae drifting along the coast is a mix of larvae from several regional sources, because gonadal studies have established that the Hampton Harbor soft shell clam spawn once a year with a single strong peak in late August to early September (Normandeau et al. 1971; NAI 1979).

The largest larval density peak observed at station P2 since 1978 occurred in September 1995 and it was two orders of magnitude larger than the preoperational average for mid-September(Fig. 9). The mean densities for the preoperational and operational periods at all three plankton stations (P2, P5, and P7) are included in Table 2. Results of the ANOVA model indicated that mean operational period density was significantly smaller than the preoperational density; however, trends in larval abundance between nearfield and farfield stations remained consistent during both periods demonstrating no effect from the operation of Seabrook Station (NAI 1996).

Evaluation and Discussion of Results.

New England tidal flat macrofauna display naturally high temporal and spatial variability; numbers of species and total numbers of organisms may vary by several orders of magnitude within and between years (Whitlatch 1982). From the very first surveys of soft-shell clams in the Hampton-Seabrook area going back to 1969, it was established that population density, size frequencies and settlement success varied considerably from flat to flat (Normandeau et al. 1971). This variation, also seen throughout the Gulf of Maine (Larsen and Doggett 1991), could be the result of sedimentary composition differences (Turk and Risk 1981), but other factors such as current patterns (Emerson and Grant 1991), differential predation, and harvesting rates of clams are probably also significant (Lindsay and Savage 1978). Predation is often invoked to explain declines of *Mya arenaria* spat and seed clams with only circumstantial evidence (Welch 1969); but when detailed data are obtained this assumption is often supported (Moller and Rosenberg 1983). In addition to spatial variability, very large variation from year to year has also been documented (Ayers 1956; Brousseau 1978b; NAI 1989). Standing crop estimates at Hampton Harbor declined by a factor of 20 between 1967 and 1977 (Table 5). Large temporal variability has been typical of both preoperational and operational periods in the annual Mya surveys at Hampton Harbor and Plum Island Sound, but differences between the two periods and their interaction with the "nearfield/farfield" effect were never statistically significant (NAI 1996).

This evaluation found no evidence for associating any of the observed variability and/or changes in soft-shell clam abundance and recruitment with the operation of Seabrook Station. Given the actual path and extent of the thermal plume from Seabrook Station discharge of cooling water (Padmanabhan and Hecker 1991), there is almost no possibility of increased water temperatures in Hampton Harbor due to plant operation. The 1°F isotherm from the thermal plume comes close to the Outer Sunk Rocks (Fig. 10), but it never even approaches the entrance of Hampton Harbor about 1 km west and slightly south of Outer Sunk Rocks (Fig. 2). Furthermore, substantially higher water temperature increases would be necessary to affect the survival rates or growth of *Mya arenaria* clams, which are naturally exposed to

potentially large temperature changes between tides. Similarly, the hypothesis of plant impact through increased turbitity in the discharge water appears unfounded, because no turbidity effects have been for macrobenthos communities in the immediate discharge area (see evaluation of the Macrobenthos Program). The only other possible source of turbidity, the Seabrook's settling pond discharge, ceased in April 1994 without having ever shown any effect on the mud flats of Hampton Harbor (NAI 1995). Higher water temperatures in the discharge plume region could affect development of drifting planktonic larvae; however Stickney (1964) established through experimental work that *Mya arenaria* larvae have a great tolerance to both temperature and salinity. Given the relatively small size of the plume (the 3° F isotherm measures about 32 acres) and the modest maximum temperature increases of up to 4° F in an even smaller area (Padmanabhan and Hecker 1991), it is highly unlikely that the thermal discharge of Seabrook Station affects in any way the soft-shell larvae in the vicinity of the discharge; this was also supported by the ANOVA model results involving nearfield stations P2 and P5, and farfield station P7 (Fig. 2). Therefore, except for larval entrainment, no reasonable mechanism exists now whereby Seabrook Station operation could affect the recruitment and growth of soft-shell clams in Hampton Harbor. Entrainment of *Mya* larvae represents only a tenth of one percent of total numbers of bivalve larvae (12 species) entrained since 1990 (Table 6). Although the relatively small numbers of *Mya* larvae entrained may appear high, they would have translated into a negligible fraction of clams surviving to reproduction age (2-3 yrs) and, likely, many of the larvae would not have settled in flats of Hampton Harbor. Thorson (1950) and Grigg (1977) established generalized survival rates for invertebrate larvae ranging from 0.1 to 0.001 percent. Predation, starvation and other mortality factors take a tremendous toll of planktonic bivalve larvae and, in general, no more than 1 percent of fertilized eggs survive to the end of the planktonic stage (Thorson 1966; Mileikovsky 1971). Brousseau (1978b) in her three year study at West Gloucester, Massachusetts reported that less than 0.1 percent of the estimated egg production of *Mya arenaria* in the Jones River resulted in a successful settlement. Ayers (1956) study concerned with the reduction of numbers of *Mya* larvae in Barnstable Harbor, Massachusetts resulting from the combined effect of flushing-out and mortality estimated that only about 1% of settled larvae survive to become sexually mature.

An important question raised during this evaluation was whether the spat set densities in Hampton Harbor are at all related to larval abundance at the plankton stations P1 and P2. NAI (1979) reported poor correlation between larval abundance off Hampton Beach and spat settlement density in Hampton Harbor. Although larval abundance in 1978 increased by a factor of nearly 20, from a five year low in 1977, spat settlement declined by a factor of 4 between 1977 and 1978. In sedentary bivalves, such as *Mya arenaria*, settlement of recently metamorphosed larvae from the plankton is the only significant source of recruitment (Brousseau 1978a). However, the establishement of a relationship between density of *Mya* larvae offshore and spat sets in nearby tidal flats is problematic at best; Brousseau (1978a) found that the spawning cycles in which the greatest number of oocytes were released did not correlate with periods of highest recruitment in terms of spat densities. She concluded that observations on larval densities are useful only as indirect measures of the frequency and duration of spawning, because larval abundance and juvenile recruitment are controlled by many factors other than local spawning alone. Feller et al. (1992) stated that attempts to predict settlement or year-class strength from observations of larvae in the plankton generally have not been successful because the transition is affected by many variables; some such as hydrodynamic processes, can be complex and have very significant role in the settlement of larvae and their successful recruitment (Butman 1987; Emerson and Grant 1991). For *Mya arenaria*, the planktonic larval stage persists for 2 to 4 weeks (Stickney 1964) permitting, under favorable hydrographic conditions, adult stocks from estuaries up to 25 miles away to repopulate a particular flat (Ayers 1956). It was reported by NAI (1979) that a late spring or early summer larval abundance peak may, in some years, precede the well documented late summer peak in the Hampton-Seabrook area; on the other hand, there is only one late summer spawning cycle in Hampton-Seabrook Estuary (NAI 1971; NAI 1979). This discrepancy could only be explained by the importation of drifting larvae spawned by clam populations well to the South of New Hampshire. If a pool of larvae not spawned locally were in the plankton off Hampton Beach, then the importance of larval entrainment would be greatly diluted and locally spawned larvae would also play a much less significant role in determining the annual spatfall in the flats of Hampton Harbor.

To answer the question of whether larval abundance at plankton stations was correlated with spat set densities in Hampton Harbor, some of the existing database on larval and spat densities were re-analyzed. The data selected were the ten most recent years (1986-1995) which included five years of pre-operational data and five years of operational data. The two plankton stations selected were P1 in Hampton Harbor, and P2 in the vicinity of Seabrook Station intakes (Fig. 2). Since the spat surveys were conducted mostly in mid-October and a few in early November, the size of the spat was restricted to Young-of-Year (1-6 mm) and the larval data were restricted to the end of September each year to leave between 2 and 4 weeks as a reasonable planktonic period prior to metamorphosis and settlement; Stickney (1964) estimated a larval period that ranged from 12 days with optimal conditions, to more than a month when water temperatures were less than 10° C. The selected raw data, larval numbers per cubic meter and spat (1-6 mm) numbers per square foot, were log-transformed prior to computing annual means for both measurements. The results of regression analyses of mean annual larval densities and mean spat set densities are summarized in Table 7 for stations P1 and P2 compared to each of the five flats sampled in Hampton Harbor each year. None of the slopes were significantly different from zero indicating no relationship between larval and spat set densities. The correlation coefficients shown in Table 7 were less than 0.10 for 7 out of 12 comparisons, and the largest correlations were 0.269 and 0.265 for flats 4 and 5 with larval densities at P1 (none of them statistically significant). The largest correlation found involving station P2 (intakes station) was only 0.158. This lack of relationship, further illustrated in Figures 11 through 16, agrees well with other investigators conclusions (Brousseau 1978a; Feller et al. 1992). Assuming that these data were representative of actual trends in larval and spat densities, the above results have important implication for the Seabrook *Mya arenaria* monitoring program. First, they suggest that monitoring the abundance of soft-shell clams in the plankton stations is neither useful to assess population effects of larval entrainment losses, nor to predict recruitment in Hampton Harbor; second, it leaves the nearfield/farfield study (comparisons of seed clams between Hampton-Seabrook and Plum Island Sound) as the only reliable program for determining if future changes in clams abundance at Hampton Harbor are related to the operation of Seabrook Station.

Finally, it should be noted that this evaluation results are supported by early expectations of EPA scientists regarding the impact of Seabrook Station. The following paragraphs (from YAEC 1982) are direct quotations from EPA's conclusions in its 316(a) determination of August 1978:

"My conclusion that the plant's effects on the local clam population will be insignificant would, for reasons to be discussed below, remain unchanged."

"... because both the intake and the diffuser are essentially outside the tidal plume excursion region..... even if the estuarine water were freely dispersed throughout the water column, adverse effects on larvae would be extremely small."

"I agree with the conclusion from the experts of Region I that even if the Hampton-Seabrook clam population is entirely self-regenerating, and benefits from no outside recruitment, the effects of the plant's operation on the population would be negligible."

"Although the plant may kill considerable numbers of planktonic eggs and larvae, the total volume of water that will be subject to the plant's adverse effects is minuscule compared to the 54 square miles of coastal water adjacent to the plant, in which this plankton may be expected to develop".

Proposed Monitoring Program after 1996

The focus of the proposed soft-shell clam program would be on monitoring this important economic resource rather than on the detection of Seabrook Station impacts, since none is expected to occur. Accordingly, the program objectives would be:

1. to ensure the continuity of the valuable database on *Mya arenaria* and its predators already accumulated, and;
2. to make available to NH State regulators and to NAESCO the information needed to explain to the public posible reasons of major changes in clam abundance at Hampton Harbor, which may occur in the future.

The specifics of each of three program components would be as follows:

Hampton Harbor Random Surveys. No change in effort from current program, but attempt to redesign sampling to improve precision and accuracy of annual estimates by size classes; take advantage of work done in this area by Cuff and Coleman (1979) and possibly by others. Sampling would be done once a year, in the fall, as at present; collections would be at Flats 1, 2, 3, 4, and 5 for spat and juveniles and at Flats 1, 2, and 4 for legal size clams (Fig. 1). Data collected would be clam abundance per square foot, starting at 1 mm of size.

Nearfield/Farfield study. No changes proposed on either effort or methodology. Ten stations would be sampled at each of the locations, Hampton Harbor Flats 2 and 4 and Plum island Sound (Fig. 1), once a year in the fall; at each station 3 replicates would be taken so that a total of 60 samples per year are taken annually. This study is a good example of an efficient sampling design that conforms with the requirements of the BACI design (Green 1979) and, thus, can be used to test statistically whether any future observed changes in abundance of seed clams at Flats 2 and 4 in Hampton Harbor, occur similarly at the control site in Plum Island Sound.

Predator Surveys. It is proposed to replace clam digger counts with recreational license data (currently used by NH Fish and Game Dept. to estimate clamming effort); or consider sampling for digger trips only Flats 1, 2, and 4, rather than all five flats as in the past. The rationale was consistency with legal size clam densities only estimated at Flats 1, 2, and 4 since 1985, and the historically low frequency of digger's trips to Flats 3 and 5 (Table 3). If the use of licenses were not acceptable, diggers counts would be conducted weekly, as in the past, except during the summer (June through August); the total number of counts per year would be 76. Regarding the green crab program, it is proposed to keep the present trapping program in place without any changes in either effort or methodology. Therefore the proposed program would continue to set traps at stations 1-4 within Flat 2 in Hampton Harbor (Fig. 1), twice

monthly except February and March when crab activity has been historically low (NAI 1990); the total number of traps set will continue to be 160, with two traps per trip.

Conclusions

After five years of Seabrook Station operation there has not been a single instance of any statistically significant change being related to the plant's entrainment of soft-shell clam larvae or to the plant's discharge of cooling water. Large variability of clam densities in all sizes, from early spat, through juvenile and legal size clams, has been documented over more than 20 years of studies and have occurred both during the preoperational and operational periods; spat and juvenile clam densities are greatly influenced by predation and by many other possible factors such as currents, sedimentary changes due to storms, etc. and legal size clams densities are mostly driven by recreational clamming effort and, perhaps neoplasia. A finding of this evaluation was that larval densities in the plankton at either station P2 (intakes) or station P1 (Hampton Harbor) do not correlate with densities of subsequent successful spat set in the flats of Hampton Harbor. This finding led us to conclude that the collection of soft-sell clam larvae in the plankton or in entrainment samples now serves no purpose and should be discontinued. The overall conclusion of this evaluation is that over 25 years of monitoring studies have not found a reasonable mechanism whereby Seabrook Station operation could affect the recruitment and growth of soft-shell clams in Hampton Harbor. Accordingly, the proposed *Mya arenaria* program shifts focus from "impact assessment" to "annual abundance surveys" of this all important marine resource for New Hampshire, and leaves unchanged the population surveys, the trapping of green crabs, and the surveys of seed clams at Hampton and Plum Island Sound Harbors. A major consideration for the continuation of these three programs was the importance of maintaining the continuity of the extensive database of *Mya arenaria* built by these studies since 1971.

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Table 1. Distribution (percent of total standing crop) of harvestable clams by flat at Hampton Harbor, 1979 through 1989. Seabrook Baseline Report, 1989 (from NAI 1990).

YEAR	FLAT				
	1	2	3	4	5
1979	33.3	6.2	2.2	55.7	2.5
1980	45.1	10.5	1.0	39.5	3.9
1981	53.0	7.3	1.5	34.4	3.7
1982	52.2	7.0	1.0	38.4	1.3
1983	62.9	25.6	0.5	10.5	0.5
1984	72.0	13.6	1.9	11.5	0.9
1985	60.2	14.6	NS	25.1	NS
1986	63.0	21.9	NS	15.1	NS
1987	40.0	15.9	NS	44.2	NS
1988	40.9	9.0	NS	50.1	NS
1989	30.1	3.1	NS	66.8	NS

NS = not sampled

Table 2. Geometric mean density (number of larvae per m^3; number of juveniles/adults per ft^2) and the coefficient of variation (CV) of *Mya arenaria* collected during preoperational and operational years and in 1995. Seabrook Operational Report (from NAI 1996).

		PREOPERATIONAL[a]		1995	OPERATIONAL[a]	
LIFESTAGE	AREA	MEAN[b]	CV	MEAN[b]	MEAN[b]	CV
Larvae	P2	5.5	17.7	2.3	3.3	10.8
	P5	5.0	12.0	2.4	3.0	26.0
	P7	5.7	13.0	1.6	3.4	28.7
1-5 mm (young-of-the-year)	HH-1	3.5	48.5	0.8	3.1	53.9
	HH-2	8.6	58.8	6.1	5.0	37.1
	HH-4	10.5	43.8	0.4	3.4	62.7
	All	6.4	49.0	1.3	3.6	46.9
6-25 mm (spat)	HH-1	1.7	127.8	0.3	1.2	96.3
	HH-2	0.7	153.5	0.1	0.4	86.8
	HH-4	3.4	89.7	0.4	1.6	70.1
	All	1.8	108.5	0.2	1.0	82.6
26-50 mm (juveniles)	HH-1	1.6	108.6	2.8	0.7	84.3
	HH-2	0.4	115.6	1.3	0.3	120.4
	HH-4	1.7	100.4	2.1	1.1	43.8
	All	1.2	97.4	2.0	0.6	75.3
>50 mm (adults)	HH-1	0.6	76.6	0.8	0.7	15.7
	HH-2	0.4	96.5	1.0	0.3	90.9
	HH-4	0.5	78.2	1.8	1.9	10.4
	All	0.5	76.5	1.0	0.7	24.0
1-12 mm (seed clams)	Hampton Harbor	5.7	70.8	6.2	6.1	72.9
	Plum Is. Sound	17.1	68.5	3.0	7.5	83.1

[a]Larvae PREOP = 1988, 1989; OP = 1991-95. Hampton Harbor (HH) PREOP = 1974-1989; OP = 1990-1995. Hampton Harbor-Plum Is. PREOP = 1987-1989; OP = 1990-1995

[b]PREOP and OP means = mean of annual means. 1995 mean = mean of the number of samples.

Table 3. Estimated distribution (percent of total) of clam diggers by flat at Hampton Harbor, spring 1980 through fall 1990. Seabrook Operational Report, 1990 (from NAI 1991).

SEASON	FLAT 1	2	3	4	5	ESTIMATED[a] TOTAL DIGGER TRIPS	ESTIMATED[b] NUMBER OF BUSHELS HARVESTED
Spring[c] 1980	12.5	17.9	1.7	52.5	15.4	3,860	1,200
Fall[d] 1980	11.3	18.4	3.3	55.1	11.8	2,700[e]	840
Spring 1981	9.7	15.6	0.8	65.9	7.9	12,500	3,900
Fall 1981	13.9	12.9	0.2	63.8	9.1	7,060	2,200
Spring 1982	12.6	13.0	0.8	67.1	6.4	10,800	3,400
Fall 1982	26.6	8.5	0.7	60.7	3.5	9,300	2,900
Spring 1983	30.7	7.1	1.3	58.6	2.2	7,700	2,400
Fall 1983	29.4	14.7	0.5	54.7	0.7	6,690	2,100
Spring 1984	22.1	26.4	0.6	49.9	1.0	6,200	1,950
Fall 1984	26.9	28.9	0.3	43.2	0.8	5,850	1,830
Spring 1985	51.6	11.3	0.4	36.1	0.8	6,940	2,169
Fall 1985	63.1	5.0	0.4	31.5	0.0	2,873	898
Spring 1986	59.3	6.4	0.3	33.4	0.6	6,210	1,941
Fall 1986	58.1	6.4	0.4	34.7	0.4	4,713	1,473
Spring 1987	39.4	8.1	1.5	49.0	2.0	1,763	551
Fall 1987	38.8	6.9	0.8	49.8	3.8	1,541	482
Spring 1988	13.2	14.3	3.7	66.4	2.4	574	179
Fall 1988	22.8	10.9	4.2	57.4	4.7	1,386	433
Spring 1989	22.1	10.6	0.0	65.3	2.0	357	112
Fall[f] 1989	--	--	--	--	--	--	--
Spring[g] 1990	--	--	--	--	--	--	--
Fall[g] 1990	--	--	--	--	--	--	--

[a]Based primarily on Friday head counts at time of low slack water; most Saturday counts are assumed from observed Fri:Sat ratio (n=14 pairs) of 2.24 ± SD 0.96; seasonal totals have approximate error of ± 18%
[b]Assumes each clammer takes 10 quarts per trip; 1 bushel = 32 quarts or 3.2 clammer trips
[c]Includes the period 1 January through weekend before Memorial Day
[d]Includes the weekend after Labor Day through 31 December
[e]Based on average Spring:Fall ratio for 1981 and 1982 (0.68 ± SD 0.02)
[f]Data collected January - March only. Flats closed April - December.
[g]Flats closed January - December

Table 4. Percent of total density for the twelve selected bivalve taxa taken at stations P2, P5, and P7 from 1988 through 1995.

Taxa	Percent
Mytilus edulis	56.3
Anomia squamula	19.5
Hiatella sp.	12.5
Modiolus modiolus	5.2
Bivalvia	2.2
Solenidae	2.0
Spisula solidissima	0.8
Macoma balthica	0.6
Mya truncata	0.6
Mya arenaria	0.4
Placopecten magellanicus	<0.1
Teredo navalis	<0.1

Table 5. Summary of standing crop estimates of adult[a] *Mya arenaria* in Hampton Harbor, 1967 through 1990. Seabrook Operational Report, 1990 (from NAI 1991).

DATE	ESTIMATED NUMBER OF BUSHELS PER ACRE	TOTAL ESTIMATED NUMBER OF OF BUSHELS
November 1967	152[b]	23,400[b]
July 1969	103	15,840
November 1971	94	13,020
November 1972	58	8,920
November 1973	41	6,310
November 1974	56	8,690
November 1975	29	4,945
November 1976	11	1,350
November 1977	6	1,060
November 1978	6	940
November 1979	9	1,400
October 1980	54	8,890
October 1981	75	12,400
October 1982	55	9,200
October 1983	78	13,020
October 1984	54	8,821
November 1985	39	4,615
October 1986	23	2,793
October 1987	8	976
October 1988	10	1,137
October 1989	19	2,295
October 1990	57	6,752

[a]Shell length >50 mm
[b]From Ayer (1968)

Table 7. Summary of regression analyses to test whether there was a relationship between the abundance of *Mya* larvae at Stations P1 (Hampton Harbor) or P2 (Intakes) and the density of spat set in Flats nos. 1, 2, 3, 4, and 5 during the last 10 years (1986-1995).

Station	Flat #	Slope estimate for the regression of Larval density vs. spat (1-6mm) set	t-test of the Null Hypothesis that the slope is equal to zero[a]		Correlation coefficient
P1	1	0.023868	t = 0.044	P = 0.9656	0.014
P2	1	-0.051717	t = 0.073	P = 0.9436	0.026
P1	2	0.212065	t = 0.388	P = 0.7081	0.136
P2	2	-0.092056	t = 0.127	P = 0.9024	0.045
P1	3	0.117155	t = 0.202	P = 0.8450	0.071
P2	3	-0.344645	t = 0.455	P = 0.6614	0.158
P1	4	0.524198	t = 0.792	P = 0.4511	0.269
P2	4	0.193620	t = 0.214	P = 0.8358	0.075
P1	5	0.486670	t = 0.778	P = 0.4592	0.265
P2	5	-0.058680	t = 0.069	P = 0.9471	0.025
P1	All 5	0.372277	t = 0.540	P = 0.6036	0.187
P2	All 5	-0.125392	t = 0.136	P = 0.8955	0.048

a: All test results (P>0.05) showed no significant relationship between *Mya* larvae and spat set densities (all regression analyses were conducted on $\log_{10}$ transformed density data of both larvae and spat).

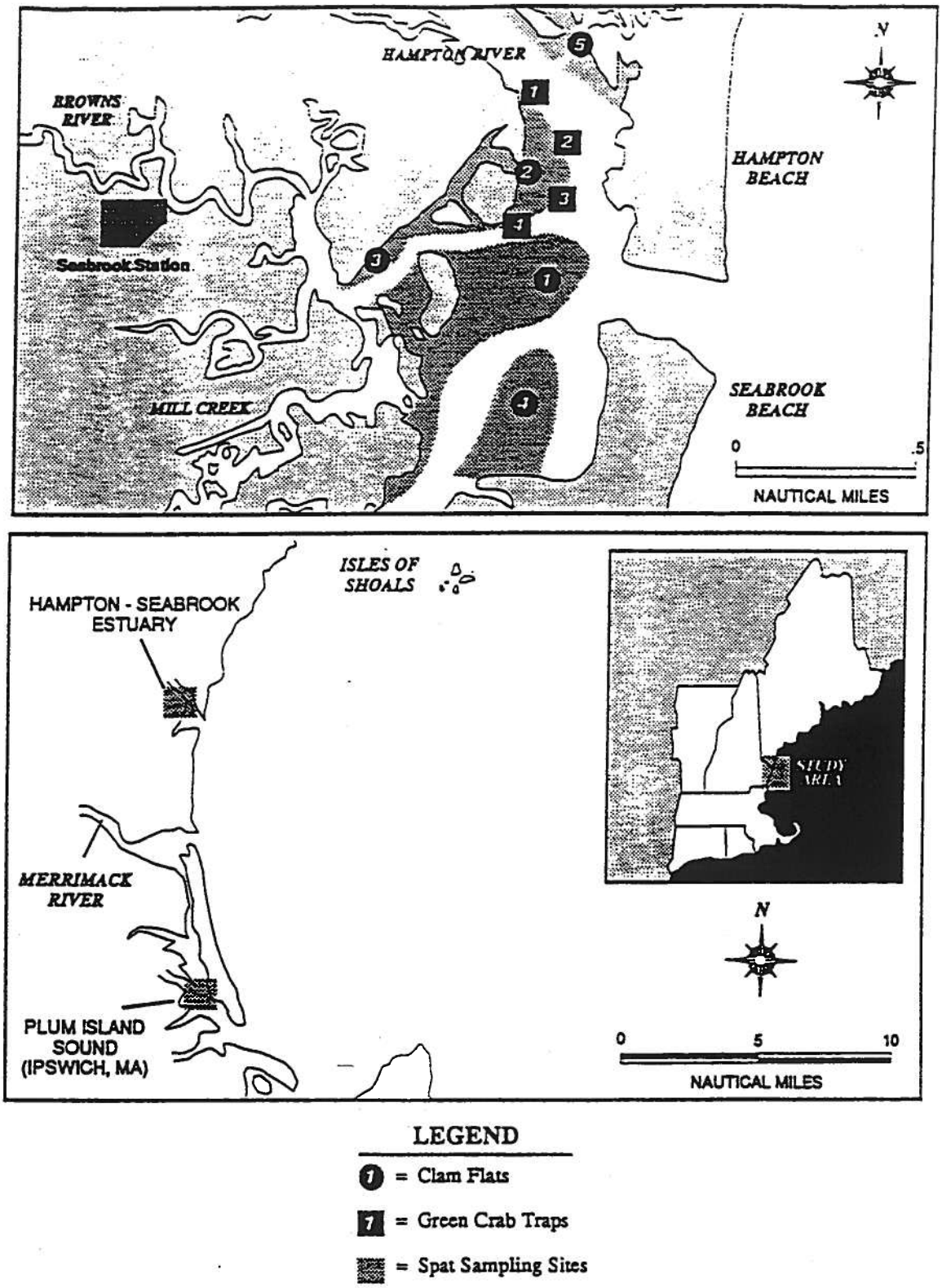
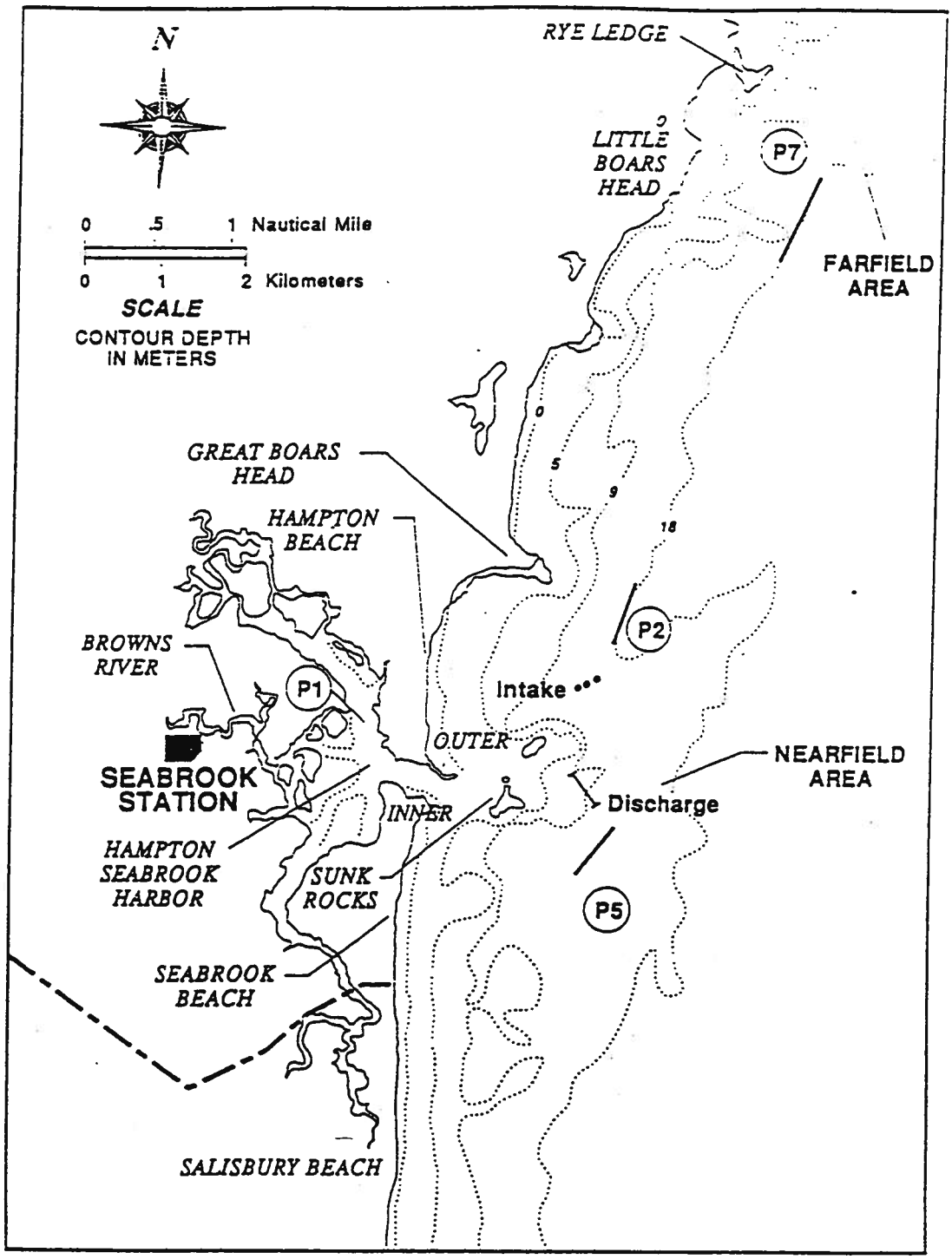


Figure 1. Hampton-Seabrook estuary and Plum Island Sound soft-shell clam (*Mya arenaria*) and green crab (*Carcinus maenas*) sampling areas. Seabrook Operational Report, 1994 (from NAI 1995).



LEGEND

—— = Bivalve Larvae Stations P1, P2, P5, P7

Figure 2. Bivalve larvae (including *Mya arenaria*) sampling stations. Seabrook Operational Report, 1994 (from NAI 1995).

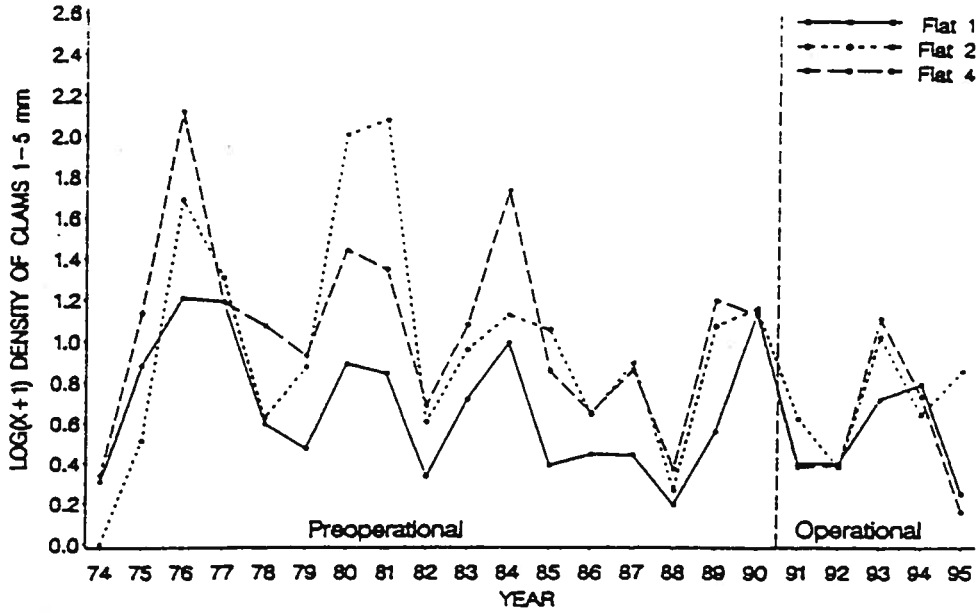


Figure 3. Annual mean $\log_{10}(x+1)$ density (number per ft^2) of clams 1-5 mm, 1974. Seabrook Operational Report, 1995 (from NAI 1996).

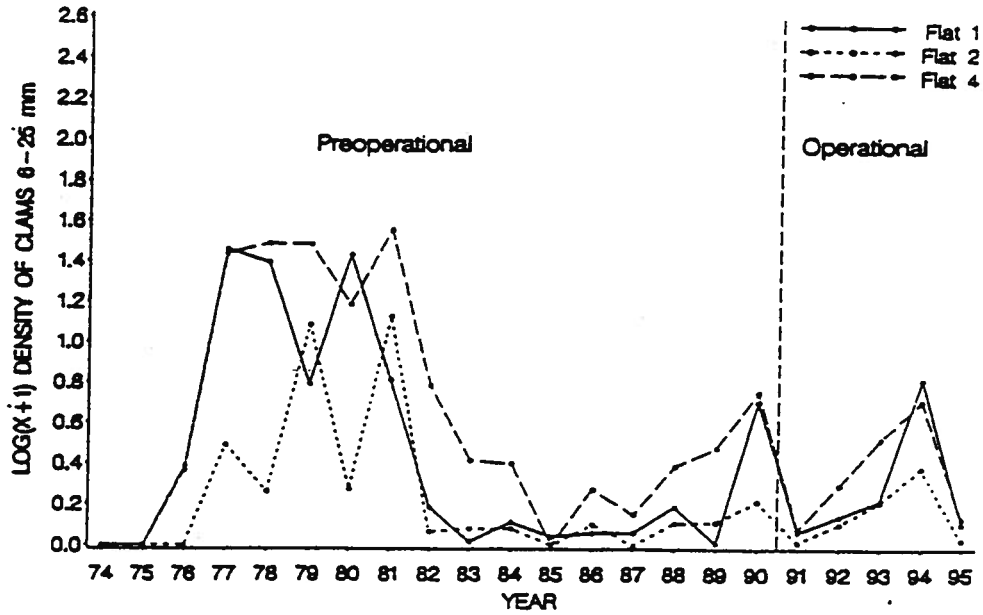


Figure 4. Annual mean $\log_{10}(x+1)$ density (number per ft^2) of clams 6-25 mm, 1974. Seabrook Operational Report, 1995 (from NAI 1996).

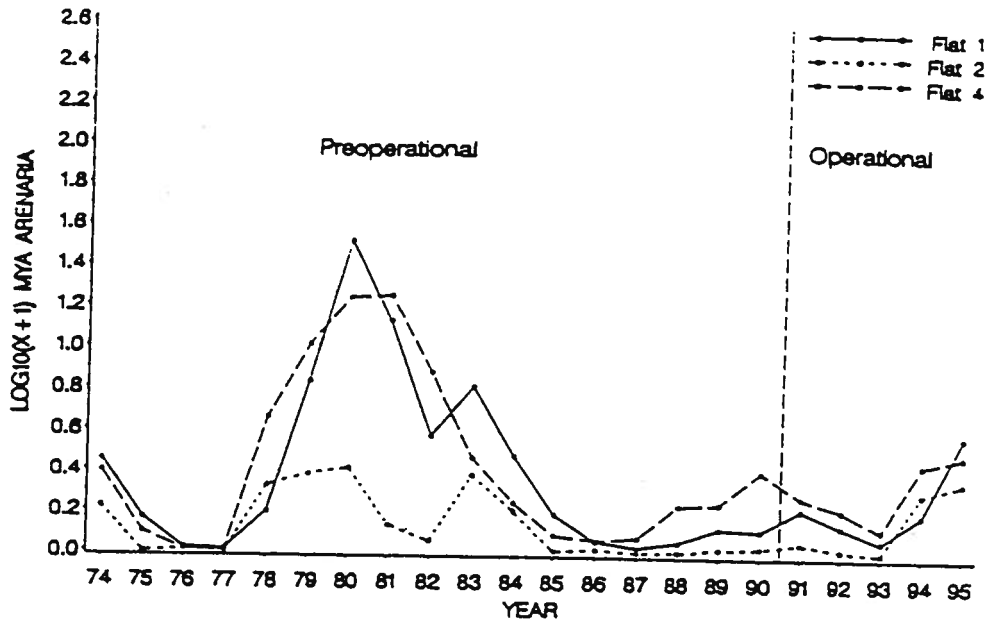


Figure 5. Annual mean $\log_{10}(x+1)$ density (number per ft^2) of clams 26-50 mm, 1974. Seabrook Operational Report, 1995 (from NAI 1996).

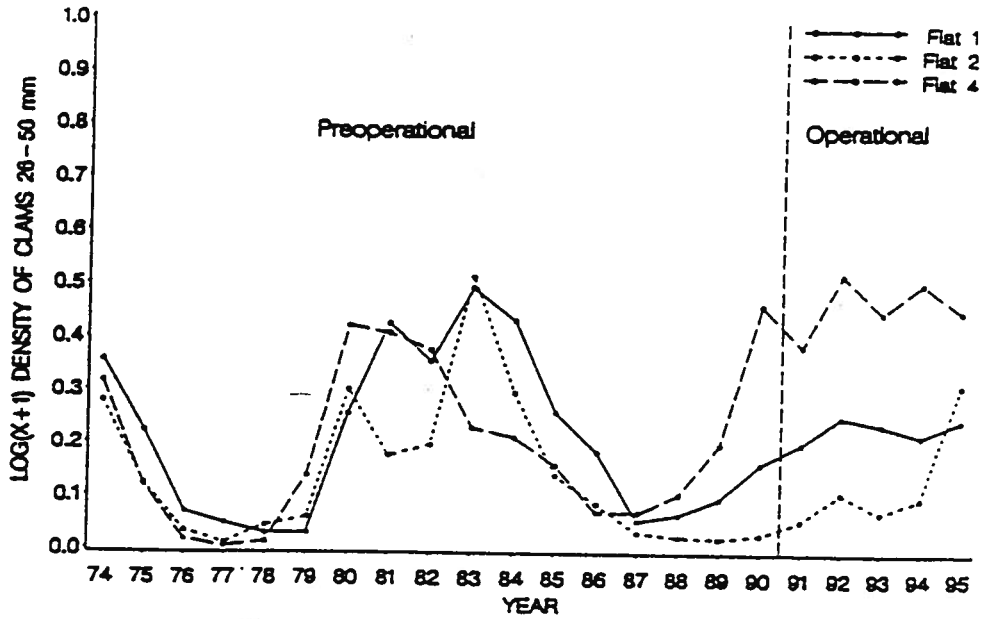


Figure 6. Annual mean $\log_{10}(x+1)$ density (number per ft^2) of clams > 50 mm, 1974. Seabrook Operational Report, 1995 (from NAI 1996).

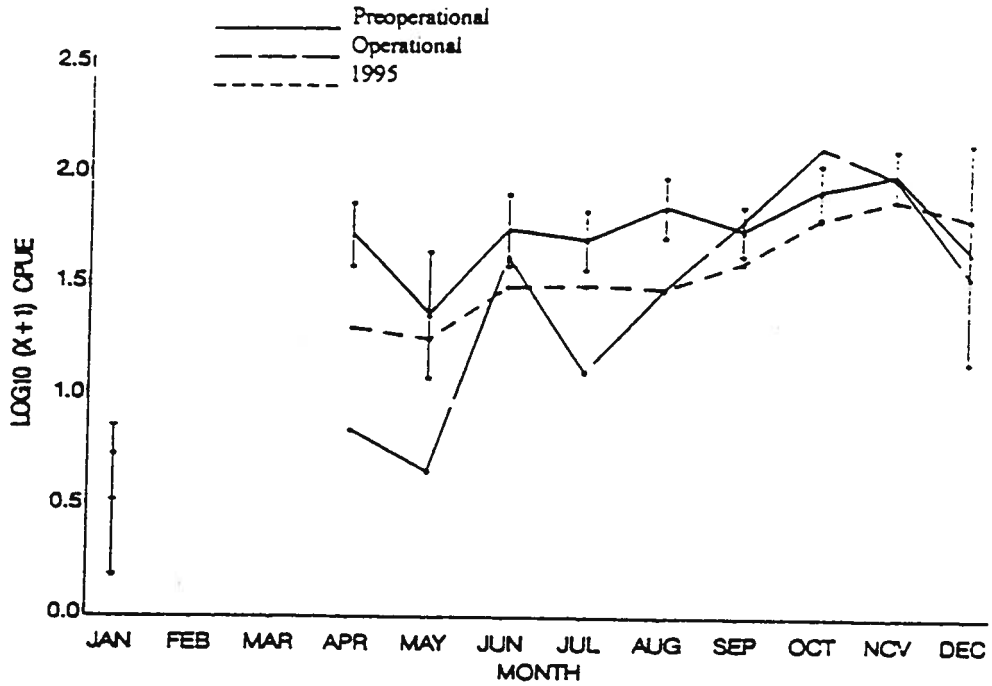


Figure 7. Mean $\log_{10}(x+1)$ monthly catch per unit effort and 95% confidence intervals of green crabs (*Carcinus maenas*) collected during preoperational years (1983-89), operational years (1991-95), and 1995. Seabrook Operational Report, 1995 (from NAI 1996).

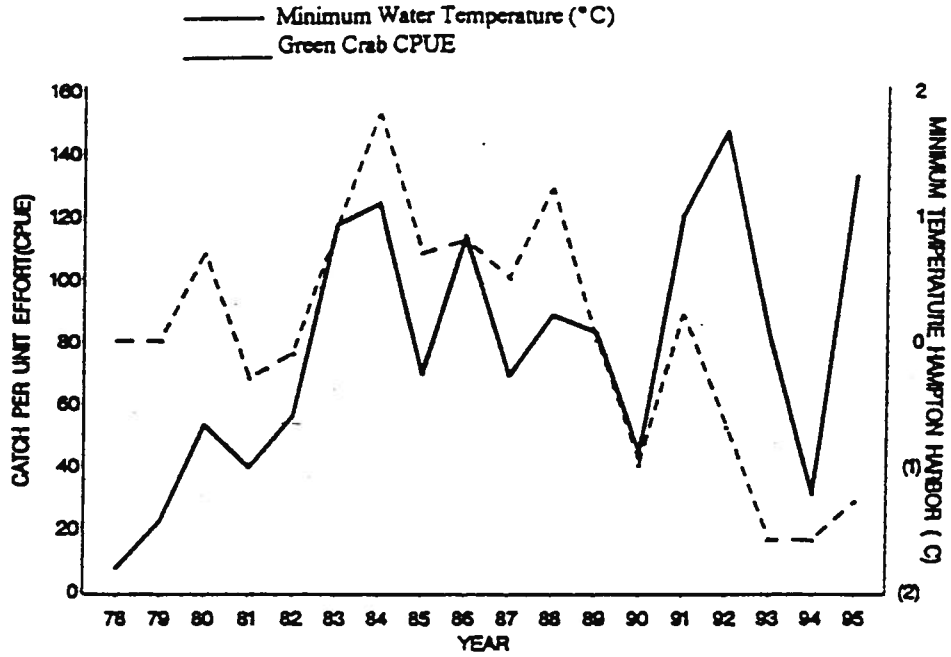


Figure 8. Mean fall (October-December) catch per unit effort of green crabs in Hampton-Seabrook Harbor and its relationship to minimum winter water temperature from 1978-95. Seabrook Operational Report, 1995 (from NAI 1996).

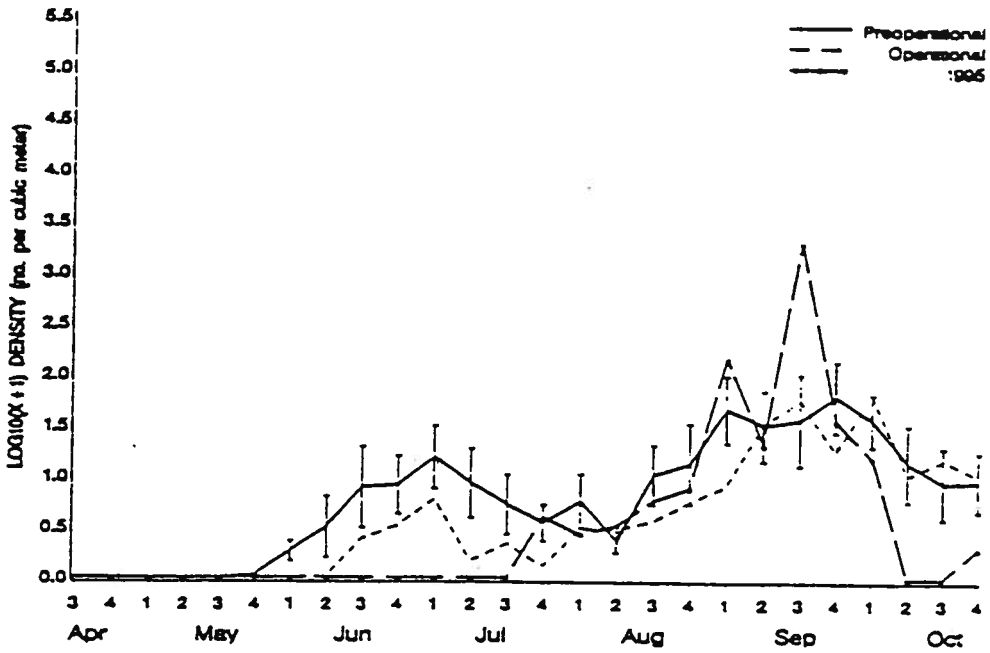


Figure 9. Weekly mean and 95% confidence interval of $\log_{10}(x+1)$ density (number per m^3) of *Mya arenaria* larvae at Station P2, during the preoperational (1978-89) and operational (1991-95) periods and in 1995. Seabrook Operational Report, 1995 (from NAI 1996).

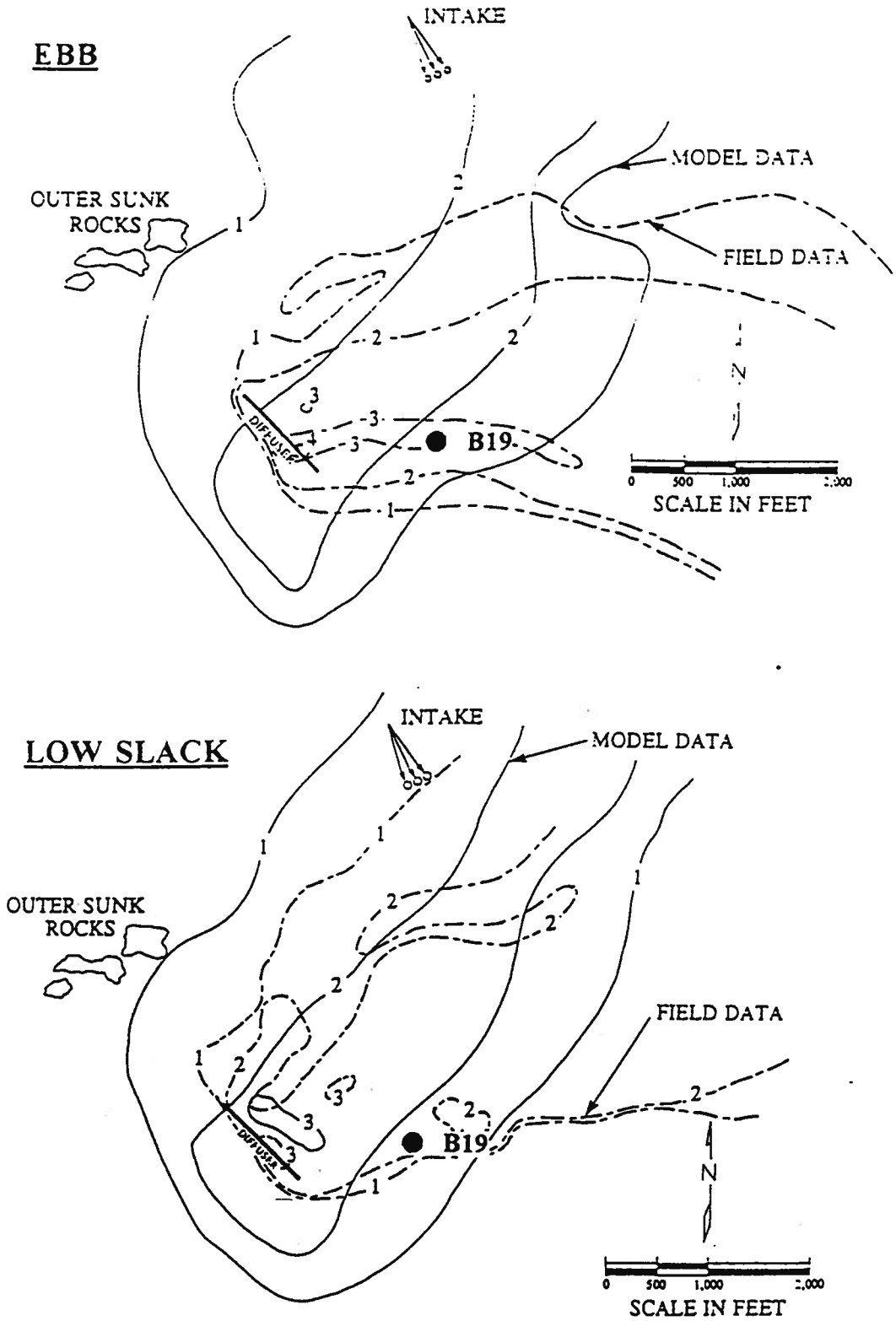
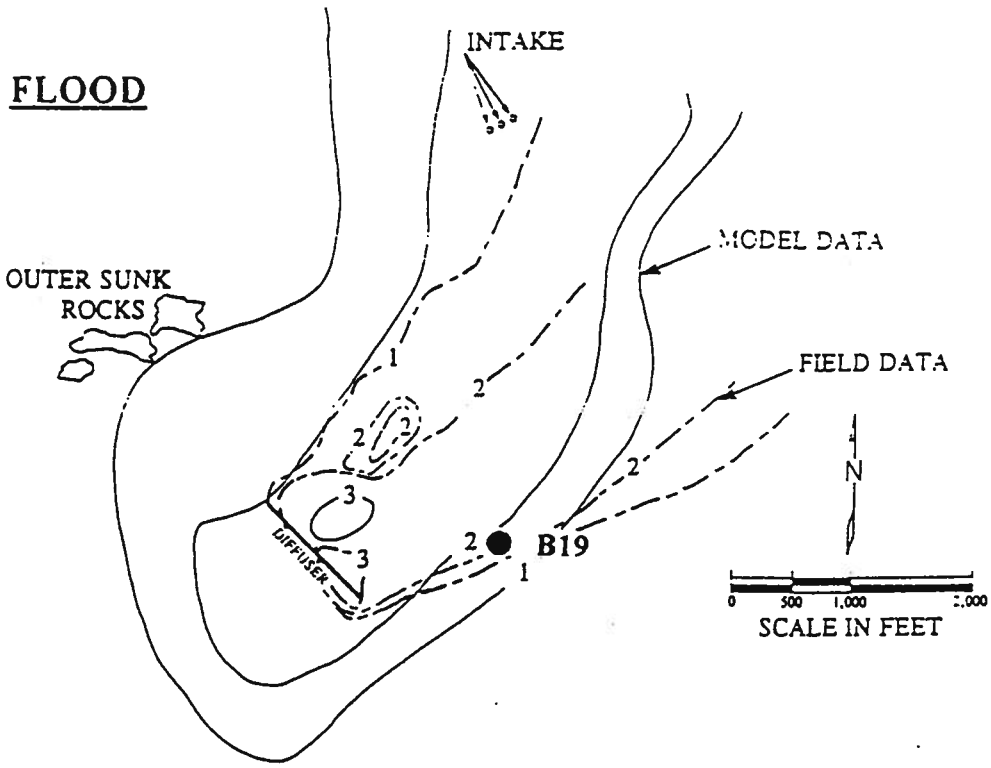


Figure 10. Locations of selected Seabrook Station thermal plume isotherms (1°F, 2°F, and 3°F) under various tidal conditions in relation to the nearfield surface panel station (B19), based on hydrothermal modeling and field verification studies (from Padmanabhan and Hecker 1991).



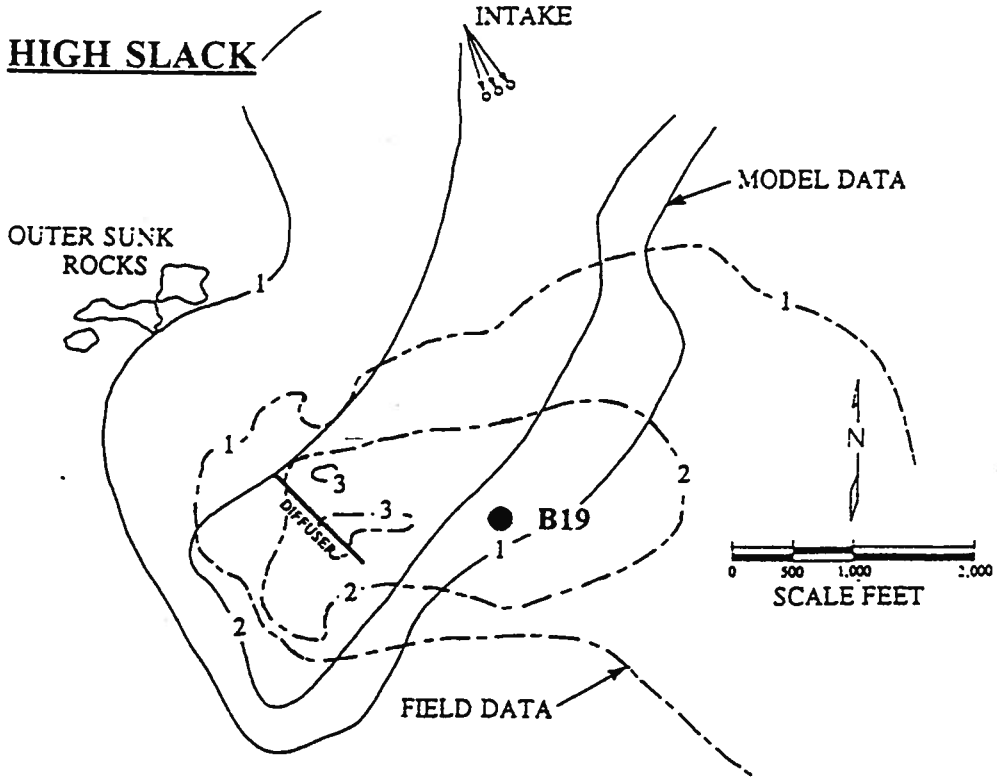


Figure 10. (continued)

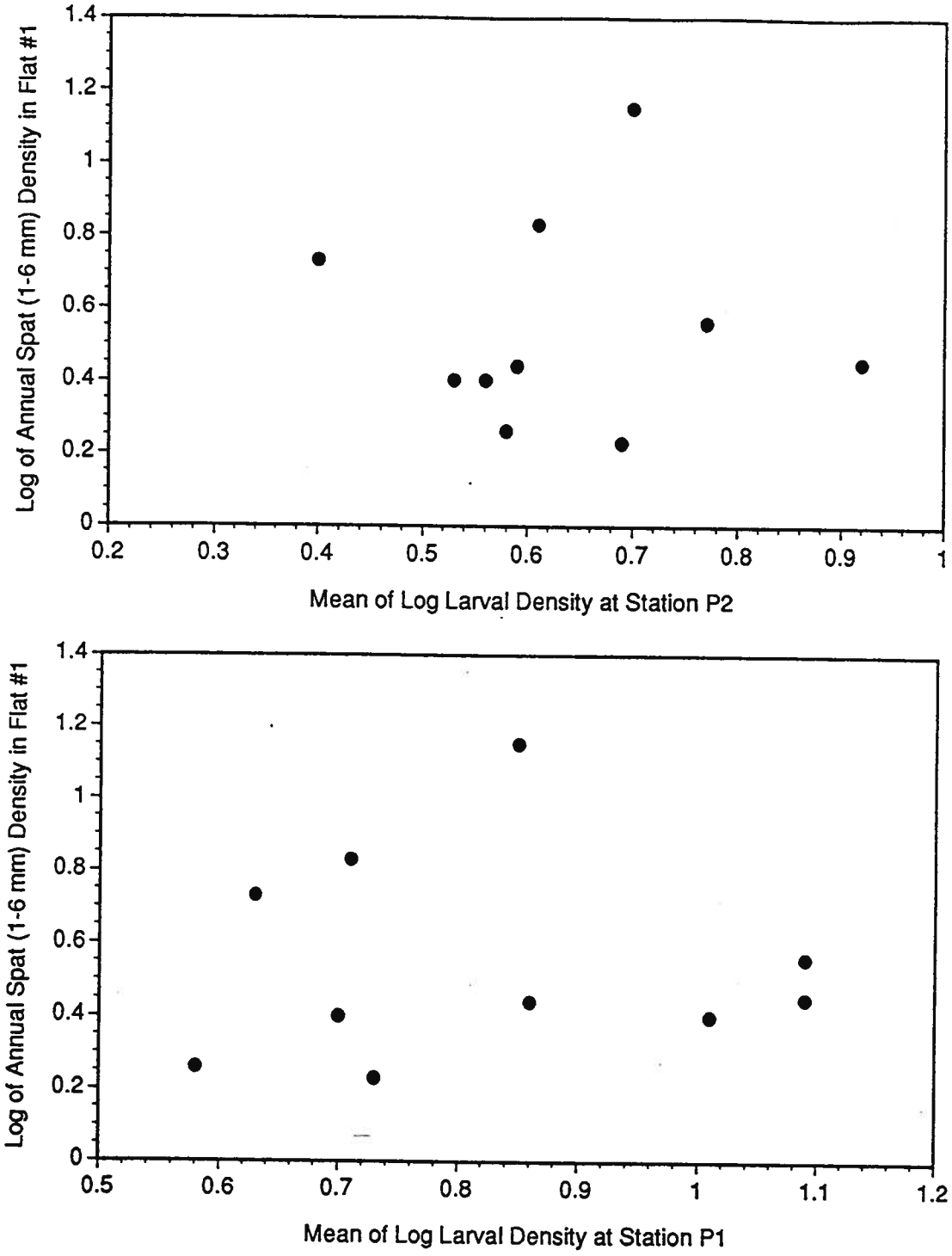
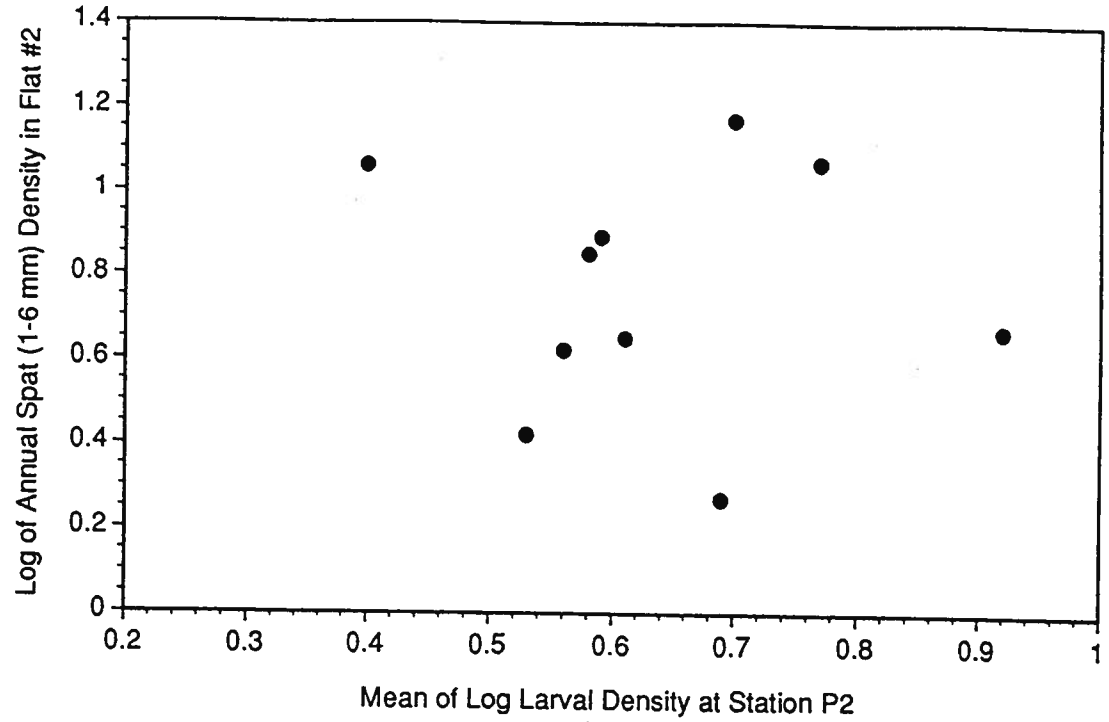


Figure 11. Relationship between *Mya arenaria* larval abundance at stations P1 and P2 and spat set in Flat #1. Data plotted are annual means (1986-95) of $\log_{10}$ transformed densities.



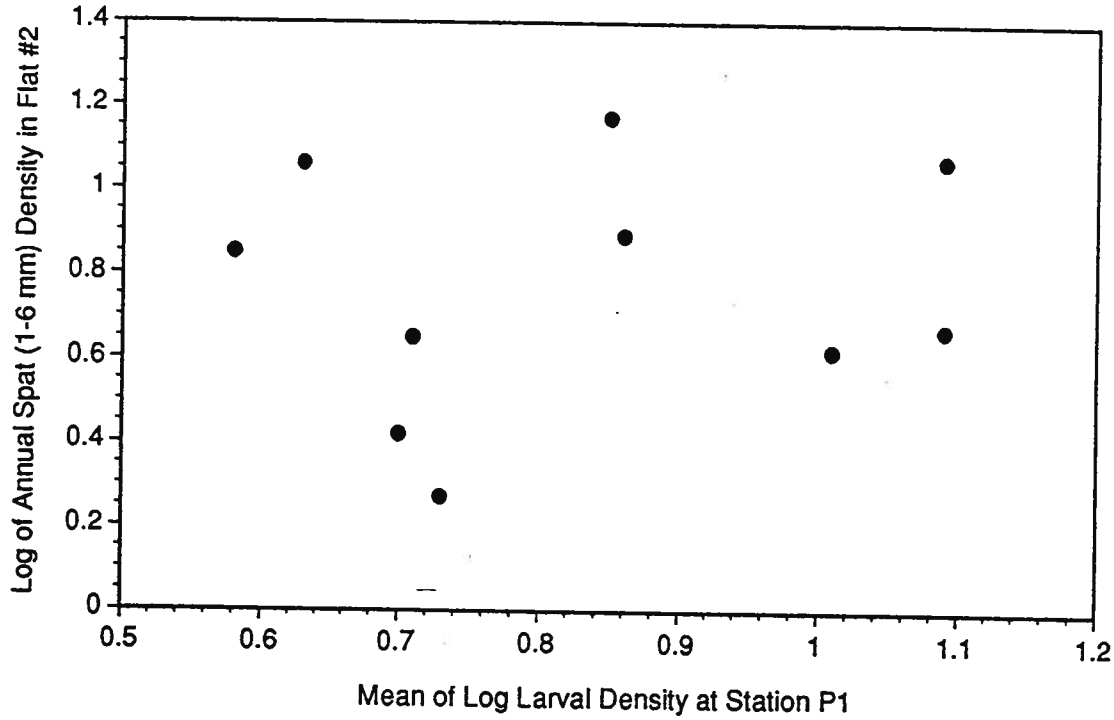
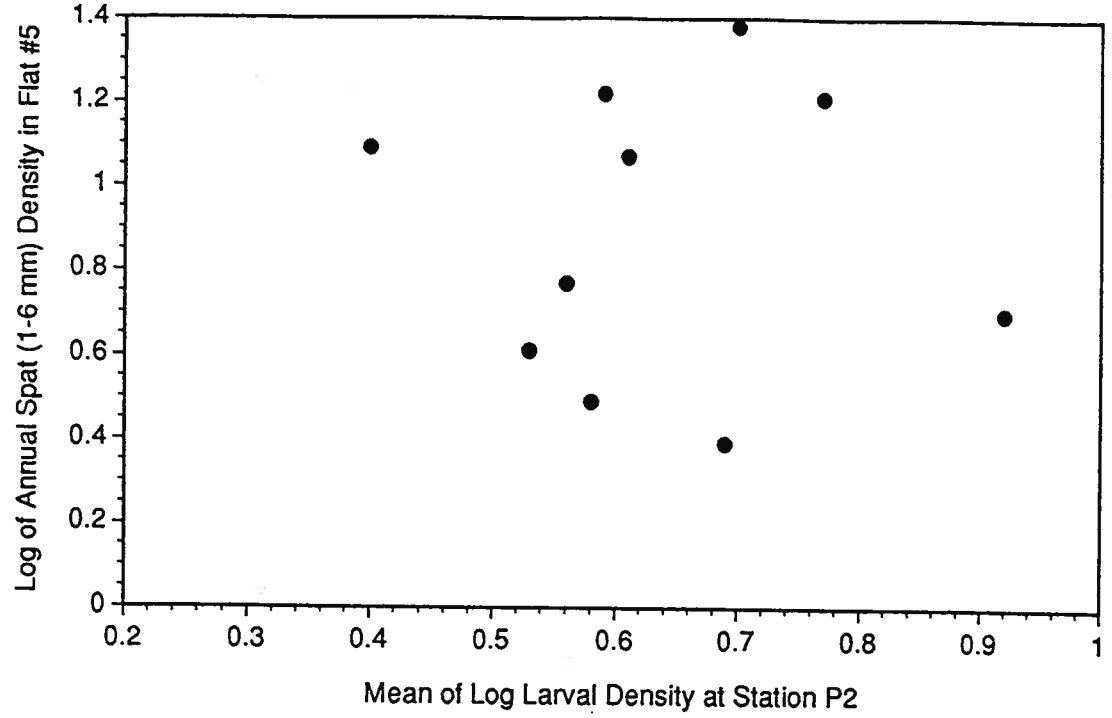


Figure 12. Relationship between *Mya arenaria* larval abundance at stations P1 and P2 and spat set in Flat #2. Data plotted are annual means (1986-95) of $\log_{10}$ transformed densities.



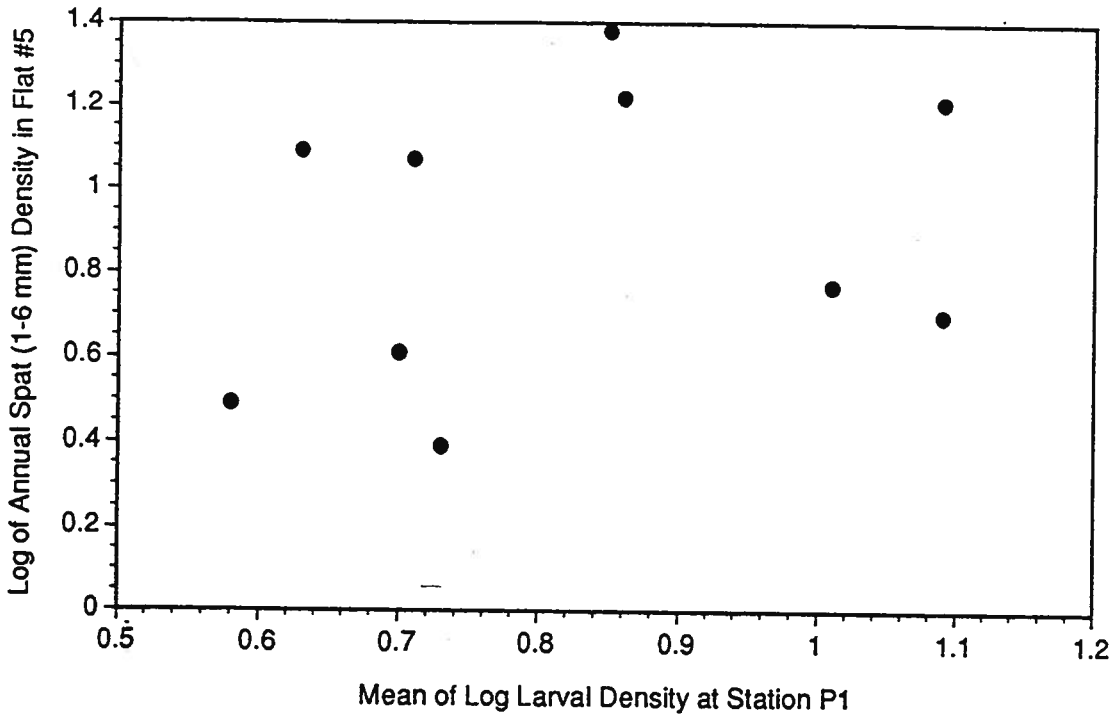


Figure 15. Relationship between *Mya arenaria* larval abundance at stations P1 and P2 and spat set in Flat #5. Data plotted are annual means (1986-95) of $\log_{10}$ transformed densities.

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FINFISH

Summary of the Proposed Monitoring Program After 5 Years of Operation

The objectives of the proposed finfish program are to provide improved quantitative measures of impact (primarily entrainment and impingement) from Seabrook Station operation and the data needed to assess these losses to fish populations. While little or no evidence of impacts has been found to date, continued or enhanced monitoring is warranted in most instances, given the ecological and economic importance of many finfishes.

1. **Ichthyoplankton sampling program** modifications are based on the results of analyses of data collected through 1995. It is proposed that ichthyoplankton be collected at station P2 and P7 and that station P5 be eliminated.

    - No differences were detected with ANOVA between the two nearfield ichthyoplankton stations (P2 and P5) for nine selected taxa. In addition, the numerical classification (cluster analyses) for fish eggs and larvae showed that species composition was very similar between P2 and P5. An additional analysis examining differences between the two nearfield stations was performed using paired testing (Wilcoxon's signed-ranks test), which showed similar abundances at the stations for eight of nine selected species tested. Therefore, based on the length of the preoperational database, which starts in 1975 for P2 and P7 but only in 1986 for P5, sampling is proposed to be discontinued at station P5. Stations P2 and P7 will continue to be sampled and the ichthyoplankton study will maintain the BACI design for future impact assessment. ANOVAs for nine selected species were re-calculated using data from only these two stations and compared to results obtained from all three stations. No significant differences were found after data from P5 were excluded from the analyses.

2. **Ichthyoplankton entrainment** estimates may be improved as densities of some species are greater in the water column during the night. Further, some smaller larvae may be extruded though the 505-μm mesh net presently used. Therefore, several changes to the program are proposed to improve the estimation of entrainment impact.

    - Entrainment estimates of fish eggs and larvae are one of the most direct measures of plant operational impact and should be as accurate as possible. A direct comparison of taxa collected in entrainment samples with those collected at station P2 indicated several discrepancies in dominant taxa. These differences may be due, in part, to sampling at night at P2 versus day sampling for entrainment. Other ichthyoplankton studies have shown that some fish larvae are more susceptible to entrainment and capture by plankton nets at night. Therefore, it is proposed that ichthyoplankton entrainment

sampling include data collected during the night. This can be accomplished by reducing water flow through the entrainment nets and collecting a sample over a long period (up to 24 h) that encompasses both day and night. Since the 24-h samples are effectively composite samples, no replicates will be taken. If nets become clogged during entrainment sampling, they can be cleaned and samples combined until sampling has been completed. This method has a further advantage because a larger volume of water will be sampled than at present. To determine differences that may result from night sampling, as many as 16 comparisons between day and night catches on the same date are planned in a special study to be performed over the course of a year.

- Nets with a 505-μm mesh are presently used for entrainment sampling. Studies have indicated that smaller (predominantly 2 to 5 mm) fish larvae can be extruded through this size mesh. Therefore, paired duplicate sampling using both 505- and 333-mm mesh nets should be conducted for at least 1 year to determine if an appreciable fraction of fish larvae are being missed in entrainment samples because of net extrusion. If no apparent differences are found between the two nets, then future samples can again be taken with 505-μm nets. If differences do exist, then all future entrainment samples should be taken with a 333-μm net. It may also be possible to use a correction factor for some taxa to modify previous data to account for undersampled larvae.

3. **Gill net sampling programs** (surface/near- bottom and mid-water) have provided data that fulfilled the objectives of these programs after 5 years of plant operation and it is recommended that they be discontinued.

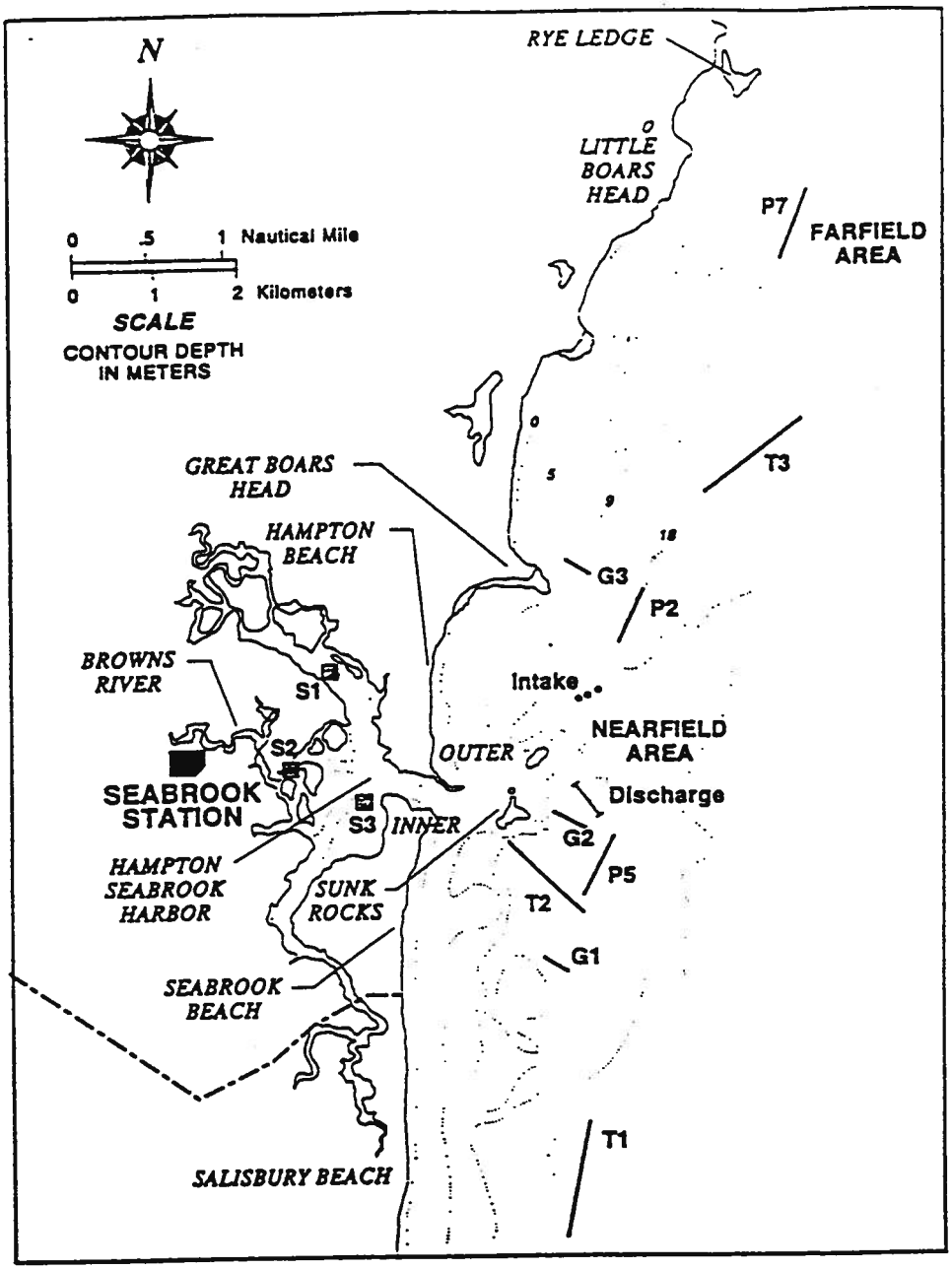
    - The gill net sampling programs (surface/near-bottom and mid-water) are proposed to be eliminated as they provide little or, in the case of mid-water sets, no useful data for the assessment of plant impact. Based on impingement and entrainment data, pelagic fishes are not as susceptible to impact at Seabrook Station as demersal fishes. No attraction to the station thermal plume was evident. Information on some of the dominants collected by gill net are available through other programs. Atlantic herring and pollock are collected in the seine and trawl monitoring programs. Nearly all juvenile and adult Atlantic mackerel have been taken by gill net. However, the annual abundance of this species, which ranks highly in annual entrainment estimates, can be determined by eggs collected in the ichthyoplankton program. Annual egg abundance can be used as a measure of spawner biomass and relative year-to-year abundance of adults in the Seabrook area. The gill net sampling is also highly destructive and it is likely that over the years more fish will be killed by this sampling than will be lost at Seabrook Station.

4. **Trawl sampling program** data provide abundance information for species that represent the local demersal fish assemblages, including several that are potentially affected by Seabrook Station and require further evaluation of impact. Therefore, no changes are recommended, except for increasing the precison of length measurements from 2 to 0.5 cm to improve the utility of the data for modeling purposes.

5. **Seine sampling program** data provide abundance information for species that represent the local estuarine fish assemblage, including several that are potentially affected by Seabrook Station and require further evaluation of impact. Therefore, no changes are recommended for this sampling program, except for increasing the precison of length measurements from 2 to 0.5 cm to improve the utility of the data for modeling purposes.

6. **Impingement sampling** needs further refinement to determine if estimates of this impact are adequate.

    - A special study of at least 1 year in duration (when plant is in full operation) is suggested to determine if small fish are lost due to decay or other reasons during the current week-long interval between samples. To accomplish this, screens would be washed after being held for about 24 hours and for a second time during the week after being held for the remaining 6 days. A numerical comparison of the catches (after adjustments to equalize effort), the species composition, and relative sizes of impinged specimens should illustrate whether or not certain taxa or sizes are inadequately represented in present impingement samples. Following the termination of this study, the impingement methodology should be again re-evaluated to optimize the frequency of sampling so that the most accurate impingement estimates can be made.



LEGEND

P = Ichthyoplankton Tows

T = Otter Trawls

G = Gill Nets

S = Seine Hauls

Ichthyoplankton and juvenile and adult fish sampling stations near Seabrook Station (from NAI 1996).

FINFISH

PROPOSED PROGRAM	PAST PROGRAM
1) Ichthyoplankton	
• **Stations/Sampling frequency:** P2 and P7 sampled four times a month	• **Stations/Sampling frequency:** P2, and, P7 sampled four times a month
• **Replicates:** 1 sample collected and processed	• **Replicates:** 2 collected; 1 processed
• **Total samples/year:** 96 (no contingency samples would be collected)	• **Total samples/year:** 288 collected; 144 processed
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae
2) Ichthyoplankton entrainment	
• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month over a period up to 24 h encompassing both day and night. In addition, as many as 16 comparisons between day and nigh catches on the same date are proposed as a special study to be performed over the course of a year.	• **Stations/Sampling frequency:** Seabrook intake structure sampled 4 times a month during the day
• **Replicates:** 1 (~24-h composite sample)	• **Replicates:** 3
• **Total samples/year:** 96; for at least 1 year of operation, two samples to be collected simulataneously, one with 0.505-mm mesh and one with 0.333-mm mesh; entrainment sampling to be re-assessed following this study.	• **Total samples/year:** 144
• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae	• **Data collected:** Density of fish eggs and larvae per $1000m^3$; length of larvae

FINFISH (continued)

PROPOSED PROGRAM	PAST PROGRAM
3) <u>Mid-water gill net</u>	
• These data were collected to monitor pelagic finfishes, such as the Atlantic menhaden, that are found in mid-water depths to determine their potential for impingement impact. The in-plant impingement program now monitors this effect directly. Few pelagic fish are impinged at Seabrook Station and this sampling program can therefore be discontinued.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly in February, June, and October • **Replicates:** 2 24-h sets • **Total samples/year:** 18 • **Data collected:** species abundance, length measurements
4) <u>Surface/near-bottom gill net</u>	
• These nets were deployed to determine if finfish would be attracted to the area becuse of the thermal plume. After 5 years of plant operation, no attraction has been demonstrated, so continued monitoring is unnecessary. This program also provides data on pelagic fish that may be impinged. As few of these fish are taken at the station, the sampiling itself may be more destructivce than impingement effects.	• **Stations/Sampling frequency:** G1, G2, G3 sampled monthly • **Replicates:** 2 24-h sets • **Total samples/year:** 144 • **Data collected:** species abundance, length measurements

FINFISH (continued)

PROPOSED PROGRAM	PAST PROGRAM
5) <u>Otter Trawl</u>	
• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly	• **Stations/Sampling frequency:** T1, T2, T3 sampled twice monthly
• **Replicates:** 2	• **Replicates:** 2
• **Total samples/year:** 144 (likely not always achievable due to lobster pots at T2)	• **Total samples/year:** 144 (not always achieved due to lobster pots at T2)
• **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Data collected:** species abundance; length measurements to nearest 2 cm
6) <u>Beach Seine</u>	
• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November	• **Stations/Sampling frequency:** S1, S2, S3 sampled monthly from April through November
• **Replicates:** 2	• **Replicates:** 2
• **Total samples/year:** 48	• **Total samples/year:** 48
• **Data collected:** species abundance, length measurements with increased precision from nearest 2 cm to at least 0.5 cm	• **Data collected:** species abundance; length measurements to nearest 2 cm

FINFISH (continued)

PROPOSED PROGRAM	PAST PROGRAM
7) Impingement	
• **Stations/Sampling frequency:** Sampling frequency of twice a week for at least for 1 year of operation in a special study to assess the effectiveness of sampling: one ~24-h sample would be compared to a 6-day sample collected during the remainder of the week to determine if there is appreciable decay or loss of small fish on screens; impingement sampling schedule to be re-assessed following this study	• **Stations/Sampling frequency:** Sampled weekly when plant was operating
• **Replicates:** N/A	• **Replicates:** N/A
• **Total samples/year:** maximum of 104	• **Total samples/year:** maximum of 52
• **Data collected:** species abundance, length measurements to nearest 0.5 cm	• **Data collected:** species abundance

WORKING DRAFT

EVALUATION OF SEABROOK STATION FISH SAMPLING PROGRAMS AFTER FIVE YEARS OF PLANT OPERATION

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Evaluation of Seabrook Station Fish Sampling Programs After Five Years of Plant Operation

Introduction

Seabrook Station, an 1150-Mwe nuclear-fueled power plant, is located in Seabrook, New Hampshire. The station uses Atlantic Ocean water to condense steam and cool vital equipment associated with the service water system. The station has three mid-water (about 17 ft off-bottom) intake structures located in depths of about 55 ft approximately 1.3 mi offshore of Hampton Beach (Fig. 1). Water withdrawn through a 19-ft diameter tunnel travels about 3.25 mi to the plant, having a transit time of around 70 min. The station is permitted to use up to 2.70×10^6 $m^3 \cdot day^{-1}$ (31.3 $m^3 \cdot s^{-1}$) of seawater, 95% for non-contact condenser cooling water and 5% for service water systems. Seawater systems at Seabrook Station are protected from withdrawing debris, seaweed, and larger organisms by three 0.375-in traveling screens. Material larger than this is impinged on the screens and later washed off for disposal, whereas most smaller items are entrained through these systems. Water used at the station is released through the onsite Discharge Transition Structure (DTS) and travels 3.1 mi through another 19-ft diameter tunnel to eleven diffusers located about 1 mi offshore of the mouth of Hampton-Seabrook Harbor at a depth of approximately 55 ft. The diffusers discharge water towards the surface at a velocity of about 15 $ft \cdot sec^{-1}$. The average monthly increase in temperature (ΔT) at the DTS can be up to 39°F and the maximum daily ΔT cannot exceed 41°F. The rise in temperature of the receiving waters cannot be greater than 5°F, except within 100 ft of the diffusers, where this limit only applies at the surface. This area is the nearfield jet mixing region. Previous hydrothermal modeling and field studies demonstrated that the area of the discharge plume is relatively small, with a surface temperature increase of 3°F encompassing an area of approximately 32 acres around the area of the discharge (Teyssandier et al. 1974; Padmanabhan and Hecker 1991).

Fish are ecologically important and occupy upper trophic levels in aquatic ecosystems. Many fishes are exploited by sport or commercial fisheries, providing substantial local, regional, and

national economic benefits. Finfish studies at Seabrook Station began in July 1975 and included investigations of all life stages of fish, including ichthyoplankton (eggs and larvae), juveniles, and adults. Initially, these studies were to establish baseline data suitable for assessing the effects of station operation by determining the seasonal, annual, and spatial trends in abundance and distribution of fish in the nearshore waters off Hampton and Seabrook. Sampling also took place within the Hampton-Seabrook estuary to see if the construction of Seabrook Station and the discharge of an onsite settling basin into the Browns River, which ended in April 1994, affected resident fish populations. Seabrook Station began commercial operation in August 1990. Once online, potential impacts of plant operation on local fishes included entrainment of eggs and larvae through the condenser cooling-water system and impingement of larger specimens on the traveling screens within the circulating water pumphouse. Also, local distribution of fishes could be affected by the thermal discharge and some eggs and larvae could be subjected to thermal shock due to plume entrainment following the discharge of condenser cooling water from the diffuser system. After plant operation commenced, the primary objective of the finfish studies was to assess whether there were any measurable effects on the nearshore fish population.

The field sampling programs for fish are directed at specific life stages or assemblages. Sampling has been accomplished with five gear types that includes the collection of ichthyoplankton using a standard 1-m plankton net (0.505-mm mesh); 30.5- X 3.7-m gill nets (paired surface-bottom sets, and mid-water sets), which are directed at pelagic fish; a 9.8-m otter trawl, which samples demersal fish; and a 30.5- X 2.4-m beach seine, which is used for smaller fish found in the shore zone of the Hampton-Seabrook estuary. Each field sampling program uses three stations (Fig. 1). Once Seabrook Station began operation, entrained ichthyoplankton (0.505-mm mesh nets) and impinged fish each were sampled at the plant using appropriate techniques. Detailed descriptions of the gear and methods used in these sampling programs are found in NAI (1996).

Data provided by the sampling programs were used in several types of analyses. These are described in detail in NAI and NUSCO (1994) and NAI (1996) and include multivariate

numerical classification and multivariate analysis of variance (ANOVA) of ichthyoplankton assemblages; graphical comparisons of annual geometric mean catch-per-unit-effort (CPUE) for gill net, otter trawl, and beach seine catches; and a fixed effects ANOVA model using specific abundance data for selected species. Data for the ANOVA model met the criteria for a Before-After/Control-Impact (BACI) design (Stewart-Oaten et al. 1986), where sampling was conducted prior to and during plant operation and sampling station locations included both potentially impacted and non-impacted control sites.

The purpose of this evaluation is to critically examine the methodologies and findings of each of the five field and two in-station impact-related sampling programs after 5 years of Seabrook Station operation. The effectiveness of each program will be assessed and proposals will be made to: 1) maintain current work, 2) enhance or modify programs where necessary, or 3) reduce sampling in cases where the data collected do not meet objectives of providing information vital to impact assessment. Annual CPUE indices by sampling gear and the BACI ANOVA model analyses focused on eleven fishes (Table 1). These species were originally chosen because of their dominance in the Hampton-Seabrook area or because they were commercially or recreationally important. With 5 years of operating history at Seabrook Station, the susceptibility of these species (and others) to impact is better known and the need to emphasize particular species in the data analyses was also evaluated.

Evaluation of Present Fish Sampling Programs at Seabrook Station With Recommendations For Future Studies

Ichthyoplankton

Ichthyoplankton sampling is currently conducted at three stations during the night four times a month. Two replicate samples are collected at each station, but only one of the replicates is processed; the remaining one is held as a contingency sample. Stations P2 and P5 are nearfield stations, located close to the Seabrook Station intakes and discharge, respectively, that are potential impacted by the operation of Seabrook Station (Fig. 1). Samples have been

taken consistently at P2 since the start of the program; P5 was not sampled from January 1982 through June 1986. Station P7 is a farfield station and serves as a control or non-impacted site and, with the exception of 1985, has been sampled from January 1982 through the present. Historically, several modifications have been made to the collection frequencies, number of replicates collected, and the stations sampled. However, since July 1986 sampling methodology has been consistent for each sampling date at all three stations.

Examination of the results from analyses of data collected through 1995 indicate that the two nearfield stations (P2 and P5) were similar in fish egg and larval species composition and abundance. In numerical classifications of fish eggs, when no data were excluded, stations P2 and P5 are lustered in the same group, except for only 2 months, January 1989 and November 1993 (Fig. 2). Similarly, fish larvae at P2 and P5 clustered together in all but two instances, February 1987 and October 1992 (Fig. 3). In addition, the results from ANOVA indicated no significant ($p < 0.05$) difference between these two stations in the nine selected larval fish taxa (NAI 1996). Further, all Preop-Op X Station interaction terms were not significant, indicating consistency in abundance trends over time among the stations and no effect from station operation (Table 2).

Additional comparisons of larval abundance of selected taxa collected at stations P2 and P5 from July 1986 through December 1995 were examined using Wilcoxon's signed-rank test for paired comparisons. Paired testing is more sensitive in detecting station differences than the presently used ANOVA model based on the BACI sampling design, which is primarily used to determine if the Preop-Op X Station interaction term is significant for assessing plant impact. All sample densities were log transformed and a mean of the transformed densities for each sample date and station was used. The total number of possible pairs was 440, but for each taxa only pairs where at least one specimen was collected at either of the two stations were used in the analyses (i.e., zero values at both stations were excluded). Thus, the number of paired comparisons for each taxon ranged from 74 to 228 (Table 3). The only significant ($p = 0.027$) difference detected between stations was for pollock larvae, which were more abundant at station P5 than at P2.

Based on the similarity between the two nearfield stations in species composition and in the abundance of selected taxa, the ichthyoplankton program is proposed to be modified to include only P2 as the nearfield station and P7 as the farfield station. This sampling design will allow the important BACI sampling design for ANOVA to be maintained. Station P2 has a long and continuous time-series of data that goes back to 1975 and, with a similar set of data from P7, will continue to provide abundance and other information on ichthyoplankton found in the vicinity of Seabrook Station.

The analysis using the ANOVA model with data from only stations P2 and P7 for the nine selected larval fishes showed no differences in the main effects of operational status and station and in the Preop-Op X Station interaction term. A comparison of the error mean squares computed for the nine larval fishes for two and three stations showed them to be very similar, although slightly higher in most instances when only P2 and P7 were included (Fig. 4). Using an F-test, a comparison was also made between the mean squares of the Preop-Op X Station interaction term from the two-station and three-station ANOVA models for each of the selected species (Table 4). In only one case, that of Atlantic mackerel, was the F-value significant ($p \leq 0.05$). However, as noted above, in both three- and two-station ANOVA models for Atlantic mackerel no significant differences were found for the main effects (Preop-Op and Station) and the Preop-Op X Station interaction term was not significant ($p = 0.84$ and 0.98, respectively). Effects of Seabrook Station on the Atlantic mackerel will be discussed further in the Surface/near-bottom Gill Net section, found below.

Ichthyoplankton Entrainment –

Entrainment samples (three replicates) at Seabrook Station are currently taken up to four times a month during the day. Two double-barrel collection devices (described in NAI 1996) use nets of 0.505-mm mesh and samples collected in each are consolidated before preservation. The volume filtered averages about 100 m^3 per replicate. From the start of plant operation in mid-1990 to the present, entrainment collections have been dominated by nine taxa of fish eggs and eight larval taxa (Table 5).

Entrainment estimates of fish eggs and larvae are one of the most direct measures of plant operational impact and should be accurately measured. Field ichthyoplankton collections are taken during the night, whereas entrainment samples at Seabrook Station are only taken during the day. This could account, in part, for some of the differences seen in species composition between the two programs (see Selected Species, below), although the location of the station's cooling-water intakes in midwater depths may also be an important factor. Nevertheless, significant diel differences in distribution occur for many fishes (e.g., among the selected species: Atlantic herring, Stephenson and Power 1988, Munk et al. 1989; Atlantic cod, Lough and Potter 1993; hakes, Hermes 1985; sand lance, Potter and Lough 1987; winter flounder, NUSCO 1987, Bourne and Govoni 1988; and yellowtail flounder, Smith et al. 1978), which would make them differentially susceptible to entrainment over the course of an entire day. Thus, it is preferable to collect larval fish during both day and night at the intakes.

The entrainment sampling program at Seabrook Station should be modified to include larval fish that may be more susceptible to entrainment at night to obtain more accurate estimates of this impact. This would be accomplished by decreasing the present sample water flow and collecting over a longer period (up to 24 h), which would include both day and night. These procedural changes would also greatly increase the volume sampled compared to the 100 m^3 currently being filtered. This new method, however, may increase net clogging during some sampling periods. However, if clogging occurs, each net should be periodically washed down and samples combined until the sampling has been completed. Each daily sample would be taken over a longer period of water-flow and contain a more accurate representative sample of ichthyoplankton. Therefore, replication of samples is inappropriate.

To examine the differences in entrainment that may be the result of sampling at night as well as during daylight, a special 1+-year (done under full plant operating conditions) study is proposed. As many as 16 comparisons (twice a month in February-August and October-November, when larval fish are most abundant) would be made between separate day and night samples taken on the same day. A comparison between day and night densities will

provide information on the relative contribution of each period to total entrainment. However, even if no substantive differences are found between day and night, entrainment samples will continue to be collected over the proposed period of up to 24 h. For the purpose of generating entrainment estimates, data from the separate day and night collections will be combined by date before calculations are made.

The feasibility of taking a sample during a 24-h period was examined in a preliminary pilot study in July 1996 (R. Sher, NAESCO, pers. comm.). The volume of water filtered was about eight times the current sample volume and collection was taken without difficulty.

Another potential source of bias in the Seabrook Station entrainment estimates is in the use of 0.505-mm mesh nets. This may result in some species being underrepresented in the samples due to net extrusion. For example, Johnson and Morse (1994) estimated that the abundance of twenty-four fish taxa was 54% higher in 0.333-mm mesh nets than in 0.505-mm mesh nets. They reported significant differences in catches (always greater in the 0.333-mm mesh nets) for hakes, pollock, cunner, and American sand lance; differences were not significant for Atlantic herring, Atlantic cod, or yellowtail flounder. Largest differences occurred in the 2 to 5-mm size-classes. This would potentially include the earlier larval stages of fishes such as the winter flounder and cunner, which are relatively small. Thus, in addition to the proposed change in sample duration, a special 1+-year study is also proposed to determine if a significant fraction of ichthyoplankton is not being accounted for in the entrainment samples. One of the collection devices would be fitted with a 0.333-mm mesh net and the other would retain the presently used 0.505-mm mesh net. Samples would be processed separately during this study and a comparison of the catches in each net would indicate whether an appreciable fraction of fish larvae are missed in entrainment samples because of net extrusion. If this is not the case, future samples could again be taken using 0.505-mm mesh nets, with the collections from both sampling devices again combined before processing. If differences between the catches by net do exist, then both nets used should be changed to 0.333-mm mesh. Using length-frequency information, it may be possible to obtain a correction factor for

some of the taxa to modify previous data and adjust entrainment estimates by accounting for undersampled sizes of larvae.

The proposed changes to the ichthyoplankton entrainment sampling (24-h sampling, day-night comparison, mesh comparison) represent enhancements that should result in more accurate estimates of larval fish losses at Seabrook Station.

Surface/near-bottom Gill Net

Sampling by gill net began in July 1975 at one farfield (G3) and two nearfield stations (G1 and G2; Fig. 1) to sample the pelagic fish assemblage, which was presumed to be the most likely attracted to the Seabrook Station intakes and become impinged. Also, pelagic fish were projected to be attracted to the thermal discharge of Seabrook Station. Samples (two consecutive 24-h sets) were taken twice a month until July 1986, when the frequency was reduced to once per month. A sampling array having nets near the bottom and at the surface was used; nets were attached to permanent moorings and tended by SCUBA divers. Gill net catches were dominated by Atlantic herring, which made up more than half of the catch (Table 6). Blueback herring, silver hake, Atlantic mackerel, and pollock were relatively common.

Atlantic herring, pollock, and Atlantic mackerel were selected for further analyses (e.g., ANOVA) because of their abundance in gill net samples. Results of the ANOVAs for these three pelagic fishes, however, indicated no significant effects (i.e., the Preop-Op X Station interaction term was non-significant for each) as a result of plant operation (Table 2). Furthermore, other significant changes in abundance (greater abundance during the preoperational period for Atlantic herring, during the operational period for Atlantic mackerel, and no difference for pollock) reflected overall population trends in the Gulf of Maine that appeared to be primarily related to fishing as reported in NOAA (1995). The only station differences found were for pollock, having similar catches at farfield station G3 and nearfield station G2 (ca. 250 m from the discharge), both of which were significantly greater than catches at nearfield station G1, located about 2 km south of the plant discharge. Thus, for the

fishes commonly collected by gill net there were no changes in distribution or abundance related to an attraction or repulsion to the thermal effluent of Seabrook Station.

Direct impacts by plant operation on the three selected species taken by gill net include entrainment and impingement. Atlantic herring eggs are demersal and none were entrained from 1990 through 1995. Larval entrainment estimates ranged from only 0.1 to 11.2 million per year (Table 5). Only 514 herrings (probably a mixture of several species, including alewife and blueback herring as well as Atlantic herring; NAI 1996) were impinged in 1994 and 231 in 1995.

One million pollock eggs were entrained in 1991, but only 100 to 400 thousand eggs were entrained in other years. Few (0-200 thousand) pollock larvae were entrained annually. Impingement estimates for pollock during 1994 and 1995 were 1,681 and 899, respectively. However, these entrainment and impingement totals only equate to 142 and 59 equivalent-adult (age-1) pollock (NUSCO, Saila, and Howell 1995).

No Atlantic mackerel were impinged during the past 2 years and entrainment estimates of larvae were from 0 to 4.7 million. Eggs of Atlantic mackerel, however, were the top-ranked fish egg entrained. None were taken in 1994, when no samples were taken from April through August while the plant was shut down, but estimates in other years ranged from 74.5 million in 1995 to 673.2 million in 1991. Female Atlantic mackerel produce from 360 to 450 thousand eggs per spawner (Sette 1943) with mortality in the egg stage as high as $41\% \cdot d^{-1}$ (Ware and Lambert 1985). Despite being occasionally found in ichthyoplankton collections in high densities, relatively few (0-4.7 million) Atlantic mackerel larvae were entrained during each year of station operation. This may be the result of the rapid developmental rate of this fish, relatively high swimming speeds, and increased surface orientation as larvae develop (Ware and Lambert 1985), which enable mackerel larvae to avoid the station intakes.

The gill net sampling is not effective in providing information about the presence of fish subject to impingement because so few pelagic fish are impinged at Seabrook Station in comparison to demersal species (see the Impingement section, below). Of all fishes collected by gill net, the only life stage predominant in entrainment or impingement collections was the eggs of Atlantic mackerel. Potential power plant impact can be better evaluated in this instance by using equivalent-adult (Horst 1975; Goodyear 1977; Saunders 1977; Boreman et al. 1981) or similar analytical methodologies, such as production foregone (Rago 1984). All three of the pelagic species that were selected for analysis are highly fecund. Both pollock and Atlantic mackerel populations are made up of several very large stocks found over wide geographical areas in the North Atlantic Ocean (NOAA 1995). The Atlantic herring has many separate spawning aggregations found throughout the Gulf of Maine (Anthony and Boyar 1968; Iles and Sinclair 1982; Sinclair and Iles 1985), but a lengthy developmental period disperses and mixes larvae over large areas. Both the Atlantic herring and Atlantic mackerel are presently increasing in abundance in the Gulf of Maine and are underexploited by the fisheries (NOAA 1995). Pollock abundance is considered to be stable and this species is currently fully exploited.

Results of ANOVA using gill net collection data indicate no significant effects by Seabrook Station after 5 years of operation on the three selected species (Table 2). Differences in abundance between the preoperational and operational periods appeared to result from long-term changes in population size occurring over a wide area that were related to fishing. Therefore, the surface-near bottom gill net sampling program are proposed to be discontinued as collections do not provide data needed for the assessment of Seabrook Station operation on fishes. Gill net sampling is also highly destructive. It is likely that the thousands of juvenile and adult Atlantic herring, blueback herring, silver hake, pollock, and Atlantic mackerel killed during gill net sampling since 1975 will exceed the mortality of these fishes imposed by Seabrook Station during its operational lifetime. If, however, abundance information for the three selected species taken by gill net is desirable, both Atlantic herring and pollock (mostly young-of-the-year) have been taken by seine, the data for which provide an annual index of year-class abundance. Pollock are also taken by the otter trawl sampling. The abundance of

Atlantic mackerel eggs and larvae as provided by the ichthyoplankton monitoring program should provide an annual index of spawner abundance of this fish.

Mid-water Gill Net

Mid-water gill net sampling began in 1980 with sets made only during February, June, and October at the three gill net stations. Mid-water gill net sampling was designed to capture fish found at a depth comparable to the Seabrook Station intakes, which presumably would have been the specimens most likely to have been impinged. However, impingement at Seabrook Station has been dominated by demersal fishes and small species not susceptible to the mesh sizes of the gill nets in use. A comparison of mid-water gill net catches with surface and near-bottom gill net catches made at the same time showed that only Atlantic menhaden were slightly more abundant in mid-water sets than at the surface or near the bottom. Other fishes relatively abundant in mid-water gill net collections included the Atlantic herring, silver hake, Atlantic mackerel, pollock, alewife, and blueback herring, but catches of these fishes were generally higher in the surface-bottom sets than in mid-water. Only seven Atlantic menhaden have been recorded in impingement samples since the start of sampling in 1990 and relatively few individuals of the other species collected by gill nets have been impinged. The mid-water gill net catch data have not been discussed in annual monitoring reports since NAI (1992) because the data have not been helpful in describing trends in impingement and because of similarities to the surface-bottom gill net collections, which are made monthly as opposed to only three times a year for mid-water sets. Therefore, it is proposed that this sampling program be terminated because the data collected are not needed for assessments of potential Seabrook Station impact.

Otter Trawl

The otter trawl program has provided monthly abundance data since July 1975 useful for characterizing the demersal fish assemblage at three inshore stations, two (T1 and T2) nearfield and one (T3) farfield (Fig. 1). Four replicate tows were made at each station once a month, but beginning in January 1985, the sampling frequency was increased to twice a month and the number of replicate tows was reduced to two.

Several selected species, including the yellowtail flounder, the hakes, winter flounder, and Atlantic cod are taken frequently in trawl samples (Table 7). These species were considered potentially susceptible to impact at Seabrook Station by entrainment of eggs and larvae or from impingement; all are also heavily exploited by the fisheries (Table 2). They all have spawning stocks made up of many age-classes and have relatively long life spans. Thus, any impacts will take time to be propagated through their population age structure. Other species present in the trawl catches included longhorn sculpin, rainbow smelt, skates, windowpane, pollock, and silver hake.

Equivalent-adult analyses were completed to determine the effect of entrainment and impingement losses on the hakes (white hake was chosen for this analysis) and winter flounder (NUSCO, Saila, and Howell 1995). These analyses showed relatively small numbers (<800 annually of hakes and 1,374-4,273 winter flounder) of equivalent-adults lost to their respective populations.

Results from the ANOVA models showed that all species selected for analysis from the trawl program were less abundant during the operational period than the preoperational period (Table 2). In addition, the rainbow smelt, winter flounder, and yellowtail flounder taken by trawl had significant Preop-Op X Station interaction terms. However, NAI (1996) concluded that differences in abundance at the trawl stations of these species were neither biologically significant nor due to station operation. Instead, the effects may be due to changes in local environmental or physical conditions.

Trawl CPUE for rainbow smelt decreased between the preoperational and operational periods at all three stations, but was greatest at T2. However, no significant differences were found when using the seine data with the ANOVA model; the seine stations are much closer to the streams in which rainbow smelt spawn. Impingement and entrainment of smelt has been very low since Seabrook Station began operation.

Winter flounder catches also decreased disproportionately at T2, a trend that began during the preoperational period. Differences in trends between control and impact stations in the period prior to the impact (i.e, plant start-up) taking place may lead to misleading significance (Smith et al. 1993) unrelated to the effect being observed. Winter flounder populations have been heavily exploited by the fisheries in recent years (NOAA 1995).

Abundance of yellowtail flounder is currently very depressed (NOAA 1995). Catches of yellowtail flounder by trawl were highest at farfield station T1, with the decline in abundance between the preoperational and operational periods somewhat larger there than at T2 or T3. This is likely related to the overfishing and the significant interaction term is unrelated to plant operation. The yellowtail flounder is only minimally affected by entrainment or impingement.

Although plant effects appear to be minimal for the fishes taken by trawl, due to the importance of the demersal fish community and the consistency of the trawl monitoring in providing abundance information over a long time period, no changes to this program are recommended.

Beach Seine

Monthly beach seine sampling (two hauls per station) have been completed since July 1975 at three stations within the Hampton-Seabrook Harbor (Fig. 1), although no samples were collected in 1985 or from April through June of 1986. Seabrook Station ceased discharging from a settling basin into the Browns River in April 1994. Thus, direct plant effects on resident estuarine fishes no longer occur except for life stages of inshore fishes that are susceptible to entrainment or impingement at the offshore plant intakes.

Atlantic silverside dominated the seine catch (Table 8) and was also the most numerous fish impinged on the traveling screens of Seabrook Station (see the Impingement section, below). Impingement of this species primarily occurs during offshore overwintering movements. The winter flounder also contributes frequently to beach seine catches, with larvae entrained and

juveniles and adults impinged, particularly during fall and winter storm events. Other fishes commonly found in the seine catches include killifishes, American sand lance, rainbow smelt, pollock, ninespine stickleback, alewife, and Atlantic herring.

Because of the long and consistent time-series of data, the lack of abundance information on the Atlantic silverside from other sampling programs, and the catch of juvenile winter flounder and other important species by seine, this monitoring program should continue until further evaluations of potential Seabrook Station impacts are performed for the fishes taken by this method.

Impingement

Traveling screens at the Seabrook Station circulating water pumphouse are generally washed once a week. Immediately following the screenwash, all impinged organisms are removed from a collection basket, identified, enumerated, and measured. Impingement has been greatest during cooler months and storm periods. Prior to October 1994, estimates of impingement were inaccurate because small fish were incompletely separated from debris (NAI 1996). Consequently, impingement counts made during the last quarter of 1994 and for all of 1995 were substantially higher (15,932-19,218) than earlier annual estimates (503-1,177). In 1994-95, the twelve most numerous species made up more than 90% of the total impingement (Table 9). This total includes at least one annual estimate of greater than 2,000 fish for Atlantic silverside, grubby, and the hakes. Relatively few rainbow smelt (213-545), herrings (231-514), cunner (32-342), and Atlantic cod (58-119), and no Atlantic mackerel were impinged in either 1994 or 1995. Although the station has mid-water intakes, a considerable portion of impingement is of demersal species, such as flatfishes, hakes, and sculpins. In comparison to other large marine electrical generating stations in New England, Seabrook Station impinges relatively few specimens as a result of its offshore mid-water intakes (Table 10).

Accurate estimates of losses are required for impact assessments as impingement directly affects fish by removing older individuals from the population. These losses occur after

natural mortality rates decrease from mortalities found during the earliest life history stages (i.e., eggs and larvae). Thus, population-level responses (e.g., density-dependent mortality) may be less effective in compensating for losses. Although estimates of impingement at Seabrook Station improved considerably in late 1994, a possibility exists that some species may still be underestimated in impingement counts. Because the screens are usually washed only once a week, it is possible that small fish may deteriorate before being encountered in a sample. To determine if this is happening, a change to the impingement sampling protocol is proposed during a special 1+-year study. Full or nearly full plant operation is required during this period to obtain estimates over all seasons and water temperatures. This study would involve holding the screens for about a 24-h period once during a week before washing them to obtain a sample. The screens would then be held for the remaining 6 days of the week and another sample then taken. Some deviations in these periods may be necessary because of plant operations. For example, during major storm events, traveling screens may run continuously for extended periods. In this instance, comparisons of short and long screenwash hold times would likely be impossible. Nevertheless, during routine weeks, impingement counts from both the short and long periods can be standardized by time (e.g., number impinged per hour). A comparison of the resulting weekly impingement CPUEs as well as the species composition and size-frequencies of fish impinged should reveal whether smaller fish or particular species are being lost during the current week-long period between screenwashes. Upon completion of the study, if loss of fish prior to sampling is not evident, the impingement sampling schedule can be reduced once again to the current weekly count. If, however, loss of fish is considered to be appreciable, impingement sampling should be scheduled more frequently to obtain more accurate estimates. Depending upon the outcome (e.g., the species involved or time of year), then further adjustments to the impingement sampling schedule may be desirable, such as a reallocation of sampling effort to a stratified random design in place of the current systematic weekly effort. This would likely lead to increased sampling during times when impingement is highest (fall-winter) and a reduced schedule when impingement is quite low (late spring-summer).

Selected Species

Currently, eleven fishes are selected for species-specific analyses for Seabrook Station studies (Table 1). However, based on the long preoperational data time-series and 5 years of operational studies, including entrainment and impingement sampling, it is clear that these fishes have variable susceptibilities to effects of station operation. Based on the results of the ANOVA model reported in NAI (1996), the potential effects of Seabrook Station on selected fishes are summarized in Table 2. There were significant differences found between the preoperational and operational periods that were not consistent among stations (indicated by a significant Preop-Op X Station interaction term) for only three species: the rainbow smelt, winter flounder, and yellowtail flounder. However, as discussed previously, it is unlikely that these differences were due to Seabrook Station operation, particularly for rainbow smelt and yellowtail flounder. Very few specimens of either species were entrained or impinged during plant operation (Tables 5 and 9). This was also true of Atlantic herring, Atlantic cod, and pollock. Species that are emphasized in the reports should include those that make up relatively large proportions of entrainment (e.g., Atlantic mackerel, cunner) and impingement (e.g., hakes) or have a stock structure (i.e., localized spawning populations) that may make them more susceptible to impact (e.g., winter flounder and Atlantic silverside). Many entrained or impinged specimens of the latter two species were likely produced locally within the Hampton-Seabrook Harbor estuary.

Predictions of the numbers of fish eggs and larvae entrained into the condenser cooling-water system of Seabrook Station were made for rainbow smelt, winter flounder, Atlantic menhaden, pollock, and Atlantic mackerel in NAI (1977). At the time, these fishes had been identified as Representative Important Species by personnel from Region I of the U.S. Environmental Protection Agency, based on their commercial and recreational importance. Predictions of entrainment once the station went online were developed from densities of ichthyoplankton observed from 1973 through 1976 and a pumping rate for one unit operating at 100% of theoretical capacity. These conservative entrainment estimates of eggs and larvae were much higher than the actual entrainment determined for 1990 through 1995 (Table 11). The predicted entrainment was much higher than what actually occurred because of several

highly conservative assumptions. The single largest single monthly density for a species observed during 1973-76 was used in the calculations, which were values considerably higher than actually found during the operational period. The predicted pumping rate for one unit was slightly higher than the actual pumping rate because of station outages and other variations in flow. Also, differences have since been noted between entrainment and field ichthyoplankton samples, possibly because of different water masses sampled, diel differences in larval distribution, or species-specific behavior that may allow larvae to avoid the intakes. Consequently, the actual entrainment impacts on fishes were, at minimum, from one to three orders of magnitude lower than predicted, particularly for some of the selected species and effects of Seabrook Station operation on finfish have not been as severe as first hypothesized.

Several species less prominent in ichthyoplankton collections, including the Atlantic snailfish, rock gunnel, and grubby, however, do predominate in larval entrainment samples (Table 12). All of these fishes are small, have no sport or commercial value, and their ecological significance is less understood than many of the other selected species. These species are generally cryptic and are often found in tide pools or subtidally among rocks, mussel clumps, or near other bottom cover (Sawyer 1967; Collette 1986; Moring 1990; Ojeda and Dearborn 1990). Each of these fishes appears only sporadically in the seine and trawl sampling, but all are seasonally abundant in the ichthyoplankton sampling. The effect of station operation on these species is yet unknown.

In summary, presently selected fishes, including the Atlantic herring, rainbow smelt, Atlantic cod, pollock, and yellowtail flounder, should be de-emphasized in the annual reports as their entrainment and impingement are low and results from the ANOVA models indicated that they are probably not affected by Seabrook Station operation. However, annual abundance information for each would remain available through the seine and trawl sampling programs, which are proposed to be continued as in the past. Also, the ANOVA models could be completed for selected species taken by these gears. Continued scrutiny of the hakes, Atlantic silverside, cunner, American sand lance, Atlantic mackerel, and winter flounder is warranted until analyses such as equivalent-adult or production foregone estimates can be performed to

assess the potential impacts of Seabrook Station on their populations. If available, life history information may be needed to assess station impacts for the Atlantic snailfish, rock gunnel, and grubby. In any event, the ichthyoplankton monitoring should provide abundance data for the early life history stages of these fishes, the indices for which also generally reflect the numbers of adult spawners.

Conclusions

The proposed finfish monitoring programs are designed to provide improved quantitative measures of possible impact from Seabrook Station operation and the data needed to assess losses to local fish populations. Given the ecological and economic importance of finfishes, continued monitoring is warranted despite the absence of evidence of impacts found to date. Entrainment and impingement sampling, two programs which provide direct measurements of plant impact, are proposed to be enhanced. The ability to sample cooling-water flow up to 24 h will provide more accurate estimates of entrainment, including all ichthyoplankton more susceptible to entrainment during nighttime hours. A special 1+-year study comparing 0.505- and 0.333-mm mesh nets will provide evidence for or against larval net extrusion and increase the reliability of entrainment estimates. Similarly, a 1+-year study of impingement sampling frequency will ascertain whether certain species or sizes of fish are lost weekly between screenwashes. Once completed, results from these studies may lead to further refinements in entrainment and impingement monitoring.

Present field sampling programs are proposed to remain intact (otter trawl and beach seine), to be modified in scope without losing essential information (ichthyoplankton), or discontinued because the programs do not provide data pertinent to assessing the effects of Seabrook Station operation (surface/near-bottom and mid-water gill nets).

Susceptibility of each of the eleven selected fishes to impact was further examined using information available following 5 years of station operation. Emphasis in reports should be

placed on those species most likely to be affected by plant operation and include the hakes, Atlantic silverside, cunner, American sand lance, Atlantic mackerel, and winter flounder. Also potentially affected are the Atlantic snailfish, rock gunnel, and grubby, although their ecological and economic significance are likely much less than for the aforementioned species. Fishes de-emphasized in analyses and reporting because of lack of susceptibility to impact (i.e., little direct loss from entrainment or impingement or no thermal effects) are the Atlantic herring, rainbow smelt, Atlantic cod, pollock, and yellowtail flounder. Abundance data for these species will continue to be provided by the trawl, seine, and ichthyoplankton monitoring programs and, with the exception of gill net catches, the ANOVAs may still be completed for these species, if so directed. In addition, monitoring of possible effects of Seabrook Station operation on selected species may also be evaluated using other appropriate analytical techniques (e.g., equivalent-adult calculations; production foregone).

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Table 1. Selected finfishes and sampling programs that contributed abundance data in species-specific analyses for Seabrook Station.

Selected Species	Predominant Sampling Programs
Atlantic herring	ichthyoplankton, gill net
Rainbow smelt	otter trawl, beach seine
Atlantic cod	ichthyoplankton, otter trawl
Pollock	ichthyoplankton, gill net
Hakes	ichthyoplankton, otter trawl
Atlantic silverside	beach seine
Cunner	ichthyoplankton
American sand lance	ichthyoplankton
Atlantic mackerel	ichthyoplankton, gill net
Winter flounder	ichthyoplankton, otter trawl, beach seine
Yellowtail flounder	ichthyoplankton, otter trawl

Table 2. Summary of the potential of the operation of Seabrook Station on selected fish taxa based on results from the BACI ANOVA models (from NAI 1996).

Species	Sampling Program	Operational Period Similar to Preoperational Period?	Preop / Op Differences[a] Consistent Among Stations?	Recent Abundance Trends in the Gulf of Maine[b]	Status of Fishery
Atlantic herring	ichthyoplankton gill net	Op < Preop Op < Preop	yes yes	increasing	under-exploited
Rainbow smelt	trawl seine	Op < Preop yes	no yes	unknown	lightly to unexploited
Atlantic cod	ichthyoplankton trawl	yes Op < Preop	yes yes	decreasing	over-exploited
Pollock	ichthyoplankton gill net	Op < Preop yes	yes yes	stable	fully exploited
Hakes	ichthyoplankton trawl	yes Op < Preop	yes yes	increasing	under to fully expl.
Atlantic silverside	seine	Op < Preop	yes	unknown	unexploited
Cunner	ichthyoplankton	yes	yes	unknown	unexploited
Am. sand lance	ichthyoplankton	yes	yes	stable?	unexploited
Atlantic mackerel	ichthyoplankton gill net	yes Op > Preop	yes yes	increasing	under-exploited
Winter flounder	ichthyoplankton trawl seine	Op < Preop Op < Preop Op < Preop	yes no no	decreasing	over-exploited
Yellowtail flounder	ichthyoplankton trawl	yes Op < Preop	yes no	decreasing	over-exploited

[a] Based on Preop-Op X Station interaction term from the ANOVA.
[b] From NOAA (1995) for commercially exploited species.

Table 3. Comparison of larval abundances at stations P2 and P5 from July 1986 through December 1996 of nine of the selected taxa tested using Wilcoxon's signed-rank test. Given are the number of paired camparisons when the taxa were collected on a sampling date at either station and the point of rejection (P).

Taxon	Number of paired comparisons	P
Atlantic herring	228	0.406 NS
Atlantic cod	145	0.122 NS
Pollock	120	0.027 *
Hakes	97	0.082 NS
Cunner	148	0.168 NS
American sand lance	214	0.063 NS
Atlantic mackerel	74	0.151 NS
Winter flounder	113	0.800 NS
Yellowtail flounder	101	0.080 NS

Table 4. Results of F-tests to determine significant ($P \leq 0.05$) differences between mean squares (MS) for the interaction term from two analysis of variance (ANOVA) tests for selected larval fish taxa. One ANOVA was based on data collected at the three stations and the other ANOVA on data collected at two stations (P2 and P7). F-values were calculated by dividing the larger of the two MS by the smaller.

Taxa	F-value	P
Atlantic herring	1.00	0.577
Atlantic cod	1.93	0.453
Pollock	2.00	0.293
Hakes	3.75	0.343
Cunner	1.70	0.322
American sand lance	1.92	0.301
Atlantic mackerel	409.90	0.035
Winter flounder	6.90	0.260
Yellowtail flounder	1.85	0.307

Table 5. Estimated entrainment (in millions) of eggs and larvae of the most abundant and other selected fishes taken at Seabrook Station from 1990 through 1995.

Taxon	June-Dec 1990	Jan-July, Dec 1991	Jan-Aug 1992	Jan-Dec 1993	Jan-Mar, Sep-Dec 1994	Jan-Dec 1995
Eggs:						
Atlantic mackerel	518.1	673.2	456.3	112.9	0	74.5
Cunner/yellowtail flounder	490.4	716.3	198.6	58.4	0	18.6
Atlantic cod/haddock/witch fl.	29.1	74.5	39.5	50.3	1.0	34.8
Fourbeard rockling/hake	114.2	35.1	50.6	32.7	1.7	27.5
Windowpane	36.4	19.9	22.5	29.1	0.1	17.4
American plaice	2.6	21.0	52.3	19.5	0.4	14.8
Fourbeard rockling	7.4	4.3	0.8	1.4	0.2	4.2
Silver hake	11.4	0	0.1	0.4	0.4	22.5
Hakes	37.3	2.6	0	0.2	0.6	25.1
Other selected species:						
Atlantic cod	0	0	0	0	0	2.2
Atlantic cod/pollock	0	0	0	0	0	0.2
Pollock	0	1.0	0.4	0.2	0.1	0.4
Yellowtail flounder	0	0	0	0	0	0.2
Other fishes	0.8	3.1	1.5	10.5	0.3	13.2
Larvae:						
Atlantic seasnail	11.6	16.0	31.5	64.4	0	26.5
Grubby	0	22.4	18.9	13.8	4.9	17.4
American sand lance	0	37.3	18.1	12.0	8.3	9.5
Atlantic herring	0.7	0.5	4.9	9.6	0.1	11.2
Rock gunnel	0	51.1	45.3	5.7	11.0	15.6
Cunner	42.7	<0.1	0	4.7	0.1	4.4
Winter flounder	3.2	9.0	6.2	2.9	0	8.0
Fourbeard rockling	37.9	0.5	0.1	2.2	0	3.9
Other selected species:						
Atlantic cod	0.7	1.5	0.4	0.1	0	2.3
Hakes	4.8	0	0	0.1	0	0.7
Atlantic mackerel	0.2	4.7	0	0	0	0
Yellowtail flounder	0.1	0.3	0.1	0	0	0.1
Pollock	0.2	0	0.1	0	0	0
Rainbow smelt	0.2	0	0.1	0	0	0
Other fishes	19.2	10.5	7.3	10.7	6.8	45.7

Table 6. Percent species composition of fishes taken by gill net at Seabrook Station from 1975 through 1995.

Species	Station G1	G2	G3	All Stations Combined
Atlantic herring	57.8	63.6	54.3	58.7
Blueback herring	6.2	7.3	9.8	7.8
Silver hake	7.3	6.3	8.9	7.5
Atlantic mackerel	7.1	6.1	6.8	6.7
Pollock	6.4	6.4	6.9	6.6
Other selected species:				
Rainbow smelt	1.4	1.1	1.7	1.4
Hakes	2.1	1.3	0.8	1.3
Atlantic cod	1.0	0.7	1.0	0.9
Cunner	0.2	<0.1	0.6	0.3
Winter flounder	0.2	0.1	0.1	0.1
Yellowtail flounder	1.0	<0.1	0.0	<0.1
American sand lance	1.0	0.0	<0.1	<0.1
Atlantic silverside	0.0	<0.1	0.0	<0.1
Other fishes	8.3	7.1	9.1	8.7

Table 7. Percent species composition of fishes taken by otter trawl at Seabrook Station from 1975 through 1995 (note that station T2 was frequently not sampled in late summer-early fall).

Species	Station T1	Station T2	Station T3	All Stations Combined
Yellowtail flounder	35.1	13.7	18.5	24.5
Longhorn sculpin	12.4	4.8	22.7	15.1
Hakes	13.8	8.8	13.1	12.6
Winter flounder	7.4	25.6	6.6	10.4
Rainbow smelt	5.3	18.3	5.3	7.7
Atlantic cod	4.7	4.4	10.4	6.9
Skates	5.2	2.1	9.2	6.2
Windowpane	5.1	4.1	2.6	3.9
Pollock	1.8	8.2	0.8	2.6
Silver hake	3.0	0.8	2.8	2.5
Other selected species:				
Atlantic silverside	0.2	0.7	0.2	0.3
Atlantic herring	0.3	0.2	0.1	0.2
Cunner	0.1	0.1	<0.1	0.1
American sand lance	<0.1	0.1	0.0	<0.1
Atlantic mackerel	<0.1	<0.1	<0.1	<0.1
Other fishes	5.6	8.1	7.7	7.0

Table 8. Percent species composition of fishes taken by beach seine at Seabrook Station from 1975 through 1995 (no samples taken in 1985 or from April through June 1986).

Species	Station S1	S2	S3	All Stations Combined
Atlantic silverside	65.0	55.1	70.5	64.4
Killifishes	14.2	15.1	<0.1	8.2
American sand lance	3.8	3.6	5.8	4.6
Rainbow smelt	0.7	1.3	8.9	4.5
Pollock	1.0	5.7	4.1	3.8
Ninespine stickleback	4.6	2.1	4.4	3.7
Alewife	0.5	8.9	0.2	2.7
Atlantic herring	1.3	4.8	0.8	2.2
Winter flounder	1.4	1.2	2.4	1.8
Other selected species:				
Hakes	<0.1	0.2	0.2	0.2
Atlantic cod	<0.1	0.0	<0.1	<0.1
Yellowtail flounder	<0.1	<0.1	<0.1	<0.1
Cunner	0.0	0.0	<0.1	<0.1
Atlantic mackerel	<0.0	<0.0	<0.0	<0.1
Other fishes	7.5	2.0	2.7	3.9

Table 9. Number and percent total of the twelve most abundant and other selected fishes impinged at Seabrook Station during 1994 and 1995.

Species	1994	1995	Number Impinged	% of total
Atlantic silverside	5348	1621	6969	19.9
Grubby	2678	2415	5093	14.5
Hakes	2822	2197	5019	14.3
Winter flounder	1435	1171	2606	7.4
Pollock	1681	899	2580	7.4
American sand lance	1215	1324	2539	7.2
Windowpane	980	943	1923	5.5
Rock gunnel	494	1298	1792	5.1
Yellowtail flounder	0	1149	1149	3.3
Northern pipefish	188	579	767	2.2
Rainbow smelt	545	213	758	2.2
Herrings	514	231	745	2.1
Other selected species:				
Cunner	32	342	374	1.1
Atlantic cod	58	119	177	0.5
Atlantic mackerel	0	0	0	-
Other fishes	1191	1409	2600	7.4

Table 10. Comparison of fish impingement at Seabrook Station with estimates from other New England power plants with marine intakes (from NAI 1996).

Station	Source Water Body	Rated Capacity (Mwe)	Nominal Cooling Water Flow ($m^3 \cdot sec^{-1}$)	Years of Study	Mean Annual Impingement	CV (%)	Range for Annual Estimates	Mean Number Impinged Per Day	Reference
Seabrook	Gulf of Maine	1,150	31.5	1995[a]	15,932	-	-	44	NAI (1996)
Maine Yankee	Montsweag Bay	855	26.6	1972-77	59,999[b]	34	31,246-73,420[b]	1,395	Evans (1978)
Pilgrim	Massachusetts Bay	670	20.3	1974-94	20,029[c]	115	1,143-87,752[c]	55	Anderson (1995)
Brayton Point 1-3	Mount Hope Bay	1,150	39.0	1972-92	54,433	136	15,957-359,394	118	MRI (1993)
Brayton Point 4	Mount Hope Bay	460	16.4	1984-85	-	-	1,479-18,095	-	LMS (1987)
Millstone 2	Long Island Sound	870	34.6	1976-87	25,927[d]	59	8,560-60,410[d]	71	NUSCO (1988)
					65,927[e]	214	8,560-511,387[e]	181	

[a] Impingement counts prior to October 1994 were underestimated.
[b] Collected in sampling only, not a calculated estimate (11.8% of the total days were sampled).
[c] Estimates adjusted assuming 100% station operation.
[d] Excluding an estimated 480,000 American sand lance taken on July 18, 1984.
[e] Including the sand lance mass impingement episode.

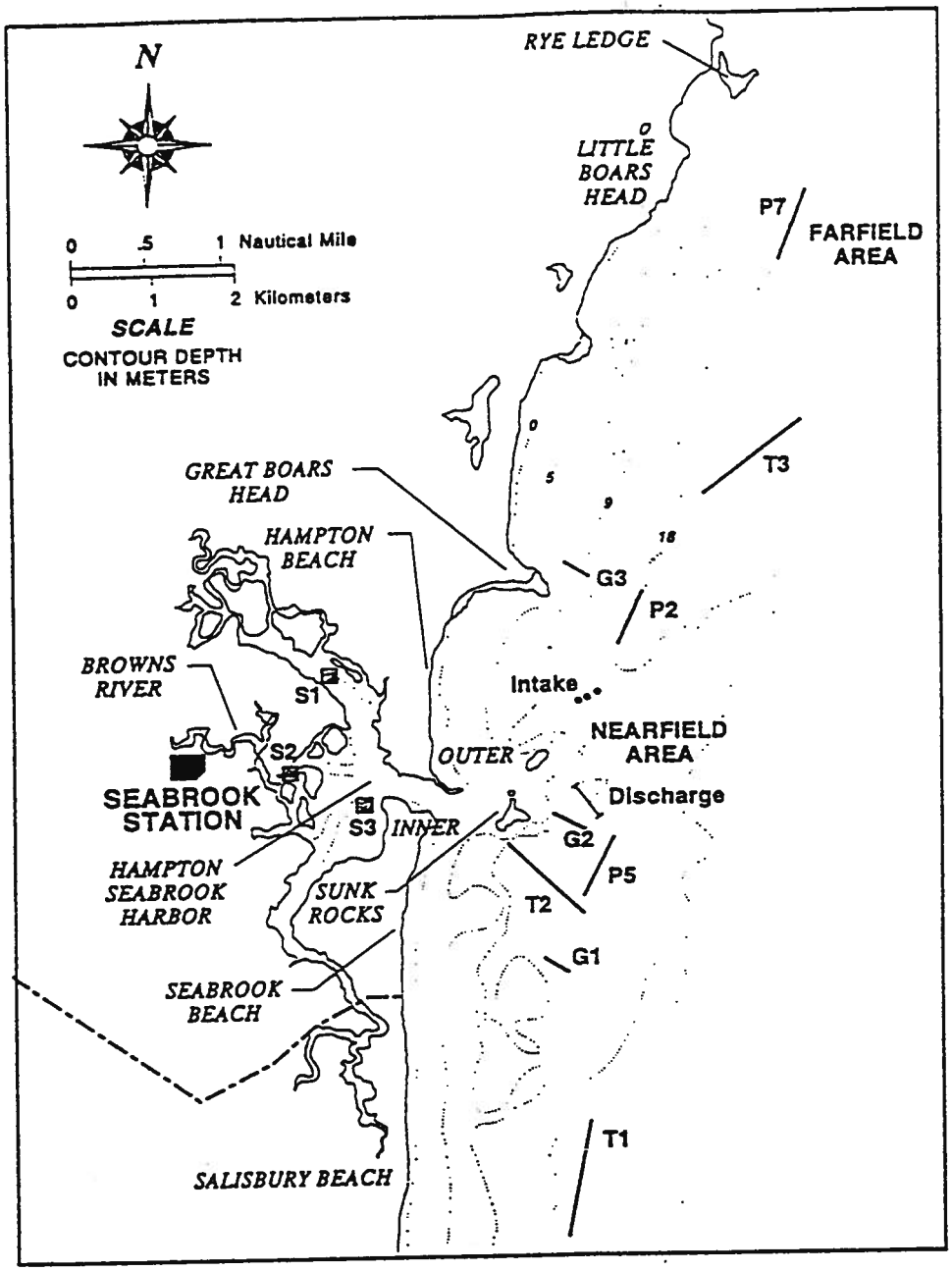
Table 11. Actual (1991-95; NAI 1996) and predicted (based on data from 1973-76; NAI 1977) entrainment of selected fish eggs and larvae at Seabrook Station with a comparison between peak monthly densities for 1973-76 and actual mean densities for the same months in 1991-95.

	Number entrained (in millions)						Peak density ($n \cdot 1000m^{-3}$)	
Species	1991	1992	1993	1994	1995	Predicted	1973-76	1991-95
Eggs:								
Atlantic menhaden	0.5	1.4	0.1	0.0	0.2	133.0	1,900	16
Pollock	0.0	0.1	0.0	0.0	0.4	133.0	780	5
Atlantic mackerel	673.1	456.3	112.9	0.0	74.5	2,665.0	37,600	12,500
Larvae:								
Atlantic menhaden	0.0	0.0	0.0	0.0	0.0	165.5	2,170	0.0
Rainbow smelt	0.0	0.1	0.0	0.0	0.0	5.5	60	0.5
Pollock	0.0	0.1	0.0	0.0	0.0	62.0	500	4.8
Atlantic mackerel	4.7	0.0	0.0	0.0	0.0	1,130.0	15,500	247.2
Winter flounder	9.0	6.2	2.9	0.0	8.0	79.0	610	80.7

Table 12. Entrainment and impingement of selected fishes at Seabrook Station as a percentage of the estimated totals collected and the predominant sampling programs in which a species was collected.

Species	% of Total Eggs Collected in Entrainment Samples	% of Total Larvae Collected in Entrainment Samples	% of Total Fish Collected in Impingment Samples	Predominant Fish Sampling Program
Presently Selected:				
Atlantic herring	-	3	-	IP[a], Gill Net
Rainbow smelt	-	-	-	Trawl, Seine
Atlantic cod	6?[b]	-	-	IP, Trawl
Pollock	6?[b]	-	7	IP, Gill Net
Hakes	6	-	14	IP, Trawl
Atlantic silverside	-	-	20	Seine
Cunner	37	9	-	IP
Am. sand lance	-	14	7	IP
Atlantic mackerel	43	-	-	IP, Gill Net
Winter flounder	-	4	7	IP, Trawl, Seine
Yellowtail flounder	-	-	3	IP, Trawl
Potentially Selected:				
Atlantic snailfish	-	23	-	
Rock gunnel	-	20	5	
Grubby	-	11	14	

[a] IP = ichthyoplankton sampling.
[b] Eggs not differentiated between Atlantic cod or pollock.



LEGEND

P = Ichthyoplankton Tows

T = Otter Trawls

G = Gill Nets

S = Seine Hauls

Figure 1. Ichthyoplankton and juvenile and adult fish sampling stations near Seabrook Station (from NAI 1996).

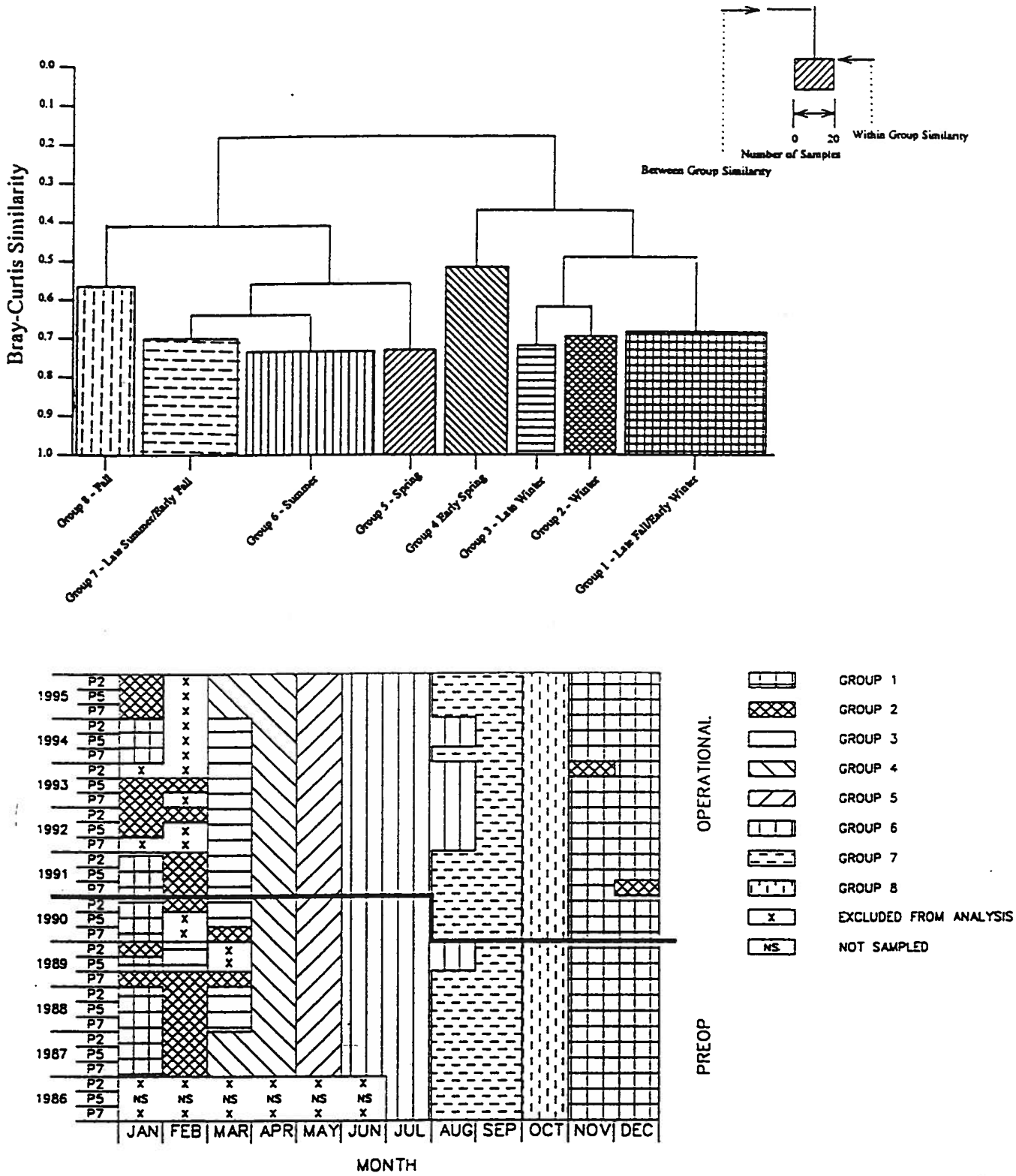


Figure 2. Dendogram and temporal/spatial occurrence pattern of fish egg assemblages formed by numerical classification of ichthyoplankton samples (monthly means of log [X+1] transformed number per 1000 m^3) at Seabrook Station nearfield (P2 and P5) and farfield (P7) stations from July 1986 through December 1995 (from NAI 1996).

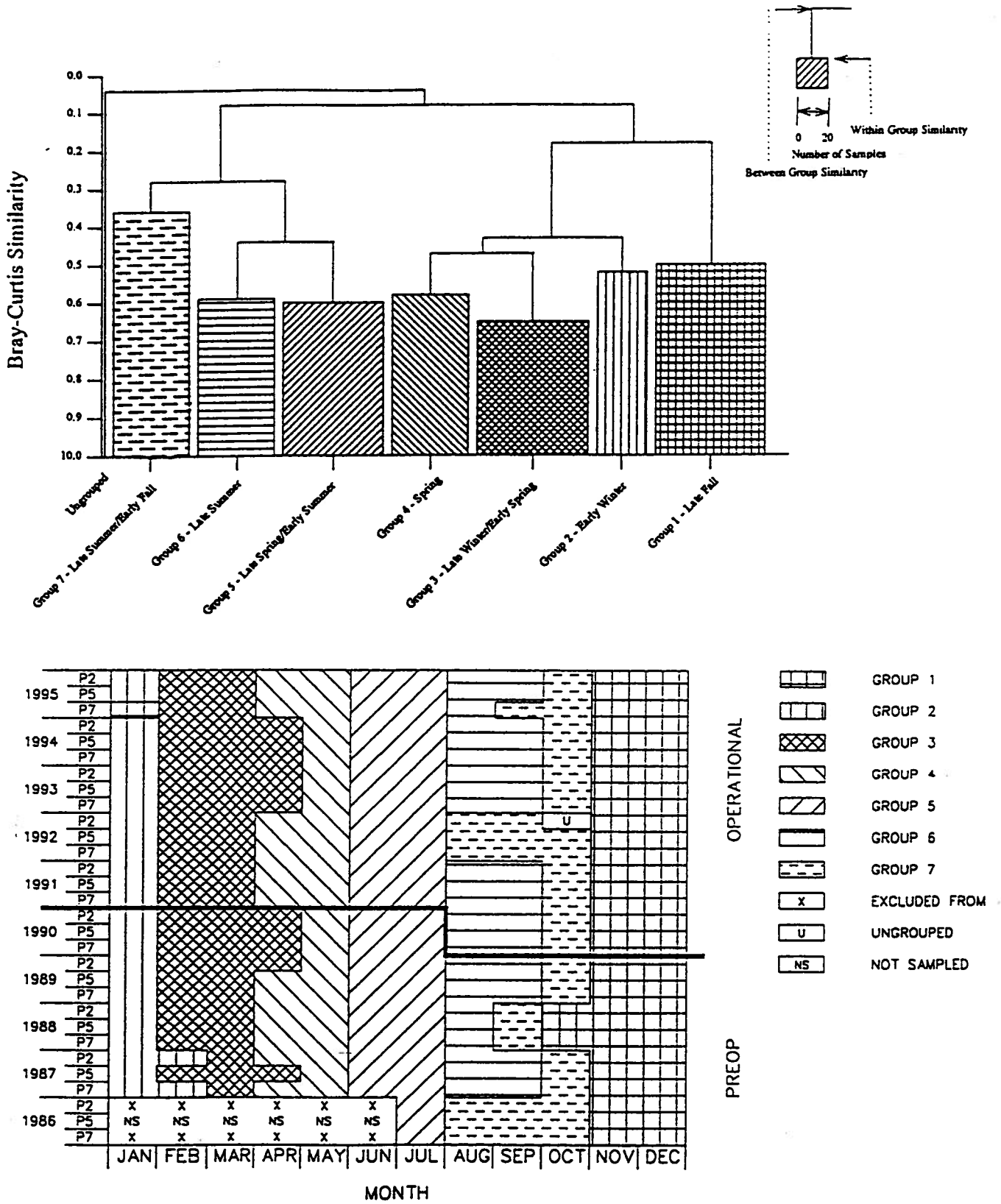


Figure 3. Dendogram and temporal/spatial occurrence pattern of fish larvae assemblages formed by numerical classification of ichthyoplankton samples (monthly means of log [X+1] transformed number per 1000 m^3) at Seabrook Station nearfield (P2 and P5) and farfield (P7) stations from July 1986 through December 1995 (from NAI 1996)

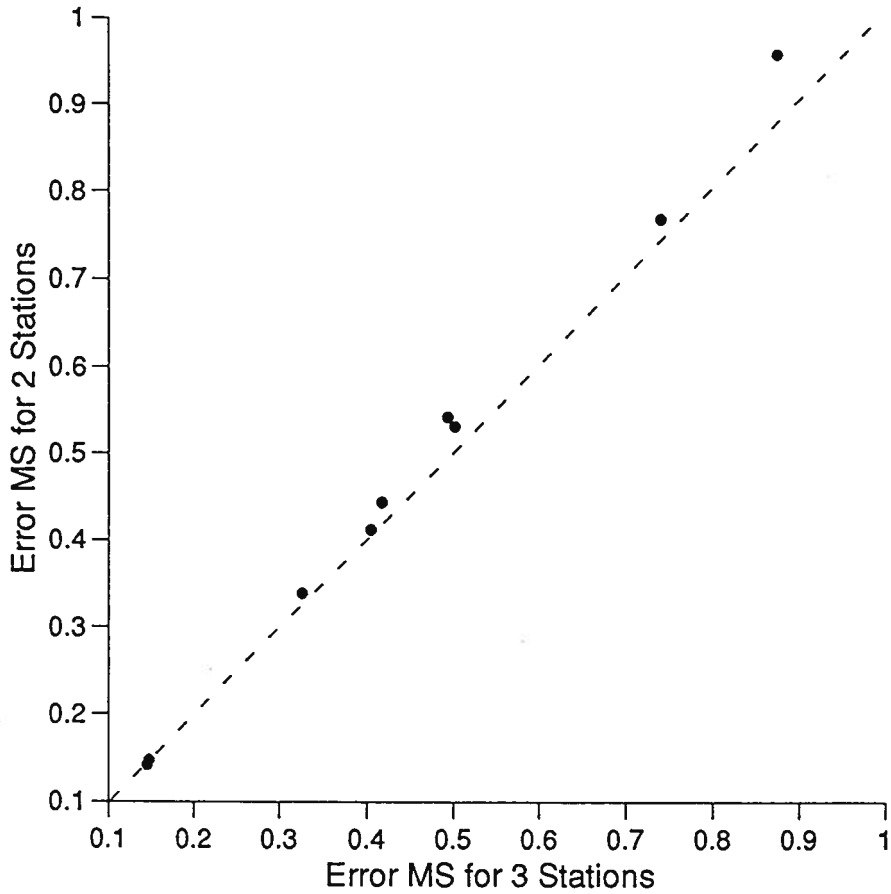


Figure 4. Comparison of the error mean squares (MS) for the nine selected larval fish taxa from two analysis of variance (ANOVA). One was based on data collected at all three ichthyoplankton stations and the other on data collected at two of the stations (P2 and P7). The dashed line represents a slope of 1.

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PHYTOPLANKTON AND CHEMICAL NUTRIENTS

Summary of the Monitoring Program after 5 Years of Operation

The objective of the phytoplankton program was to monitor the effects of Seabrook Station operation on phytoplankton, which was expected to be affected by entrainment through the plant cooling water system (through-plant entrainment) and into the thermal discharge (thermal plume entrainment). The phytoplankton sampling design was based on collections made at one farfield and two nearfield stations. In addition, concentrations of chlorophyll *a* and chemical nutrients (orthophosphate, total phosphorus, nitrate, nitrite, and ammonium) were taken along with phytoplankton abundances, as these parameters control or influence primary production. These programs have served their purpose as part of the Seabrook Station environmental monitoring studies.

1. The **phytoplankton program,** which includes enumeration of cells ≥ 10μm and the ultraplankton (cells < 10 μm), is recommended to be discontinued because after 5 years of plant operation the program has met its objective of assessing potential impact on this community. These organisms have very rapid generation times (as quick as 1-3 days) and no significant effects were detected.

    - All quantitative analyses performed indicated no impact by Seabrook Station on phytoplankton. Mean abundances of total phytoplankton and for the dominant diatom *Skeletonema costatum* were greater during the operational period than the preoperational period. The BACI ANOVA model Preop-Op X Station interaction terms were not significant, indicating no plant effects. Overall, species abundances (top 15 taxa) were not significantly different among the three stations. Nearfield-farfield comparisons of ultraplankton abundances during the operational period showed no significant differences. The concentrations of chlorophyll *a* remained consistent among periods and the ANOVA interaction term was not significant, showing that a difference found among stations (P5 > P7) was consistent, regardless of plant operation.

    - Due to the very rapid generation times of phytoplankton, it is not surprising that impacts have not been detected for this community at Seabrook Station. Rapid generation turnover rates and large reproductive capacities of these organisms enable them to compensate for high natural mortality and environmental perturbations. Because of their high thermal tolerance, thermal plume entrainment should not affect these organisms.

    - In addition, it has been well documented that other coastal marine power plants do not appreciably affect phytoplankton communities, and, as a result, their long-term phytoplankton studies have been concluded.

2. The **chemical nutrient program** indicated no significant effect of Seabrook Station operation after 5 years, and it is recommended that this sampling program be concluded. Further, there is no likely mechanism by which station operation could affect concentrations of chemical nutrients.

    - Preop-Op differences were only found for nitrite and ammonium (both with Op > Preop). No significant differences were found for the Preop-Op X Station interaction term for any of the chemical nutrients, indicating no plant effects.

    - The small volume of cooling water utilized by the station for cooling purposes compared to the total volume that passes through the nearfield area via longshore transport would make it unlikely that plant operations could affect the natural cycling of nutrients, even if a credible mechanism to do so exists.

Therefore, it is proposed that the programs for phytoplankton and chemical nutrients be discontinued because of the very high reproductive capacity of the potentially affected organisms and the lack of significant impacts found during 5 years of plant operation by the monitoring programs.

WORKING DRAFT

EVALUATION OF SEABROOK STATION
PHYTOPLANKTON AND CHEMICAL NUTRIENTS SAMPLING PROGRAMS
AFTER FIVE YEARS OF PLANT OPERATION

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Evaluation of Seabrook Station Phytoplankton and Chemical Nutrients Sampling Programs After Five Years of Plant Operation

Potential Effects of Seabrook Station Operation on Phytoplankton

Seabrook Station, located in Seabrook, New Hampshire, uses Atlantic Ocean water for condensing steam and cooling vital equipment through the service water system. The station withdrew relatively small volumes of seawater for testing various systems from July 1986 through December 1987. Low power testing with intermittent water use began in April 1990. Commercial power operation commenced on July 23, 1990, necessitating the full-scale withdrawal of cooling water and production of a heated discharge. Seabrook Station, rated at 1150 MWe, has three intake structures located about 1.3 mi offshore of Hampton Beach, New Hampshire (Fig. 1). The mid-water intakes are located about 17 ft above the bottom in depths of about 55 ft. Water is drawn through a 19-ft diameter tunnel approximately 3.25 mi long; transit time is 70 min. The current NPDES permit for Seabrook Station allows for up to 2.70 X 10^6 $m^3 \cdot day^{-1}$ (31.3 $m^3 \cdot s^{-1}$) of seawater to be used, 95% of which is for non-contact condenser cooling water and 5% for service water systems. Water used at the station is released through the onsite Discharge Transition Structure (DTS) and travels 3.1 mi through another 19-ft diameter tunnel to eleven diffusers located about 1 mi offshore of the mouth of Hampton-Seabrook Harbor at a depth of approximately 55 ft. The diffusers discharge water towards the surface at a velocity of about 15 $ft \cdot s^{-1}$. According to the NPDES permit, the average monthly rise in temperature (ΔT) at the DTS can be up to 39°F and the maximum daily ΔT cannot exceed 41°F. The rise in temperature in receiving waters cannot be greater than 5°F, except within 100 ft of the diffusers, where this limit applies only at the surface. This area is known as the near-field jet mixing region. Hydrothermal modeling and field studies demonstrated that the area of the discharge plume is relatively small. A surface temperature increase of 3°F encompassed an area of approximately 32 acres around the area of the discharge (Teyssandier et al. 1974; Padmanabhan and Hecker 1991).

Biofouling in plant structures is controlled by continuous low-level chlorination. Chlorine (as sodium hypochlorite) is injected at the offshore intakes and a concentration of 0.2 $mg \cdot L^{-1}$ is permitted at the DTS. In an evaluation after plant start-up, the chlorine residual in the effluent at the diffusers was found to be below limits of detection.

As a result of Seabrook Station operation, phytoplankton can be affected in two ways: by entrainment through the cooling water system described above and entrainment from ambient ocean water into the heated discharge plume as it rises from the bottom diffuser and mixes with surface waters. The former impact will be referred to as "through-plant entrainment" and the latter as "thermal plume entrainment" to differentiate between them in this document. From through-plant entrainment, potential damage and mortality to organisms can be induced by the rapid change in temperature within the condensers and by mechanical damage (e.g, abrasion; rapid pressure changes). The use of chlorine as a biocide in the intake system can also damage or kill entrained phytoplankton. Contact with the full-strength thermal plume at the diffuser discharges could cause mortality to some phytoplankton, although the rapid cooling of the Seabrook Station thermal plume reduces the potential severity of this effect. In addition, the thermal plume could affect mixing and vertical stratification, which can influence primary production in the ocean.

Collections of phytoplankton in the vicinity of Seabrook Station started as early as 1978 at two near-field stations to establish baseline

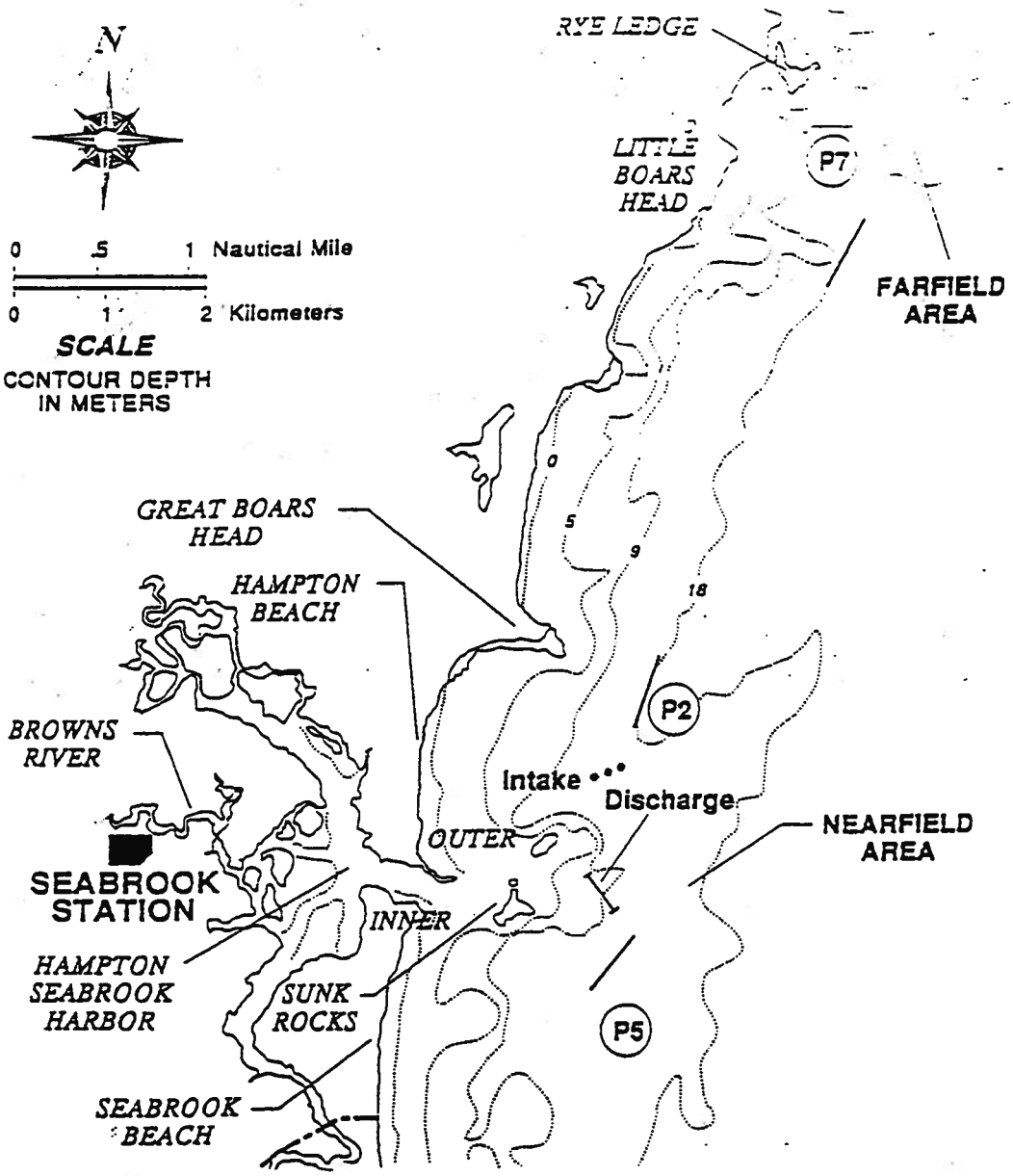

FIGURE 1. Seabrook Station and the Hampton-Seabrook study area. Phytoplankton and chemical nutrient sampling stations (P2, P5, P7) are shown along with the plant intake and discharge. (From NAI 1995).

data for future plant impact assessment studies. The collections continued with some interruptions and minor changes into the early 1980s. The initial sampling design was augmented in 1982 with the inclusion of a far-field station. Both near- and far-field stations were sampled for 6 months in 1986 and every month from April 1990 through the present. Water quality studies include the measurement of dissolved chemical nutrients (orthophosphate, total phosphorus, nitrate, nitrite, and ammonium) and chlorophyll *a* and were conducted concurrently with phytoplankton collections.

The purposes of this document are to examine the phytoplankton studies conducted at Seabrook Station, to briefly summarize the impact, if any, of this power plant on this community in the Hampton-Seabrook area, and to evaluate whether further research is

warranted. The chemical nutrients sampling program is also examined, because dissolved nutrients play a key role in determining phytoplankton community structure. A general discussion of phytoplankton and factors affecting their abundance and distribution is presented first. Following is a brief summary of the studies conducted through 1995 by Normandeau Associates, Inc. (NAI) on behalf of Public Service of New Hampshire and North Atlantic Energy Service Corporation. Recent work comparing phytoplankton and nutrient data during Seabrook Station pre-operational and operational periods is emphasized. This is followed by a summary of phytoplankton studies conducted between 1962 and 1982, mostly at ocean and estuarine electrical generating stations located on the eastern coast of the United States. Additional details of these studies are presented in an appendix. Finally, Seabrook Station phytoplankton and water quality studies are evaluated in light of the general and specific findings presented, the impact of this facility on the phytoplankton community is assessed, and the necessity for further studies is discussed.

The Role of Phytoplankton and Factors Generally Affecting Their Distribution and Abundance

Phytoplankton are microscopic floating algae that produce most of the organic matter in the sea through photosynthesis, which is limited to surface waters where sufficient light is available for plant growth. The formation of organic matter requires the use of many elements by phytoplankton, of which carbon, nitrogen, and phosphorus are of primary concern. In the case of diatoms, a class of phytoplankton that has siliceous cell walls, silicon is also important. Phytoplankton in shallow, coastal areas are either consumed by zooplankton or planktivorous fish, or sink out of the surface waters to be consumed by benthic organisms or decomposed by microbes. This results in a transfer of energy and elements to other trophic levels in both pelagic and benthic regions. The subsequent processes of consumption, respiration, excretion, and decomposition complete the cycle by regenerating basic nutrients necessary for new production of organic matter.

The phytoplanktonic community consists of a diverse group of algal species and cyanobacteria. Each species within the community is influenced by a multitude of physical, chemical and biological factors, including light intensity, distribution of growth-limiting nutrients, temperature, advection and diffusion, grazing pressure, and sinking. Some of these factors (e.g., temperature and incident light) undergo seasonal changes, while others (e.g., ambient light, essential nutrients) exhibit rapid changes within a time span of minutes, hours, or days. The result is complex and variable interactions among factors that influence the growth and reproduction of phytoplankton. In turn, these relationships determine phytoplankton species composition and spatial distribution. A brief review of some of the physical, chemical, and biological factors that control or influence the abundance and distribution of phytoplankton in the sea follows.

Light. In oceanic waters, peak absorption of light by phytoplankton occurs at depths from 20 to 40 m, and at typically low oceanic densities only 1% of the light energy reaching the surface is absorbed by phytoplankton for photosynthesis. In coastal waters, peak absorption of light occurs at depths from 2 to 4 m, and at the higher algal densities found there, 50 to 60% of incident light can be absorbed by phytoplankton. At shallower depths, suspended particulate and dissolved matter absorb the majority of light and at deeper depths, the water itself is responsible for most of the absorption (Lorenzen 1976). The depth at which minimum light intensity necessary for effective photosynthesis occurs is called the compensation depth. More precisely, the compensation depth is where metabolic gains from photosynthesis just balance metabolic losses from respiration, and the light intensity is generally thought to be

about 1% of the incident radiation, but it may be deeper (Venrick et al. 1973; Littler et al. 1985). The water column above the compensation depth is known as the euphotic zone and is usually the top 100 m for open ocean and the top 10 m for coastal waters. At low light intensities, the idealized relationship between primary production and light intensity is linear; further increases in light intensity saturate the enzymes involved in photosynthesis and a peak or plateau is reached. At still higher light intensities, like those observed at the surface, photoinhibition or a decrease in photosynthesis is observed and is thought to be caused by ultraviolet (UV) radiation (Strickland 1965). A static water column exacerbates photoinhibition near the surface because phytoplankton cells are not advected out of the range of harmful UV radiation, which can result in reduced primary production compared to a well-mixed water column (Platt and Gallegos 1980). The linear relationship between primary production and light intensity is a function of how efficiently different phytoplankton groups use light. Under similar conditions of nutrients, light adaptation, and temperature, green algae and diatoms can attain maximum photosynthesis rates at lower light levels than dinoflagellates, and therefore may be better suited to areas or depths where low light persists (Ryther 1956).

Nutrients. The production of organic matter in the sea is due primarily to phytoplankton. Primary production requires the presence and utilization of elements used in the synthesis of protein, carbohydrate, and lipid. Typically, this results in organic matter containing 50-60% protein, 30-40% carbohydrate, and 10-20% lipid. The synthesis of organic matter from the elements found in seawater results in phytoplankton with the atomic ratios of phosphorus, nitrogen, and carbon of approximately 1:16:106 (Redfield 1958).

Inorganic phosphorus is present in seawater as orthophosphate at very low concentrations (<1 μg-at PO_4-P·L^{-1}). Two factors are important in maintaining low levels of orthophosphate: adsorption onto clay particles, calcium carbonate, and oxyhydroxides (Krom and Berner 1980; Stumm and Morgan 1981), and precipitation of insoluble compounds after combining with calcium, aluminum, and iron (Valiela 1984). Although the ambient surface concentration of dissolved inorganic phosphorus (DIP) is typically less than 1 μg-at P·L^{-1}, DIP is rapidly regenerated and recycled. For example, 68 to 87% of the DIP used in surface production is regenerated above 75 m (Knauer et al. 1979), primarily by zooplankton excretion and egestion, and microbial activity. Regeneration of DIP by microbes in sediments can be significant in shallow coastal waters, providing an average of 28% of phytoplankton requirements (Fisher et al. 1982).

Inorganic nitrogen is present in seawater as nitrate (NO_3), nitrite (NO_2), ammonium (NH_4), and nitrogen gas (N_2). With the exception of N_2, nitrate is the most abundant form of dissolved inorganic nitrogen, followed by ammonium and nitrite (Parsons et al. 1984). Concentrations generally range from low values at the surface to higher concentrations in deeper waters. Typical concentrations are <1 to 25 μg-at NO_3-N·L^{-1}, 0 to 2 μg-at NH_4-N·L^{-1}, and <1 μg-at NO_2-N·L^{-1}. Decomposition of organic matter and excretion by zooplankton release into the water ammonium, which is oxidized to nitrite and then to nitrate by nitrifying bacteria. Phytoplankton preferentially use ammonium over nitrate, probably because less energy is needed to reduce its oxidation state within the cell (Conway 1977). In coastal waters, 54 to 70% of primary production is based on utilization of regenerated ammonium, while in oceanic waters, ammonium supplies 82 to 87% (Eppley and Peterson 1979).

Dissolved inorganic carbon is present in seawater in a variety of forms originating from the reaction of dissolved carbon dioxide (CO_2) with water (H_2O):

$$H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow H^+ + CO_3^=$$

Bicarbonate (HCO_3^-) is the most prevalent ion, with much lower concentrations of CO_2,

$CO_3^=$, and H_2CO_3 present. Carbon dioxide (CO_2) is removed from the water by photosynthesis and added to it by respiration. However, because of the rapid equilibria among the various chemical species, absolute proportions do not change appreciably. These same equilibria also buffer seawater within the pH range of 7.5 to 8.5.

The utilization of potentially growth-limiting nutrients, such as nitrogen, by phytoplankton can be described by a hyperbolic function where the nutrient uptake rate increases as the ambient concentration increases until an asymptote is reached and the nutrient concentration is no longer limiting to growth. Nitrogen is the principal growth-limiting nutrient in coastal (Ryther and Dunstan 1971) and oceanic waters (Thomas 1969), although phosphorus, silicon, and trace elements are also essential (Hecky and Kilham 1988; Morel et al. 1991).

Temperature. Temperature is not a primary limiting factor for phytoplankton growth in temperate regions of the oceans (Valiela 1984). It may be more important as a factor influencing photosynthetic pigments, enzymes, and carbon content (Steemann Nielsen and Jorgensen 1968), which enable cells to utilize light more efficiently at low temperature. Although higher temperatures can increase nutrient uptake and photosynthetic rates, in most temperate regions the spring bloom occurs during or near the time of coldest water temperatures. Temperature plays a more important role in stratifying the water column so that phytoplankton are retained above the compensation depth.

Growth and Distribution. The growth rates of phytoplankton allow for doubling times that range from 5 to 9 days in oceanic waters (Falkowski 1980) and from 1 to 3 days in coastal waters (Valiela 1984). Growth rate is controlled or influenced by light, availability of nutrients, and temperature, which in turn are influenced by vertical stability of the water column and regeneration of nutrients by bacteria and heterotrophic protists.

Physical, chemical, and biological processes also play key roles in determining spatial distributions of phytoplankton. Langmuir circulation is a significant cause of horizontal and vertical patchiness. Langmuir circulation cells may extend to 400 m in length, and can be several meters in diameter. Resulting flow patterns can cause accumulations of phytoplankton cells in areas of convergence between cells (Stavn 1971). Tidally generated internal waves can also result in patchiness at intermediate (10-100 m) spatial scales (Haury et al. 1978).

Because growth-limiting nutrients, such as nitrogen, influence the abundance of phytoplankton populations, diffusion and advection play important roles in supplying phytoplankton with nutrients, as do zooplankton excretion and bacterial regeneration. Zooplankton grazing pressure can have a significant impact on phytoplankton density and species composition. In laboratory tank experiments, grazing pressure reduced the diatom population, which allowed small flagellates to dominate (Ryther and Sanders 1980).

Phytoplankton sinking also affects population density and species composition. Larger cells sink faster and grow slower than smaller cells and, under stratified conditions, sinking could reduce the population density of larger species (Smayda 1970). Under stratified and low-nutrient conditions, dinoflagellates would be favored over the immobile phytoplankton groups by their ability to migrate vertically and utilize the more abundant nutrients in deeper waters with a subsequent return to the surface to photosynthesize (Blasco 1978). Also, dinoflagellates and flagellates are known to excrete substances that may adversely affect the growth of other planktonic species in the laboratory (Johnston 1963; Pratt 1966), but field evidence for allelopathy is very tenuous, even in the more restricted volumes of freshwater systems (e.g., Keating 1978).

Summary of Phytoplankton Studies at Seabrook Station Through 1995

Study design, sampling methods, treatment of data, and statistical tests for the phytoplankton sampling program are found in NAI (1991, 1995). Briefly, samples for phytoplankton and chlorophyll *a* concentration were taken 1 m below the surface at three stations (Fig. 1) using an 8-L water bottle sampler. Collections were made during the day once per month in January, February, and December, and twice monthly during the remainder of the year. Data were available for analyses from the plant discharge (station P2) from 1978 through 1984, the intake (P5) during 1978-81, and the farfield station (P7) during 1982-84. After a hiatus, samples were again taken at all three stations beginning in July 1986 for chlorophyll *a* and in April 1990 for phytoplankton, with collections continuing through the present. For analytical purposes, phytoplankton were classified into two groups: "ultraplankton" (cells <10 μm) and "phytoplankton" (cells ≥10 μm; Marshall and Cohen 1983). Although analyses were conducted primarily to examine the impact of thermal plume entrainment, through-plant entrainment effects may not be separable in the comparison of data from the intake to nearfield discharge and farfield control stations. Even though waters offshore of Seabrook-Hampton may thermally stratify to some degree from about May through October, phytoplankton cell counts did not differ greatly between near-surface and formerly collected near-bottom samples (NAI 1981). Consequently, considerable numbers of phytoplankton are entrained through the plant and discharged with the thermal plume. For impact assessment, analysis of variance (ANOVA) models (NAI 1995, 1996) were used to test the null hypothesis that spatial and temporal differences during the preoperational and operational periods were not significantly ($p>0.05$) different.

In general, phytoplankton species composition in the Seabrook area has been similar to that reported for other areas in the Gulf of Maine and the northeastern continental shelf (NAI 1993). Phytoplankton samples were dominated by diatoms (Bacillariophyceae) for 10 months of the year with abundance peaks occurring in spring and fall. *Skeletonema costatum* was a consistent numerically dominant species in all years that were sampled. Other diatoms (e.g., *Chaetoceros* spp., *Leptocylindrus* spp., *Rhizosolenia* spp., *Nitzschia* sp.) were also abundant during various periods of the year. The only other highly abundant phytoplankter was the alga *Phaeocystis pouchetii* (Prymnesiophyceae), which predominated during spring of some years, although it was absent or scarce in other years. Dinoflagellates (Dinophyceae) and *Cryptomonas* sp. (Cryptophyceae) also were occasionally numerous. Because occasional large blooms of a particular species have occurred, different taxa have dominated in various years, and no one particular year can be described as typical (NAI 1992). A multivariate analysis of variance showed that species abundances (top 15 taxa) were not significantly different among the three stations sampled (NAI 1996).

Total phytoplankton abundance at station P2 was greater during the operational period relative to preoperational abundances (NAI 1996). An ANOVA was used to compare abundances of total phytoplankton at nearfield stations P2 and P7 (Table 1). Overall, mean abundances during the operational period were significantly higher than during the preoperational period and densities at P2 were significantly greater than at P7. However, the interaction term (Preop-Op X Station) was not significant, indicating that differences among the stations were consistent, regardless of whether the plant was operating or not.

Ultraplankton have been dominated by the cyanobacteria (formerly the blue-green algae or Cyanophyceae), which accounted for 70 to 75% of the assemblage. Chlorophyceae (unicellular and flagellated green algae) and Cryptophyceae (*Chroomonas* sp.) were secondarily important. Ultraplankton abundances were highest during summer and winter. Temporal changes in ultraplankton

TABLE 1. Results of analysis of variance[a] comparing abundances of phytoplankton between stations P2 and P7 during preoperational years (1982-84) and operational years (1991-95) at Seabrook Station. (From NAI 1996).

Parameter	Source of variation	Degrees of freedom	Mean squares	F value[f]	Multiple comparisons
Total abundance of phytoplankton	Preop-Op[b]	1	1.09	34.93 ***	Op > Preop
	Year (Preop-Op)[c]	6	1.00	32.27 ***	
	Month (Year)[d]	88	0.59	19.09 ***	
	Station	1	0.17	5.61 *	P2 > P7
	Preop-Op X Station[e]	1	0.03	0.86 NS	
	Error	94	0.03		

[a] ANOVA based on mean of twice-monthly collections from March through November and monthly collections from December through February. Only years when collections at these stations were concurrent and when all 12 months were sampled were included in the model.

[b] Preoperational versus operational period, regardless of station.

[c] Year, regardless of preoperational or operational period.

[d] Month nested within year, regardless of station or year.

[e] Interaction between main effects.

[f] NS = not significant ($p \geq 0.05$)
* = significant ($0.01 \leq p < 0.05$)
*** = very highly significant ($p \leq 0.001$).

abundance were difficult to assess because of differences in methodology used over the years of study (NAI 1995). In earlier years, ultraplankton forms were only partially identified, with the picoplankton (<2.0 μm) fraction generally not identified. Beginning in the mid-1980s, efforts were made to identify smaller forms using improved techniques (e.g., phase contrast microscopy). Because ultraplankton were only enumerated in detail only during the operational period, Seabrook Station impact assessment was limited to a nearfield-farfield station comparison during years of station operation (1991-94). During this period, densities were not significantly different among the three stations (Table 2). NAI (1993, 1995) also reported that the ultraplankton forms present were similar to those reported for other areas of the Gulf of Maine during both the preoperational and operational periods (Murphy and Haugen 1985; Glover et al. 1986; Shapiro and Haugen 1988; Haugen 1991).

The abundance of the dominant diatom *Skeletonema costatum* and total phytoplankton biomass (as measured by chlorophyll *a* concentration) were chosen to be analyzed in greater detail for Seabrook Station impact assessment. Because of the dominance of *Skeletonema costatum* in the local community of phytoplankton, its spatial and temporal abundances were chosen for examination using the ANOVA model. Abundances during the 1991-95 operational period at stations P2 and P7 were significantly higher than during the 1982-84 preoperational period (Table 3). Similarly, abundances at P2 and P5 were higher after Seabrook Station began operation than during the 1979-81 preoperational period. Abundance at nearfield station P2 was significantly higher than at farfield station P7. However, no significant differences were found between the two nearfield stations (P2 and P5). The interaction term (Preop-Op X Station) was not significant in either ANOVA calculated for *Skeletonema*

TABLE 2. Results of analysis of variance comparing abundances of ultraplankton between stations P2 and P7 during operational years (1991-94) at Seabrook Station. (From NAI 1995).

Parameter	Source of variation	Degrees of freedom	Mean squares	F value[c]
Total abundance of ultraplankton	Year	3	0.25	0.67 NS
	Month (Year)[a]	44	0.35	11.13 ***
	Station	2	0.05	0.92 NS
	Year X Station[b]	6	0.06	1.82 NS
	Error	88	0.03	

[a] Month nested within year, regardless of station or year.
[b] Interaction between main effects.
[c] NS = not significant ($p \geq 0.05$)
*** = very highly significant ($p \leq 0.001$).

costatum, indicating that differences among the stations were consistent, regardless of the plant operational status.

Chlorophyll *a* concentrations were used as a measure of phytoplankton biomass, but this measure may not be directly proportional to absolute abundance (i.e., cell counts) because of variations in size and physiology between and within each species. Nevertheless, as with cell counts, chlorophyll *a* concentrations generally peaked in spring and fall, with some month-to-month variability in the timing of maximum biomass each year. Chlorophyll *a* concentrations found after the commercial operation of Seabrook Station were not significantly different from those of the most recent (1987-89) preoperational years (Table 3). Throughout the study, chlorophyll *a* concentrations were higher at nearfield station P5 than at farfield station P7, but the differences were not significant between P5 and P2 nor between P2 and P7. Furthermore, the interaction term was not significant, indicating that differences among the stations were consistent, regardless of whether the plant was operating or not.

The importance of nuisance algae in the area was defined as the toxicity levels of the alga *Alexandrium tamarense*, which is responsible for paralytic shellfish poisoning (PSP). PSP toxicity levels from blue mussels (*Mytilus edulis*) collected in Hampton Harbor were provided by the State of New Hampshire. During the preoperational period, average weekly PSP toxicity levels were above the detection limit (44 μg PSP·100g^{-1} mussel tissue) and periodically above the closure limit (then defined as 80 μg PSP·100g^{-1} mussel tissue) during late spring and early summer (NAI 1996). However, PSP toxicity was rarely found during the operational period and even then it was at levels below closure limits. Finally, the presence of PSP in the Hampton-Seabrook area was thought to be related to coastal transport from Maine rivers (Franks and Anderson 1992a, b) that occurred independently of Seabrook Station operation.

The operation of Seabrook Station has not caused detectable changes in the abundance or community structure of phytoplankton in the study area (NAI 1995, 1996). Although abundances of total phytoplankton and *Skeletonema costatum* were statistically higher in operational years than in preoperational years, this was attributed to a natural region-wide trend and not to operation of Seabrook Station. High variability in densities and changes in community structure from year to year were probably influenced by physical and chemical factors, some cyclical and some transitory. Ultraplankton abundance was similar to that found elsewhere in the Gulf of

TABLE 3. Results of analysis of variance[a] comparing abundances of *Skeletonema costatum* and chlorophyll *a* concentrations among stations P2, P5, and P7 during preoperational years (varies by test) and operational years (1991-95) at Seabrook Station. (From NAI 1996).

Parameter	Source of variation	Degrees of freedom	Mean squares	F value[f]	Multiple comparisons[g]
S. costatum	Preop-Op[b]	1	6.73	32.80 ***	Op > Preop
(Preop: 1982-84)	Year (Preop-Op)[c]	6	2.62	12.78 ***	
(P2 vs. P7)	Month (Year)[d]	88	3.05	14.87 ***	
	Station	1	1.03	5.03 *	P2 > P7
	Preop-Op X Station[e]	1	0.39	1.89 NS	
	Error	94	0.20		
S. costatum	Preop-Op	1	9.96	32.66 ***	Op > Preop
(Preop: 1979-81)	Year (Preop-Op)	6	1.80	5.66 ***	
(P2 vs. P5)	Month (Year)	87	4.41	13.85 ***	
	Station	1	0.97	3.04 NS	
	Preop-Op X Station	1	0.07	0.22 NS	
	Error	93	0.32		
Chlorophyll *a*	Preop-Op	1	0.02	0.33 NS	
(Preop: 1987-89)	Year (Preop-Op)	6	1.09	19.52 ***	
(all stations tested)	Month (Year)	88	0.84	15.06 ***	
	Station	2	0.17	3.07 *	P5 P2 P7
	Preop-Op X Station	2	0.06	1.03 NS	
	Error	188	0.06		

[a] ANOVA based on mean of twice-monthly collections from March through November and monthly collections from December through February. Only years when collections at these stations were concurrent and when all 12 months were sampled were included in the model.
[b] Preoperational versus operational period, regardless of station.
[c] Year, regardless of preoperational or operational period.
[d] Month nested within year, regardless of station or year.
[e] Interaction between main effects.
[f] NS = not significant ($p \geq 0.05$)
* = significant ($0.01 \leq p < 0.05$)
*** = very highly significant ($p \leq 0.001$).
[g] Underlining indicates no significant difference.

Maine (Murphy and Haugen 1985; Glover et al. 1986; Shapiro and Haugen 1988; Haugen 1991). Chlorophyll *a* concentrations remained similar among preoperational and operational periods and although statistically significant differences were found among stations, they were not ecologically significant. PSP levels were apparently also related to region-wide events and have not been affected by Seabrook Station operation. No differences were found in any of the ANOVA interaction terms (Preop-Op X Station), which indicated that any differences that occurred among stations were consistent, regardless of plant operational status. Thus, there has been no evidence that the operation of Seabrook Station has had any biologically significant effects on the local phytoplankton community.

Summary of Chemical Nutrient Studies at Seabrook Station

During the past 17 years, concentrations at the surface of five dissolved chemical nutrients, including orthophosphate, total phosphorus, nitrate, nitrite, and ammonium, have been measured at the three phytoplankton stations (Fig. 1), although not concurrently before mid-1986. These nutrients control or influence phytoplankton growth and were examined to evaluate the potential impact of Seabrook Station operation on their concentration, although it is unlikely that plant operation could affect levels of nutrients.

Sampling at each station followed the general methods and schedule given previously for chlorophyll *a*. Details of field collection, laboratory processing, and analytical methods may be found in NAI (1995). The ANOVA model mentioned previously in the phytoplankton section was also used to assess the effects of Seabrook Station on water quality parameters.

In general, concentrations of the five nutrients exhibited distinctive seasonal patterns. For example, nitrate-nitrogen shows a rapid decrease in concentration during the spring phytoplankton bloom to undetectable levels (<10 $\mu g \cdot L^{-1}$), which are maintained during the summer by phytoplankton utilization. Water column stratification is strongest in July and August, which prevents mixing of nutrient-rich bottom water with nutrient-poor surface water. By September, macrozooplankton populations, which have attained peak abundance, are likely excreting peak amounts of nitrogen and phosphorus. At the same time, a weakening of the vertical stratification of the water column begins to introduce limited quantities of nutrients into surface waters. These factors, with reduced grazing pressure, contribute to an October phytoplankton bloom. In late fall, declining incident radiation decreases algal growth and nutrient utilization rates. Concurrently, decomposition of organic matter, a breakdown of vertical stratification, and subsequent mixing with nutrient-rich deep waters return surface nitrate concentrations to levels (>80 $\mu g \cdot L^{-1}$) observed during the previous winter. Orthophosphate, a non-growth limiting nutrient, showed a similar, but more subdued seasonal cycle than nitrate. Orthophosphate had a fall-winter peak and a summer low, which is typical for northern temperate waters and associated with seasonal nutrient requirements of the primary producers. Ammonium, however, did not show a pronounced seasonal pattern as the other nutrients (NAI 1995).

A comparison of nutrient concentration was made between preoperational years when all three stations were monitored concurrently (1987-89) and operational years (1991-95). Although annual mean concentration of nitrate varied over a wide range from the start of the preoperational period through 1995 (Fig. 2), there were no significant differences in its concentration between preoperational and operational periods (Table 4). Concentration of both nitrite and ammonium were higher during the operational than the preoperational period. However, the Preop-Op X Station interaction term was not significant, indicating consistent differences among stations regardless of plant operation.

The mean concentrations of orthophosphate were less variable than nitrate (Fig. 3). Concentrations of orthophosphate and total phosphorus were not significantly different among stations or between preoperational and operational periods (Table 4). This suggests that plant operations have not affected the natural cycling of nutrients in the nearfield area. This is not surprising because of the small volume of water utilized for cooling purposes compared to the total volume that passes the nearfield area via longshore transport. Hydrographic studies showed that the near- and farfield areas are exposed to the same water masses (NAI 1985). Although changes in nutrient levels have been observed from year to year, these same changes have been observed in the farfield area located approximately 4.3 mi upcurrent of the nearfield area, and simply represent region-wide natural variability in nutrient concentrations.

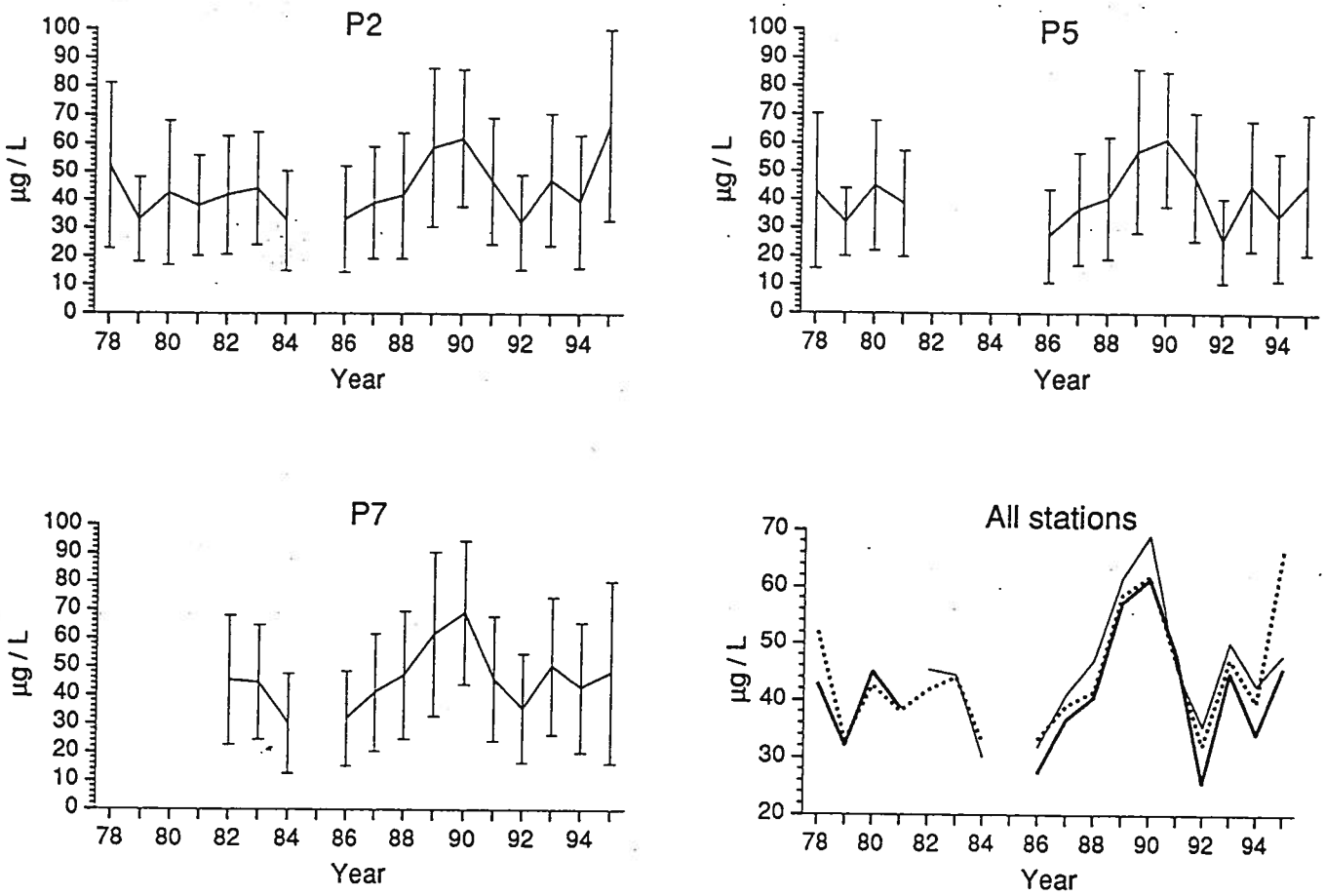

FIGURE 2. Surface nitrate-nitrogen concentrations ($\mu g \cdot L^{-1}$) at stations P2, P5, and P7. Annual means with 95% confidence interval for years sampled during 1978 through 1995 are shown for each station and annual means for each station are compared. Note that graphs for individual stations and the one for all stations combined have different scales.

Effects of Other East Coast Ocean- and Estuarine-Sited Power Plants on Phytoplankton

Historically, phytoplankton studies were included in many environmental monitoring programs, particularly during the 1970s, because no data bases were available at the time to illustrate potential effects of coastal power plant operation on phytoplankton communities. Both baseline and operational-period studies were customarily required to prepare environmental statements necessary for the licensing of power plants under various provisions of the Clean Water Act administered by the U.S. Environmental Protection Agency (YAEC 1982) and, in some cases, by Technical Specifications of the U.S. Nuclear Regulatory Commission. Consequently, there exists a wealth of information from phytoplankton studies designed specifically to address the impact of once-through cooling water systems of power plants. Many of the studies at these power plants evaluated entrained phytoplankton or populations found in discharge canals, which represent worst cases in terms of impacts.

A major component of the present Seabrook

TABLE 4. Results of analysis of variance[a] comparing the concentrations of dissolved chemical nutrients among stations P2, P5, and P7 during recent preoperational years (1987-89, except for ammonium) and operational years (1991-95) at Seabrook Station. (From NAI 1996).

Parameter	Source of variation	Degrees of freedom	Mean squares	F value[h]	Multiple comparisons[i]
Orthophosphate	Preop-Op[b,c]	1	6.93	1.26 NS	
	Year (Preop-Op)[d]	6	148.08	27.13 ***	
	Month (Year)[e]	88	237.51	43.28 ***	
	Station[f]	2	13.32	2.43 NS	
	Preop-Op X Station[g]	2	0.31	0.06 NS	
	Error	188			
Total phosphorus	Preop-Op	1	51.07	1.42 NS	
	Year (Preop-Op)	6	1987.32	55.15 ***	
	Month (Year)	87	393.65	10.92 ***	
	Station	2	65.92	1.83 NS	
	Preop-Op X Station	2	22.20	0.62 NS	
	Error	187	36.04		
Nitrate	Preop-Op	1	194.44	2.32 NS	
	Year (Preop-Op)	6	4013.64	47.92 ***	
	Month (Year)	88	10886.83	127.97 ***	
	Station	2	547.46	6.54 **	P7 P2 > P5
	Preop-Op X Station	2	119.69	1.43 NS	
	Error	188	83.76		
Nitrite	Preop-Op	1	3.65	6.26 *	Op > Preop
	Year (Preop-Op)	6	3.92	6.72 ***	
	Month (Year)	88	7.82	13.41 ***	
	Station	2	2.58	4.43 *	P7 > P2 P5
	Preop-Op X Station	2	0.65	1.12 NS	
	Error	188	0.58		
Ammonium	Preop-Op	1	348.13	39.57 ***	Op > Preop
	Year (Preop-Op)	5	1235.37	140.41 ***	
	Month (Year)	74	78.15	8.88 ***	
	Station	2	18.27	2.08 NS	
	Preop-Op X Station	2	3.52	0.40 NS	
	Error	158	8.80		

[a] ANOVA based on averaged monthly collections.
[b] Preoperational years were 1987-89 at each station, except for ammonium, which was April 1988-December 1989.
[c] Preoperational versus operational period, regardless of station.
[d] Year nested within preoperational and operational periods, regardless of station.
[e] Month nested within year nested within preoperational and operational periods, regardless of station.
[f] Station P2 versus P5 versus P7, regardless of year.
[g] Interaction between main effects.
[h] NS = not significant ($p \geq 0.05$)
* = significant ($0.01 \leq p < 0.05$)
** = highly significant ($0.01 \leq p < 0.001$)
*** = very highly significant ($p \leq 0.001$).
[i] Underlining indicates no significant difference.

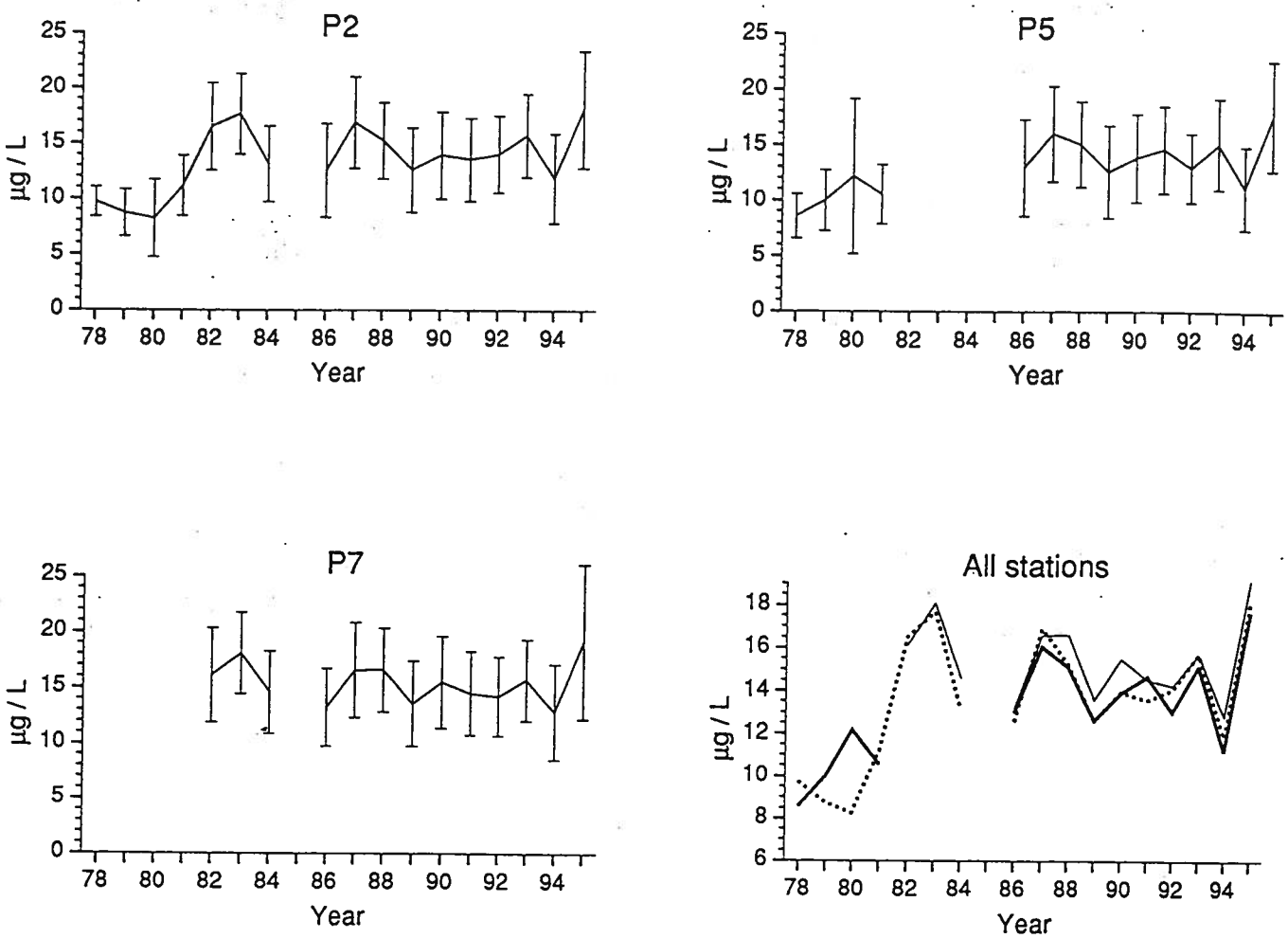

FIGURE 3. Surface orthophosphate concentrations ($\mu g \cdot L^{-1}$) at stations P2, P5, and P7. Annual means with 95% confidence interval for years sampled during 1978 through 1995 are shown for each station and annual means for each station are compared. Note that graphs for individual stations and the one for all stations combined have different scales.

Station phytoplankton and chemical nutrients evaluation was a review of the results and conclusions made following the termination of studies at other marine electrical generating facilities. Some of the studies were started and, in many cases, completed before phytoplankton studies at Seabrook Station were initiated in 1978. All phytoplankton studies at these stations were discontinued a decade or more ago (Table 5). Nearly all the studies examined were from power plants sited on the ocean or estuaries along the United States east coast in waters having diverse and abundant phytoplankton communities. The circulating water systems, discharges, and other operational aspects of the 13 power plants from which findings were examined differed in many respects from each other and from Seabrook Station. However, cooling water flows at all the stations were generally similar in magnitude, although Seabrook Station, for its size (1150 MWe), has a lower demand for cooling water (31.3 $m^3 \cdot s^{-1}$) and higher ΔT (39°F) for its

TABLE 5. Characteristics of east coast ocean- and estuarine-sited power plants and studies that provided information on phytoplankton for comparison to Seabrook Station.

Power plant	State	Number of generating units	Net generation (MWe)[a]	Cooling-water flow ($m^3 \cdot s^{-1}$)[a]	ΔT (°F)[b]	Years reported for studies of phytoplankton[c]
Crystal River	FL	2	897	43.8	11.0	1971-72
Marshall	NC	4	2136	64	18.9-36.7	1970-71
Chesterfield	VA	6	1416	43.9	18.9-27.4	1970-71
Calvert Cliffs	MD	2	1620	73	12.0	1974-81
Chalk Point	MD	2	656	30	15.0	1962-79[d]
Indian River	DE	1	347	17	11.0-12.5	1970-71
Millstone	CT	3	2680	117.7	21.4	1970-82[d]
Brayton Point	MA	4	1590	46.8	26.6	1972-76
Montaup	MA	1	500	?	18.0-23.4	1976-77
Cape Cod Canal	MA	2	1100	?	30.6-31.5	1976-77
Pilgrim	MA	1	655	20.3	29.0	1973-75
Salem	MA	4	775	26.6	17.3	1973-74
Maine Yankee	ME	1	855	26.6	28.8	1969-77[d]
Seabrook	NH	1	1150	31.3	39.0	1978-present[d]

[a] Electrical generation and nominal cooling-water flow combined for all units.
[b] Average nominal value for all units at full load or for ΔT reported at time of studies.
[c] Studies at power plants other than Seabrook Station believed to be terminated following last year given.
[d] Years during which data were collected varied; not inclusive for all aspects of these particular studies.

discharge than many of the other plants (Table 5). Brief summaries of these phytoplankton studies are provided as an appendix to this evaluation.

Many of the power plant studies had similar effects observed and final conclusions that led to the termination of the phytoplankton sampling programs. A review of completed studies (see appendix for citations) showed that impacts to phytoplankton by power plant operation were localized and of short duration. Many studies showed that primary productivity was either enhanced or was not affected until water temperatures exceeded some threshold, typically at 77°F or greater. Also, diatoms, which dominate the phytoplankton community near Seabrook Station, seemed to be less sensitive to thermal and chlorination effects than flagellates or dinoflagellates. Although cells may be killed during through-plant entrainment, particularly when chlorine is used as a biocide, several studies reported enhanced photosynthesis in discharge waters by survivors with no long-term deleterious effects to the population as a whole. Few differences in abundance, biomass, species composition, or productivity were found between discharge and control stations. Thermal plume entrainment was shown to be a transitory phenomenon with little or no mortality associated with it. In fact, exposure to moderate elevation in temperature when ambient temperatures were about 75°F or less often resulted in enhanced productivity. At higher temperatures, the rapid cooling of the thermal plume in coastal waters limited the influence of thermal plume entrainment on phytoplankton. Also, several

studies indicated that killed cells were available to grazers and decomposers within the water column and that nutrients were quickly recycled to phytoplankton. Furthermore, natural nutrient cycles were not affected by plant operation. No evidence was found that nuisance species of algae proliferated and became community dominants. Because no significant long-term changes were found in primary productivity, higher trophic levels were not affected. Because of the lack of significant power plant impacts to phytoplankton, it is not surprising that monitoring phytoplankton and chemical nutrients at other northeastern power plants has been discontinued for more than a decade.

In addition to studies done at specific coastal power plants, several reviews (Ecological Analysts, Inc. 1978; Tetra Tech, Inc. 1978; LMS 1979; YAEC 1982) also summarized relevant findings and made generalized conclusions about ocean-sited power plant impact on phytoplankton. These references noted that no long-term changes were found in species composition of phytoplankton communities as a result of power plant operation. Any compositional changes found were associated with local seasonal changes in temperature, salinity, or nutrients. No shifts towards nuisance species were ever observed. Although, in some cases, productivity was depressed by through-plant entrainment with respect to intake waters, inhibition was usually restricted to warmer months (intake temperatures >68-83°F; discharge temperatures >86°F) or was the result of chlorination. However, the quick dilution and cooling of heated discharges and rapid phytoplankton growth and reproductive rates offset the potential for large changes in phytoplankton standing crop. Any reductions in biomass or productivity were localized and transitory. Exposure to high temperatures was usually brief due to rapid thermal plume dispersion in marine waters. Thermal plume entrainment did not cause mortalities nor were there statistically significant differences found for variables when compared to control sites. The absence of wide-spread effects in the marine environment was not unexpected as coastal phytoplankton have high thermal tolerances and rapid reproductive rates. Quick dispersion and cooling of coastal thermal discharges limits phytoplankton exposure to high plume temperatures. Finally, marine phytoplankton populations are large, with short generation times, and only a small fraction is affected by power plant operation because of the relatively small amounts of water withdrawn from large open coastal water bodies that are constantly replenished by longshore transport.

Conclusions

Compared to other United States east coast power plants, Seabrook Station uses a smaller volume of cooling water (31.3 $m^3 \cdot s^{-1}$ as opposed to 57 $m^3 \cdot s^{-1}$ for the similarly-sized Millstone Nuclear Power Station Unit 3), but discharges it at a higher temperature (39°F above ambient versus 17°F for Millstone Unit 3). This design strategy was chosen to reduce the number of organisms killed from through-plant entrainment by lowering intake volume. The location and design of the eleven offshore diffusers facilitate rapid mixing and cooling of the thermal discharge with ambient ocean waters. This limits thermal plume entrainment and through-plant entrainment effects on phytoplankton. The small 3°F increase in temperature in the 32 acres surrounding the discharge is not likely to affect phytoplankton abundance or distribution. Furthermore, the discharge creates a well-mixed water column in this area, which, according to Platt and Gallegos (1980), is likely to enhance primary productivity. The offshore location means that phytoplankton cells withdrawn in the cooling water are rapidly replenished by other cells advected into the area by coastal oceanic currents. The volume of water used by Seabrook Station is exceptionally small in comparison to the volume of water that passes the intake area via longshore transport. Therefore, the fraction of the phytoplankton population affected is also quite small.

Studies of phytoplankton conducted to

determine the impact of Seabrook Station operation through its initial 5 years of operation showed significantly higher abundances of total phytoplankton and the diatom *S. costatum* during the operational period. Minimal differences were found among the three stations (two nearfield and one farfield). Where significant operational or station differences were indicated, the interaction term (Preop-Op X Station) of the ANOVAs was not significant, indicating that the differences among the stations were consistent, regardless of the plant operational status. Regardless of their length, alternative results from Seabrook Station phytoplankton studies would not be expected. This is because phytoplankton reproduction is very rapid, with generation times of 1 to 3 days in coastal waters. If any significant effects were to be observed, they should have occurred within the initial 5 years of operation.

In conclusion, through-plant and thermal plume entrainment effects have not affected the balanced indigenous population of phytoplankton in the nearshore Atlantic Ocean off Seabrook Station. Phytoplankton community structure and biomass have not changed to any measurable extent nor in such a manner as to affect higher trophic levels. Similarly, abundance and distribution of dinoflagellates causing PSP or other nuisance species have not been affected as a result of plant operation. Therefore, it is proposed that phytoplankton studies at Seabrook Station be eliminated from the Seabrook Station marine monitoring program as soon as possible. Chemical nutrient data collected are primarily linked to the production of phytoplankton. There is no likely mechanism by which the operation of Seabrook Station could affect nutrient levels. Differences found between the near- and farfield stations were minor for nitrate and nitrite and the ANOVA interaction terms were not significant, indicating that the differences among the stations were consistent, regardless of the plant operational status. Therefore, the measurement of chemical nutrients should be discontinued along with phytoplankton collections.

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APPENDIX

Summaries of Other Phytoplankton Studies

The following is a series of summaries from a review of phytoplankton studies conducted between 1962 and 1982 at thirteen electrical generating stations on the eastern coast of the United States. Most of these power plants were sited on the ocean or on estuaries. The summaries are ordered geographically from south to north, with generally increasing relevance to Seabrook Station. Operational characteristics of these plants and dates of the phytoplankton studies are given in Table 5.

Crystal River. Fox and Moyer (1973, 1975) reported on effects to phytoplankton of the Crystal River Power Plant, located in Florida on the Gulf of Mexico. They initially conducted a series of experiments designed to examine the effects of the plant's thermal discharge alone. A second set of experiments took place when the plant intakes were being chlorinated. They demonstrated that changes in primary production were related more to the ambient water temperature than to the plant-induced increase in water temperature. With a $\Delta T \geq 9°F$, decreases in productivity of 14 to 48% occurred when intake temperatures exceeded 81°F. However, in one case, when the intake temperature was 76°F, an 8% increase in productivity was found. The decreases in productivity did not necessarily indicate death of organisms, but rather a reduction in the efficiency of photosynthesis. Also, loss of some cells due to through-plant entrainment was offset by increasing rates of photosynthesis by survivors in the discharge. Primary production decreased 57% as a result of through-plant entrainment in conjunction with chlorination, but only a 13% loss in primary production occurred in the absence of chlorine. It was concluded that the number of microorganisms killed by the Crystal River Power Plant was insignificant, except when the plant was chlorinated. Nevertheless, loss of primary production from plant operation was offset by increased photosynthesis. Also, dead organisms were believed by Fox and Moyer (1973) to be rapidly recycled by decomposers that released soluble nutrients immediately available to primary producers.

Marshall, Chesterfield, and Indian River. Smith et al. (1974) described the effects of plant entrainment on phytoplankton photosynthesis at several mid-Atlantic power plants (Marshall, reservoir; Chesterfield, riverine; Indian River, estuarine). Intake and discharge samples were experimentally manipulated to distinguish irreversible effects of condenser passage from temporary photosynthetic responses to increases in temperature. Photosynthetic rates were stimulated by increases in temperature from power plant operation when ambient temperatures were low, but rates were depressed when temperatures approached ambient summer maxima. An exception occurred at the plant located on a reservoir which drew cool hypolimnetic water into its intakes; no depression in photosynthetic rate was observed. Mortality of phytoplankton from through-plant entrainment was noted only during chlorination or when intake temperatures exceeded some threshold value. These temperatures varied seasonally and geographically, but typically ranged from 77 to 86°F. Longer exposure experiments were conducted to evaluate effects of passage through a discharge canal and, consequently, gradual cooling. Low mortality was found until intake temperatures exceeded 86°F.

Calvert Cliffs. Relatively long-term ecological studies for the Calvert Cliffs Nuclear Power Plant were summarized in Heck (1987). The discharge of this plant is released along the 10-ft depth contour from a conduit about 850 ft offshore in the Maryland waters of Chesapeake Bay. Sellner and Kachur (1987a, b) presented results from an 8-year study of phytoplankton in the bay and a 5-year study of through-plant entrainment. Similar to Seabrook Station, the spring assemblages were dominated by diatoms (*Cyclotella caspia* and *Chaetoceros* spp.), summer collections by microflagellates and dinoflagellates (although 35% of the total were diatoms), and in winter, again by diatoms (*Skeletonema costatum* and *Chaetoceros* spp.). Through-plant entrainment frequently resulted in reductions of phytoplankton density and in chlorophyll *a* concentrations, particularly in summer when species of flagellates dominated the collections. Photosynthesis, as measured by oxygen evolution or ^{14}C uptake, showed significant differences between intake and discharge stations, with entrainment-induced inhibition greatest during warmer months when flagellates were most abundant and ambient water temperatures exceeded 77°F. In track autoradiography experiments with four commonly entrained

species, carbon fixation in the flagellate *Cryptomonas acuta* was significantly depressed from July through September. However, the dinoflagellate *Prorocentrum minimum* and the diatoms *Cyclotella caspia* and *Thalassionema nitzschioides* were not affected by entrainment. Furthermore, brief exposure to the thermal plume was generally non-lethal. Although through-plant entrainment apparently caused changes in cell densities (particularly for flagellates), chlorophyll *a* concentrations, and carbon fixation rates, no demonstrable effects were seen in the near-field vicinity of the plant. Sellner and Kachur (1987b) suggested that the Calvert Cliffs Plant had limited detectable effects on phytoplankton and primary productivity in the waters of Chesapeake Bay.

Chalk Point. Biological studies at the Chalk Point Steam Electric Station, located on the Patuxent River, a tributary of Chesapeake Bay in Maryland, were summarized by MMES (1985). The productivity of phytoplankton near this station was higher relative to many other estuaries due to anthropogenic sources of nutrients and algal blooms (>60-100 μg of chlorophyll $a \cdot L^{-1}$) were common. Because of the strong natural gradients in salinity and nutrients near the station, spatial changes in phytoplankton biomass and productivity were high and quantification of power plant effects was difficult to distinguish from natural events. Phytoplankton biomass as measured by chlorophyll *a* concentrations generally declined following through-plant entrainment. In 13 of 16 observations, chlorophyll *a* was higher at the plant intake than at the end of the 1.25-mi long discharge canal, with an average reduction of 20%. Much of the loss appeared to have been related to mechanical damage, although intermittent chlorination also reduced productivity. In the absence of chlorine and under reduced power production (i.e., lower ΔT), productivity was frequently enhanced. No increase in the abundance or distribution of nuisance species (e.g., blue-green algae) was found at the station. Through-plant entrainment did cause mortality of phytoplankton, but surviving cells usually recovered and reproduced before reaching the end of the discharge canal. It was concluded that entrainment-related losses (or gains) did not have consistent near-field effects on phytoplankton and Chalk Point Station's impact on phytoplankton was limited to the discharge canal. Plant operation was therefore relatively unimportant in determining phytoplankton productivity or biomass.

Indian River. Jensen et al. (1974) summarized the effects of the Indian River Station (Delaware) on phytoplankton and primary productivity. When ambient water temperatures of the Indian River estuary were ≤72°F, which was for about 8 months of the year, primary productivity was stimulated by the plant's thermal discharge. During summer, some depression of productivity occurred in the thermal plume. However, this occurred when primary production in the Indian River was at a seasonal maximum and when primary consumers (i.e., zooplankton, filter-feeding fish) were at seasonal minima. Therefore, Jensen et al. (1974) thought that a severe alteration in the energy flow to higher trophic levels was unlikely. Primary production was stimulated by plant operation when it was otherwise below annual peak levels and this occurred in conjunction with maximum populations of zooplankton and filter-feeding fish. This yielded additional food resources to higher trophic levels. They concluded that the plant did not permanently alter the photosynthetic capacity of phytoplankton in the Indian River nor did it significantly affect the ecology of the estuary.

Brooks (1974) gave additional details on the effects of phytoplankton through-plant entrainment at the Indian River Station. He described chlorophyll *a* measurements, ^{14}C uptake experiments, and cell counts. These variables tended to follow similar patterns that were related to the annual water temperature cycle. In approximately half of the samples the concentration of chlorophyll *a* was higher at the intake station than in the discharge. He suggested that chlorophyll *a* losses were

related to the presence of relatively fragile species (flagellates and naked dinoflagellates) that may have been affected by mechanical damage during plant passage. However, chlorination of cooling water reduced chlorophyll *a* concentrations by 17 to 73%. At high (>72°F) summer temperatures the 10.8-12.6°F ΔT caused lower ^{14}C uptake at the discharge relative to the intake, but during the rest of the year uptake rates were stimulated. The length of exposure to elevated temperatures in the discharge plume had little effect on ^{14}C uptake rates during cooler months, but long exposures during summer depressed uptake rates significantly. He concluded that rapid cooling to ambient temperatures after exposure to elevated temperatures minimizes the influence of power plants on phytoplankton productivity.

Millstone. The largest electrical generating facility in New England is the Millstone Nuclear Power Station, located on eastern Long Island Sound in Waterford, CT. When in operation, all three units discharge heated water into a quarry pond, where the average transit time before the effluent reaches Long Island Sound through two openings in the quarry wall is about 85 minutes. NUSCO (1983a) reported that 120 taxa of phytoplankton (about two-thirds of them diatoms) were collected in through-plant entrainment studies conducted at Millstone Units 1 and 2 from 1977 through 1980. The top ten taxa, however, comprised about 90% of the total, with various microflagellates (41%) and *Skeletonema costatum* (20%) most abundant. Diatom blooms occurred from February through April and microflagellates and dinoflagellates peaked during summer. A secondary diatom bloom was found in late August and September. Annual cycles found were characterized as typical of many northern temperate coastal areas. Carpenter et al. (1972, 1974) studied the effects of through-plant entrainment at Millstone Station with and without the additional effect of chlorination. In the absence of chlorine and at a ΔT of 23.4°F, a 25 to 40% decrease in photosynthesis (as measured by ^{14}C uptake) occurred from March through May, when ambient temperatures were 41 to 50°F. When ambient temperatures increased from 61 to 72°F, reductions of 60 to 90% were found. In fall, when intake temperatures were 48 to 65°F, a 5 to 25% increase in productivity occurred. In January and February, productivity was sometimes two to three times greater at the discharge than the intakes, although the average increase was about 25%. When plant chlorination occurred, it was found to decrease primary productivity by about 70 to 80% (Carpenter et al. 1972). However, the chemical and particulate forms of dead, entrained phytoplankton were not altered and cells did not sink or disintegrate (Carpenter et al. 1971). Therefore, dead cells were not lost as a potential source of carbon to other trophic levels. Because of the short generation time and rapid reproduction of phytoplankton, the quick dilution of the Millstone Station thermal plume in Long Island Sound, the survival of many cells following through-plant entrainment, and the availability of dead cells to other organisms, it was concluded that the operation of this plant did not have any adverse effects on the phytoplankton community (NUSCO 1976, 1983b).

Brayton Point. Brayton Point Generating Station, located on Mount Hope Bay in Massachusetts is the second-largest generating station in New England. MRI and NEPCO (1978) summarized a 5-year study of phytoplankton that was designed to examine station operation under a maximum allowed discharge temperature of 95°F. Phytoplankton abundance, number of species, diversity, growth, and photosynthetic rates were compared between observations at control stations not exposed to the thermal plume and a test station which had maximum exposure. No immediate damage was found for phytoplankton immediately following through-plant entrainment, but a slight decrease in ^{14}C uptake was found at the end of the 3,200-ft long discharge canal. Overall, exposure to elevated temperatures had little effect on

cultures of phytoplankton collected at the test and two control stations. In most cases no differences in growth were observed, or, in some instances, growth rates were higher for discharge samples. No significant differences were found in the number of species, diversity, or densities among the stations. Although somewhat variable from month to month, the ratio of the abundance of the dominant diatoms *Skeletonema costatum* and *Thalassiosira psueudonana* to total phytoplankton remained similar at test and control stations. No occurrence of nuisance species was observed as a result of the thermal effluent. MRI and NEPCO (1978) concluded that the phytoplankton populations in Mount Hope Bay were not affected by plant operation. Furthermore, no effects on higher trophic levels were expected to occur as a result of any changes to the phytoplankton population.

Montaup and Cape Cod Canal. Goldman and Quinby (1979) examined the effects of through-plant entrainment and chlorination at the Montaup and Cape Cod Canal Power Plants on phytoplankton productivity in laboratory cultures. Species found at these two electrical generating stations in Massachusetts were predominately diatoms. Although many algal cells were killed following plant passage, the survivors grew and multiplied at rates comparable to control samples. The recovery of survivors, whether measured by abundance, chlorophyll *a* concentration, or adenosine triphosphate (ATP), was similar among heated discharge, heated-chlorinated discharge, and intake samples. The only difference was a 1 to 6-day lag in recovery that occurred in some of the discharge samples. This was likely due to smaller initial numbers of cells in the culture because of entrainment mortality. Goldman and Quinby (1979) concurred with the findings of Fox and Moyer (1975), indicating minimal effects to phytoplankton, as long as entrainment temperatures are quickly lowered to ambient levels.

Pilgrim. Toner (1984) summarized phytoplankton studies completed in Cape Cod Bay relating to Pilgrim Nuclear Power Station, located near Plymouth, Massachusetts on the northwestern shore of Cape Cod Bay. Peak phytoplankton densities were found in February or March with a secondary peak in July. Seasonal lows occurred in December and January. The community was dominated by diatoms, particularly *Skeletonema costatum*, *Leptocylindrus* spp., and *Thalassiosira nordenskioldii*. Flagellates and dinoflagellates were also common, but less numerous than diatoms. Observed fluctuations in species composition and abundance were noted to have been similar to other studies done in the Gulf of Maine. No significant differences were found in species composition of phytoplankton between the plant discharge area and at offshore control stations.

MRI (1976) presented results of ^{14}C uptake experiments conducted on phytoplankton collected at Pilgrim Station. When the plant was chlorinating, a significant reduction (48-98%) was found in ^{14}C uptake on 11 of 12 occasions for phytoplankton collected at the discharge in comparison to samples taken at the plant intake. When just mechanical and thermal effects of through-plant entrainment were considered, ^{14}C uptake actually increased in most discharge samples relative to intake samples. With no thermal addition (mechanical effects only), results were equivocal as about one-half of the tests had greater uptake in discharge samples and one-half had greater uptake for the intake samples. Cultures of dominant species showed no significant long-term adverse effects from entrainment. Many of the species tested showed better growth in cultures from discharge samples than in those from intake samples. It was concluded that Pilgrim Station operation did not appreciably affect local phytoplankton populations and, subsequently, studies were discontinued by the Pilgrim Nuclear Power Station Technical-Advisory Committee (BECO 1976).

Salem Harbor. Phytoplankton biomass and seasonal fluctuations in ATP, ^{14}C uptake, and chlorophyll *a* concentrations were observed by Anderson et al. (1975) at the Salem Harbor Generating Station in Massachusetts to predict effects of the operation of a fourth generating unit. Results showed no significant differences in ATP levels or in primary productivity among intake, discharge, and control stations. The seasonal pattern of chlorophyll *a* appeared to follow that of other temperate estuaries. They concluded that little mortality of phytoplankton occurred from through-plant entrainment and that operation of Salem Harbor Unit 4 apparently had little effect on the local phytoplankton population.

Maine Yankee. The Maine Yankee Nuclear Generating Station is located in Wiscasset, Maine on the western shore of Montsweag Bay, off the Gulf of Maine. The thermal effluent is discharged through a 44-ft deep mid-channel diffuser in the bay. The two 500-ft long diffuser pipes result in high speed jets (12.8 $ft \cdot s^{-1}$) of heated water that rapidly entrain and mix with ambient water. Lindsay et al. (1978) reported on a 5-year study of through-plant entrained phytoplankton. A late spring to mid-summer bloom typically was found, with lowest abundance in winter. Of all taxa collected, *Chaetoceros* spp. was the most abundant, with *Skeletonema costatum* also commonly collected. Overall, mortality of through-plant entrained phytoplankton was slight when discharge temperatures were low, but during summer increased mortality was observed. *Chaetoceros* spp. were most sensitive and 24-hour survival following entrainment was found to have been inversely correlated with discharge temperature. Generally, survival of *Chaetoceros* exceeded 75%, but nearly 100% mortality occurred when discharge temperatures exceeded 84°F. Because high survival rates were found in samples when there was no thermal output from the plant, most mortality was probably heat-related. Crippen (1974) found that the thermal tolerance of *Chaetoceros* depended upon the species (25 were reported in Montsweag Bay by McAlice and Jones 1978). *S. costatum* had nearly 100% survival following through-plant entrainment, even when discharge temperatures exceeded 86°F. Crippen (1974) reported that this diatom, when grown at 77°F, was not affected by a ΔT of 25°F; cultures held at 68°F were affected by this temperature change, but were able to recover. Lindsay et al. (1978) cited other studies (Matsue 1954; Hirayama and Hirano 1970) which demonstrated that *S. costatum* was able to resist temperatures as high as 97 to 104°F. However, Briand (1975) reported that average survival of *S. costatum* was 35.5% following through-plant entrainment at a coastal California power plant, even though discharge temperatures never were greater than 88°F.

Lindsay et al. (1978) noted that one possible effect of through-plant entrainment mortality would be a gradual decline in abundance of species most sensitive to this impact, with their replacement by more hardy forms. For example, an increase in the occurrence and abundance of *Melosira numuloides* (a very heat-resistant diatom) coincided with a concurrent decrease in *Chaetoceros* spp. since the start-up of the Maine Yankee Plant. However, McAlice and Jones (1977) concluded that the changes observed in species abundance were within limits of annual variability. Other species, including *S. costatum*, remained at relatively similar levels of abundance during the study.

McAlice and Jones (1978) assessed the effect of the operation of the Maine Yankee Nuclear Generating Station on species composition, abundance, and distribution of phytoplankton populations at five stations located throughout Montsweag Bay. Twenty species were chosen for analysis from the 290 taxa collected. They found that the bay was not warmed by the thermal discharge from the plant. No significant changes occurred in mean cell densities or in species diversity as a result of power plant operation. Through-plant entrainment effects appeared to be minimal and the heated effluent did not have direct effects on phytoplankton. Lindsay et al.

(1978) also noted that because of the relatively small amounts of water withdrawn from Montsweag Bay in comparison to its volume and tidal prism and because of the rapidity of phytoplankton reproduction (conservatively, one division every 2 days), the impact of through-plant entrainment at the Maine Yankee plant appeared to be slight. In addition to the phytoplankton studies, McAlice et al. (1978) concluded after an 8-year study of water quality at the Maine Yankee Nuclear Generating Station that the operation of that plant had no detectable effects on the spatial or seasonal distribution of nutrients (nitrate, phosphate, silicate).

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The Northeast Utilities System

November 21, 1997

NPDES Permit No. NH0020338
NYE-97036

AR #97027946

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Seabrook Station
Kelp Evaluation and Study Plan

North Atlantic Energy Service Corporation (North Atlantic) provides herein "An Evaluation of Kelp Communities in the Hampton-Seabrook Area," (Enclosure) as was committed to in the November 6, 1997, Seabrook Station Technical Advisory Committee Meeting and the Revised Long-Term Environmental Monitoring Program.[1] The evaluation concludes that recent declines in the kelp species, *Laminaria digitata*, are not likely caused by Seabrook Station. The exact environmental factor or factors responsible for the decline have not been identified. Therefore, North Atlantic will conduct a one-year special study to collect the physical data related to potential impact mechanisms (i.e. temperature and turbidity increases).

To characterize temperature conditions, North Atlantic shall deploy remote continuous temperature data loggers throughout the year at kelp sites (B17/B35 and B19/B31). Two replicate temperature data loggers would be deployed at each station.

Potential turbidity effects in the nearfield area will also be assessed with remote data loggers. Continuous turbidity data loggers shall be deployed near the bottom at mid-depth stations B19 and B31 for one month during a period of historically high phytoplankton abundance.

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1 Letter dated November 20, 1997 from J. Hart (North Atlantic) to C. Deloi (EPA) and E. Schmidt (NHDES), "Revised Long-Term Environmental Monitoring Program."

Following analysis and review of the special study results from 1998, the results will be presented to the Technical Advisory Committee.

If you have additional questions, please contact me at (603) 773-7762.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

cc (with attachment)

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ENCLOSURE 1 TO NYE-97036

An Evaluation of Kelp Communities in the Hampton-Seabrook Area

Introduction

Several kelp species form extensive canopies over many subtidal hard substrate habitats in the Gulf of Maine, including the Hampton-Seabrook area. Kelp are an important component of macrobenthic communities because they are highly productive (Mann 1973) and provide habitat for a variety of other species, including invertebrates and other seaweeds (Sebens 1986; Witman 1987; Ojeda and Dearborn 1991). Because of their ecological importance, and their proximity to the Seabrook Station intake and discharge structures, kelp have been monitored as part of the marine macrobenthos studies since 1978 to determine if power plant operations have had any effect on nearby populations. Kelp populations are monitored using a non-destructive transect study (NAI 1997) conducted in two depth zones (Fig. 1). The shallow subtidal stations (B17 and B35; 4-8 m depth) were established to monitor possible thermal plume effects. The mid-depth stations (B19 and B31; 9-12 m depth) were established in deeper water to monitor possible effects of increased turbidity and sedimentation (i.e., 'detrital rain' from entrained plankton).

More than 20 years of marine macrobenthos studies, including 7 years of Seabrook operation, have documented that balanced indigenous communities continue to thrive on subtidal rocky habitats near the Seabrook discharge, with little change beyond that expected from natural variability (NAI 1997). A possible exception to this generalization that has become an issue of concern is the decline of the kelp *Laminaria digitata* in the nearfield area, particularly at mid-depth station B19. The purpose of this report is to address these concerns by providing: 1) detailed analyses of historical data collected to date; 2) a review of current literature on the status of kelp populations and subtidal communities in the Gulf of Maine and nearby areas; and 3) if necessary, recommendations for additional studies to answer any remaining questions regarding changes in local kelp populations.

Review of Historical Data

Kelp densities have been monitored in the Hampton-Seabrook area since 1978, and preoperational/operational period trends have been assessed annually in the annual Seabrook Environmental Monitoring Reports (e.g., NAI 1997) using analysis of variance (ANOVA). While overall conclusions based on these analyses indicate that balanced indigenous communities continue to occupy subtidal habitats near the Seabrook discharge, there has been a decline in the kelp *Laminaria digitata* in recent study years (NAI 1997). Specifically, the significant interaction term of the ANOVA model applied to shallow subtidal data indicated a decline of *L. digitata* at nearfield station B17 in the operational period relative to the preoperational period, while no difference between periods was detected at farfield station B35. *L. digitata* densities also declined at both nearfield (B19) and farfield (B31) mid-depth stations, but to a greater extent at the nearfield station, resulting in a significant interaction term of the ANOVA model. Possible mechanisms affecting local kelp populations, such as power plant impact, sea urchin grazing, storms and competition, were considered in NAI (1997), but conclusions indicated that, based on analyses presented, factors responsible for the observed decline of *L. digitata* remained unclear.

Additional analyses, presented below, were undertaken to further investigate possible causes for changes in local kelp communities. Complete time-series of annual mean densities (plants/m^2) of all kelp species are presented for mid-depth and shallow subtidal stations in Figures 2 and 3, respectively. At mid-depth stations, *Agarum clathratum* and *L. digitata* form most of the canopy along with small amounts of *Alaria esculenta* and *L. saccharina*. *A. clathratum* is the clear dominant at nearfield B19, with densities typically fluctuating between 5 to 11 plants/m^2 over the study period (Fig. 2). Trend analysis of annual *A. clathratum* densities at B19 indicated no significant trend over the study period. *L. digitata* was considerably less abundant at B19. Annual mean densities were generally around 1 plant/m^2 from 1978 to 1987, increased to nearly 4 plants/m^2 in 1988, then steadily declined to about 0.2 plants/m^2 in 1992 and have remained at that level through 1996. Trend analysis performed on annual *L. digitata* mean densities did not reveal a

significant trend over the entire time series. At the farfield station (B31), kelp dominance alternated between *A. clathratum* and *L. digitata*. *A. clathratum* densities at B31 were generally lower than at B19, typically ranging from 2 to 6 plants/m^2 from 1978 to 1993, but increasing to nearly 9 plants/m^2 in 1994 and remaining high thereafter. Despite the increase in recent years, trend analysis indicated no significant trend over the complete time series for *A. clathratum* density at B31. Conversely, *L. digitata* densities were higher at B31 than at B19. Highest densities were observed in early study years (up to 8 plants/m^2), but have declined since that time to less than 2 plants/m^2. Trend analysis indicated that the decline of *L. digitata* at B31 since 1978 was significant (slope=-0.345 plants/m^2/yr; $p<0.01$).

Kelp communities at shallow subtidal stations are almost entirely dominated by *Laminaria saccharina* and *L. digitata* (Fig. 3). At B17 in the nearfield area, *L. saccharina* was generally most abundant with annual mean densities exceeding 8 plants/m^2 in the first study year (1979), but mostly fluctuating between 1 and 5 plants/m^2. Densities of *L. digitata* were also highest at B17 during early study years (2-4 plants/m^2 during 1979-1984), but were around 1 plant/m^2 or less after that period. Trend analysis indicated a significant decline in annual *L. digitata* densities at B17 since 1979 (slope=-0.054 plants/m^2/yr; $p<0.01$). *Laminaria* spp. densities at the farfield station (B35), monitored since 1982, were similar to those at B17. *L. saccharina* was dominant during most study years at B35, with densities fluctuating between 2 and 5 plants/m^2. As with B17, *L. digitata* densities were highest in early study years (~3 plants/m^2), but gradually declined to 1 plant/m^2 by 1996. This decline was significant, based on trend analysis (slope=-0.180 plants/m^2/yr; $p<0.05$).

Laminaria digitata trends were also examined using mean percent-cover for each sampling period (April, July and October) since 1985, and compared to adult sea urchin (*Strongylocentrotus droebachiensis*) densities (no./m^2) over that same time period. In both mid-depth (Fig. 4) and shallow subtidal (Fig. 5) zones, *L. digitata* percent-cover trends closely followed trends described above for species density. Cover was as high as 40% during peak years (1988-90) at B19, but has been ≤3% since 1991. Urchin densities were low (<1/m^2) during 1985-1991, but increased after that (during the operational period) and peaked to nearly 10/m^2 by 1994. At B31, *L. digitata* cover was highest in

1985 (~60%), but decreased over the study period to <10% during the most recent study years. Urchin density trends at B31 were similar those observed at B19; urchins were not abundant until 1993-1995, when densities were as high as 20/m^2.

Laminaria digitata cover was lower at shallow subtidal stations (≤30%; Fig. 5), and exhibited moderate declines similar to those observed for plant density. Urchin densities were also lower than those observed at mid-depth stations, generally less than 1/m^2. Short-term increases in density were observed at near- and farfield stations; 4 urchins/m^2 were observed at B17 in 1985, and 6/m^2 during 1994 at B35, the latter peak coinciding with urchin increases observed at mid-depths stations.

Kelp communities were also assessed by examining time-series of annual densities of all kelp species combined (Fig. 6). At shallow subtidal stations, kelp densities were highest during the early study period, and were as high as 13 plants/m^2 at B17 (1979) and 9 plants/m^2 at B35 (1982). Total kelp densities generally declined at both stations to about 3-4 plants/m^2 by 1996. Kelp densities were higher at mid-depth stations; peak densities were 17 plants/m^2 at B31 (1980) and 15 plants/m^2 at B19 (1988). For the most part, total kelp densities at B19 and B31 followed similar trends over the study period, with the exception of 1987-91 when B19 densities increased while densities at B31 fluctuated little. This was largely due to increases in both *Laminaria digitata* and *Agarum clathratum* at B19 during that time (Fig. 2).

Discussion

Kelp community dynamics are controlled by complex interactions of physical and biological mechanisms which determine spatial and temporal patterns of distribution and community composition. Many of these mechanisms are natural (e.g., temperature, depth and available light, water movement, storm disturbance, grazing and predation, and competition; Kain 1979, Dayton 1985). However, in coastal areas, anthropogenic effects including pollution (Axelsson and Axelsson 1987; Yarish et al 1990; Schroeter et al. 1993; Reed et al. 1994; Reed and Lewis 1994), introduced species (Berman et al. 1992; Lambert et al. 1992; L. Harris (unpublished)), and indirectly, overexploitation of

commercial fisheries (Breen and Mann 1976; Elner and Vadas 1990; Vadas and Steneck 1995) must also be considered. In the case of Seabrook Station, the primary objective of kelp monitoring studies is to determine if changes in kelp communities in the nearfield area are related to impacts from the plant condenser cooling water discharge. Given this objective, the impact mechanisms and possible effects of this discharge on local kelp populations will be considered first below, followed by discussion of recent scientific literature about other mechanisms unrelated to Seabrook operation that may be affecting local kelp community dynamics.

Potential Power Plant Effects

The type of impact a community is vulnerable to is dependent upon its relative position in the water column (e.g., temperature effects for shallow water sites, turbidity effects at deeper water sites). The nearfield sampling site used for the Seabrook shallow subtidal kelp studies (B17) was selected because it occurs within, and best represents, the shallow water communities that are most susceptible to incursion by the Seabrook Station discharge thermal plume. Hydrodynamic modeling, conducted prior to plant start-up to predict the areal extent of the thermal plume under various meteorological and current regimes, indicated that thermal incursion to this site would be minimal, with temperature increases of <1°C (Teyssandier et al. 1974). Subsequent field studies after Seabrook began commercial operation verified this prediction by measuring temperature increases of <1°C at the shallow subtidal site (Padmanabhan and Hecker 1991). Long-term temperature data measured directly at station B17 are lacking, however. Even so, based on plume studies it is unlikely that this low level of thermal incursion is stressful to *L. digitata*, given the typical ambient temperature maxima of 13-14°C at the bottom and 17-19°C at the surface (NAI 1997). Kain (1979) and tom Dieck (1992) noted optimal growing temperatures of 10-17 °C for *L. digitata*, with no growth reduction occurring until temperatures reached 20-21°C. In laboratory culture experiments, Bolton and Lüning (1982) had similar results, and further noted that 22-23°C was the maximum survival temperature for gametophytes.

Another possible impact resulting from operation of coastal nuclear power plants is related more to altered water circulation patterns than to thermal incursion. Specifically, the

introduction (discharge) of turbid water to an area of historically lower levels of turbidity can decrease light penetration and increase sedimentation rates. Possible sources of this turbidity include suspended inorganic and organic particles, if intakes are located in more turbid waters, and potentially, increased detrital deposition resulting from settlement of entrained organisms. Higher sedimentation rates (and impacts to nearby macrobenthic communities) associated with a thermal effluent were evident in the operation of a nuclear power plant in California (Osman et al. 1981; Schroeter et al. 1993). Here, the major source of turbidity was fine inorganic sediments transported from inshore waters where plant intakes were located. The organic component of these sediments contributed little to the overall flux of sediments, and organic enrichment was not observed at sites near the discharge.

The Seabrook intake is located about 2 km offshore, 5 meters above the seafloor, and thus draws in relatively low turbidity water, similar to that near the discharge. Therefore, transport of fine inorganic particles is unlikely and any increase in sedimentation would be the result of settlement of organic material from entrained organisms. However, this type of impact has never been documented for any coastal power plant. As such, organic loading near Seabrook discharge appears unlikely and has not been evidenced during the operational period. In addition, the stability of all other algal and faunal species and community parameters monitored in the nearfield area over the last 19 years (NAI 1997) further demonstrates that turbidity-related impacts are not occurring, and therefore not responsible for the decline of *Laminaria digitata*.

Effects Unrelated to Seabrook Operation

Over the last several decades, increased grazing activities by the green sea urchin, *Strongylocentrotus droebachiensis,* has been shown to have considerable influence on kelp community structure in the northwest Atlantic (Chapman and Johnson 1990). Locally dense aggregates of sea urchins in the subtidal zone can preferentially eliminate populations of foliose algae (Breen and Mann 1976; Novaczek and McLachlan 1986; Johnson and Mann 1988). What remains after severe grazing is a barren ground of primarily crustose coralline algae. Urchin dominated barren grounds extend over wide

areas throughout the northwest Atlantic, including the Gulf of Maine and coastal New Hampshire (Sebens 1985; Witman 1985).

While barren grounds have not been observed at Seabrook study sites, urchin densities have increased during the operational period and the concomitant decline of *Laminaria digitata* may be related to these increases. Urchin densities of 2-10/m^2, similar to those observed during the operational period at mid-depth stations (Fig. 4) have resulted in overgrazing of kelps (Wharton and Mann 1981). Urchins preferentially graze on *L. digitata* over other foliose algae, while the other dominant kelp in the mid-depth zone, *Agarum clathratum*, is the least preferred (Larson et al. 1980; Keats et al. 1982; Himmelman et al. 1983; Himmelman and Nédélec 1990). Kelp community changes in the Seabrook study area (i.e., *L. digitata* decrease, with maintenance or increase of *Agarum* canopy) are consistent with changes observed elsewhere attributed to moderate levels of urchin grazing (Miller 1985; Keats et al. 1990).

Urchin grazing may also explain the sharper decline of *L. digitata* at the nearfield mid-depth station B19 relative to B31 in the farfield area. Urchin grazing can determine the lower depth limit of kelps. Miller (1985) found that *L. digitata* was limited to shallower depths (<10 m) when urchins were present, but was found as deep as 12 m in areas without urchins. *Agarum clathratum* had a similar distribution with or without urchins. Similarly, at nearby Isles of Shoals off the New Hampshire coast, Witman (1987) found that kelps (including *L. digitata*) were abundant at depths of 4-8 m and declined sharply to 11-12 m prior to urchin removal, but extended to >12 m following removal of urchin fronts. The nearfield mid-depth study site B19 is deeper than the farfield study site B31 (12 m versus 9 m). Therefore, it is likely that the *L. digitata* population at B19 was near the depth limit for this species prior to urchin increases, and more susceptible to grazing effects from moderate increases in urchin density observed in the study area during the operational period. Furthermore, conditions near the depth limit for this species may slow recovery by reducing recruitment and growth relative to shallower areas.

Another grazer, the gastropod *Lacuna vincta,* can also reduce kelp canopy (Kain 1979; Johnson and Mann 1986; Johnson and Mann 1988) and retard recovery through infestation of young kelp (Miller 1985). *Lacuna* densities in destructive samples near kelp study sites increased during the operational period by 50 to 100%, relative to

preoperational years (NAI 1997). New Hampshire algal stands, including populations of *Laminaria digitata* and *L. saccharina,* were virtually destroyed by *Lacuna* during the early 1970s (Fralick et al. 1974). In another New Hampshire study, Witman (1987) suggested that *Lacuna* grazing was an important cause of juvenile mortality and may also increase the vulnerability of kelp to storm defoliation.

Storms, even without grazing damage, are another important mechanism causing kelp mortality (Kitchings 1937; Dayton 1985; Chapman and Johnson 1990). Large scale removal of kelps (particularly *Laminaria digitata* at B19) was noted after Hurricane Bob in 1991 (NAI 1992).

A species recently introduced to the Gulf of Maine is also thought to negatively impact kelps. The introduction and spread of the encrusting bryozoan *Membranipora membranacea* appears to have contributed to the defoliation of kelp beds (*Laminaria saccharina* and *L. digitata*) at Cape Neddick in York, Maine by making lamina more brittle and more likely to break during storms (Berman et al. 1992; Lambert et al. 1992).

Competitive exclusion of *Laminaria digitata* by other species may be related to successional community developement under the new environmental regime created by mechanisms described above (e.g., increased grazing and suseptibility to storm damage), or a natural long-term cycle. A closed canopy in a perennial kelp forest can discourage recruitment (Kain 1979). In recent years, dense canopies of *Agarum* have been noted at both mid-depth stations (Figs. 2 and 3). This dominance by *Agarum* may be related to depth (at B19) or selective grazing by sea urchins (at B31). Scheibling (1986) suggested that *Agarum* canopy may limit recruitment of juvenile *Laminaria* spp. Given the longer life expectancy of *Agarum* (5-7 years vs. 2-4 years for *L. digitata*; R. Vadas, pers. comm.; Smith 1985), an established canopy could limit recruitment of other kelps for long periods of time. Additionally, red algal turfs such as those present at subtidal study sites have been shown to significantly reduce kelp recruitment (Chapman and Johnson 1990). Removal of red algal turf has been shown to enhance *L. digitata* recruitment by as much as ten times (Chapman 1984; Witman 1987).

Conclusions

Spatial and temporal kelp community characteristics in the Seabrook area are determined by complex interactions of many environmental factors. In recent years, these interactions have created conditions that resulted in a significant decline of one kelp species in particular, *Laminaria digitata*. While power plant impacts were considered in an attempt to explain observed declines, they appear unlikely for several reasons: 1) significant decline of *L. digitata* has occurred at most study sites, including both farfield stations and began prior to Seabrook start-up, suggesting an area-wide change; 2) data from physical (thermal plume studies) and biological (plankton) studies suggest that the possibility of impact (i.e., thermal plume and 'detrital rain') to nearfield study sites is remote; and 3) scientific research has documented significant changes to Gulf of Maine kelp communities brought about by ecological events unrelated to Seabrook operation (e.g., increases in sea urchin grazing and introduced species). Still, the exact environmental factor or factors responsible for the observed decline of *L. digitata* have not been identified. In any case, changes in kelp communities, whether related to power plant impacts or natural factors, have not resulted in significant changes to the remainder of the balanced indigenous macroalgal or macrofaunal communities currently monitored (NAI 1997). This stability of the understory communities is likely due to the maintenance of a dense kelp canopy, albeit of different species composition, at all kelp monitoring stations.

Recommendations

A considerable amount of biological data has been collected since 1978 to document long-term trends in macrobenthic communities in the Hampton-Seabrook area, such as those observed for kelps described above. However, relating these trends to Seabrook Station operation is difficult due to the lack of *in situ* physical data related to potential impact mechanisms (i.e., temperature and turbidity increases). To address this, a one-year special study is proposed to collect this necessary data and help determine if

Seabrook operation is affecting the physical environment at kelp monitoring stations. To characterize temperature conditions, it is recommended that remote continuous temperature data loggers be deployed throughout the year at all kelp sites (B17/B35 and B19/B31). Two replicate temperature data loggers would be deployed at each station. Potential turbidity effects in the nearfield area would also be assessed with remote data loggers. Continuous turbidity data loggers would be deployed near the bottom at mid-depth stations B19 and B31 for one month during a period of historically high phytoplankton abundance (late spring or autumn).

Following analysis and review of special study results from 1998, the need for additional work will be discussed with the Seabrook Ecological Advisory and Technical Advisory Committees.

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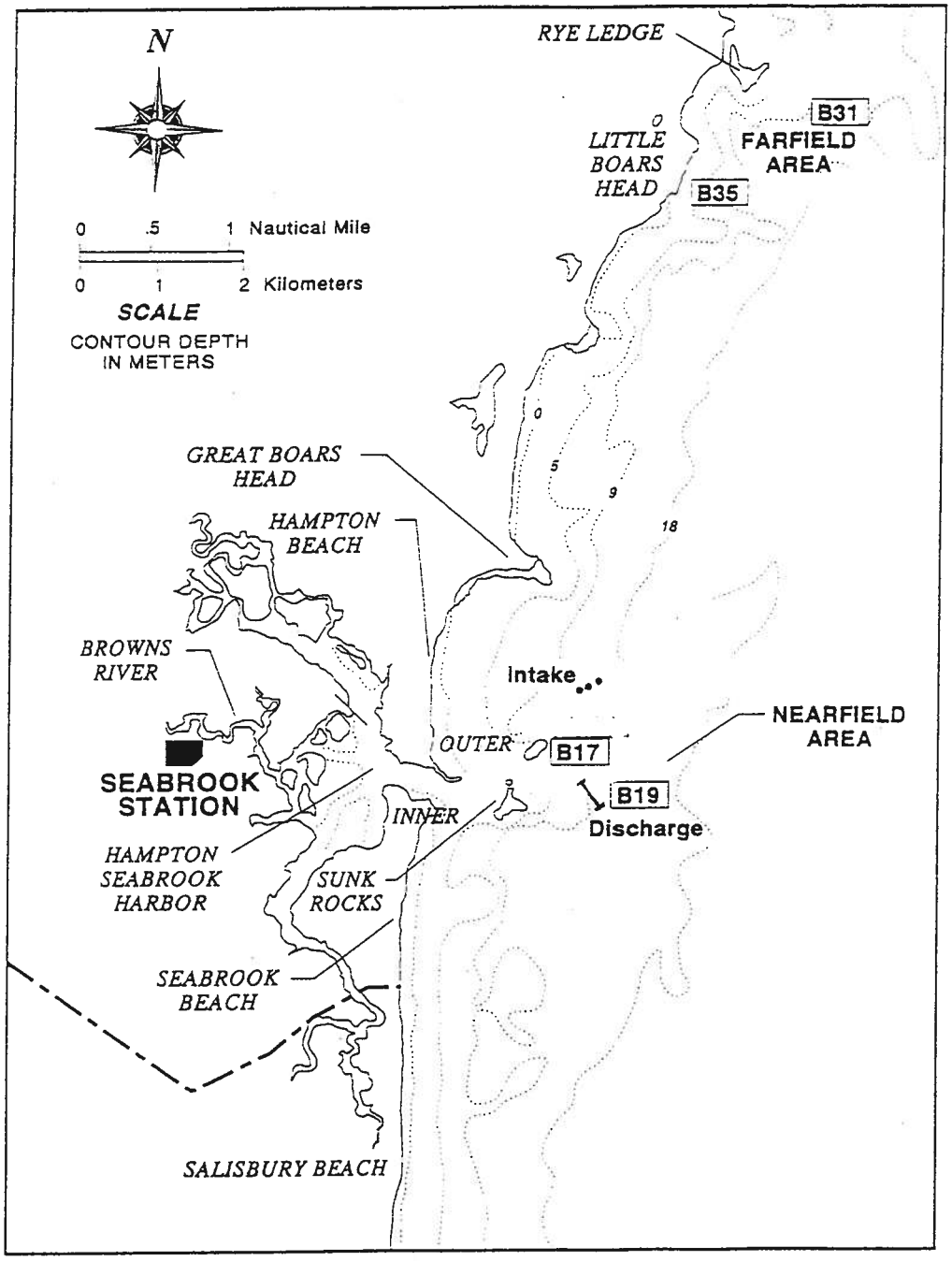


Fig. 1. Non-destructive kelp sampling stations used for Seabrook marine macrobenthos studies.

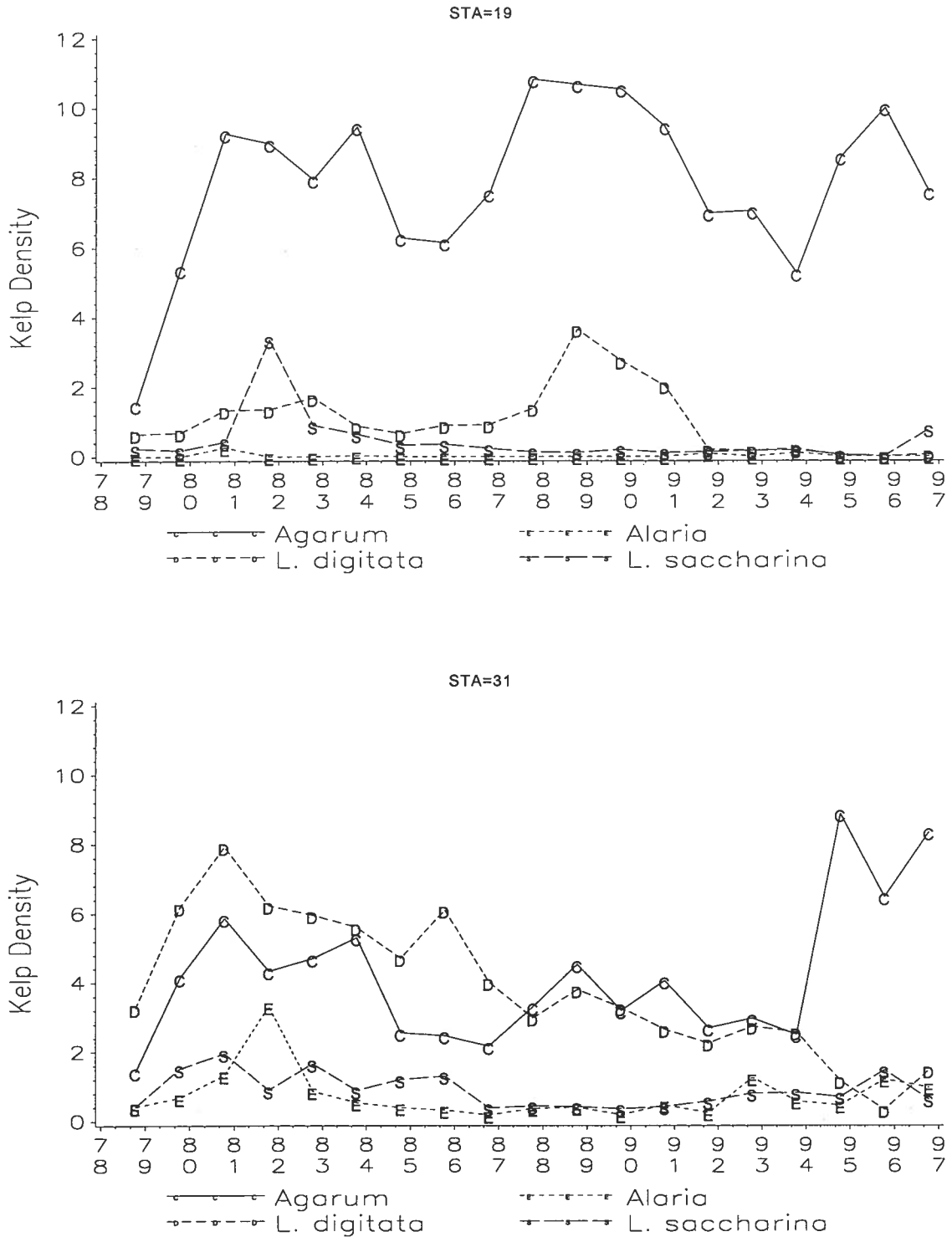


Fig. 2. Annual mean kelp densities (plants/m^2) at mid-depth stations, nearfield (B19) and farfield (B31), 1978-1996.

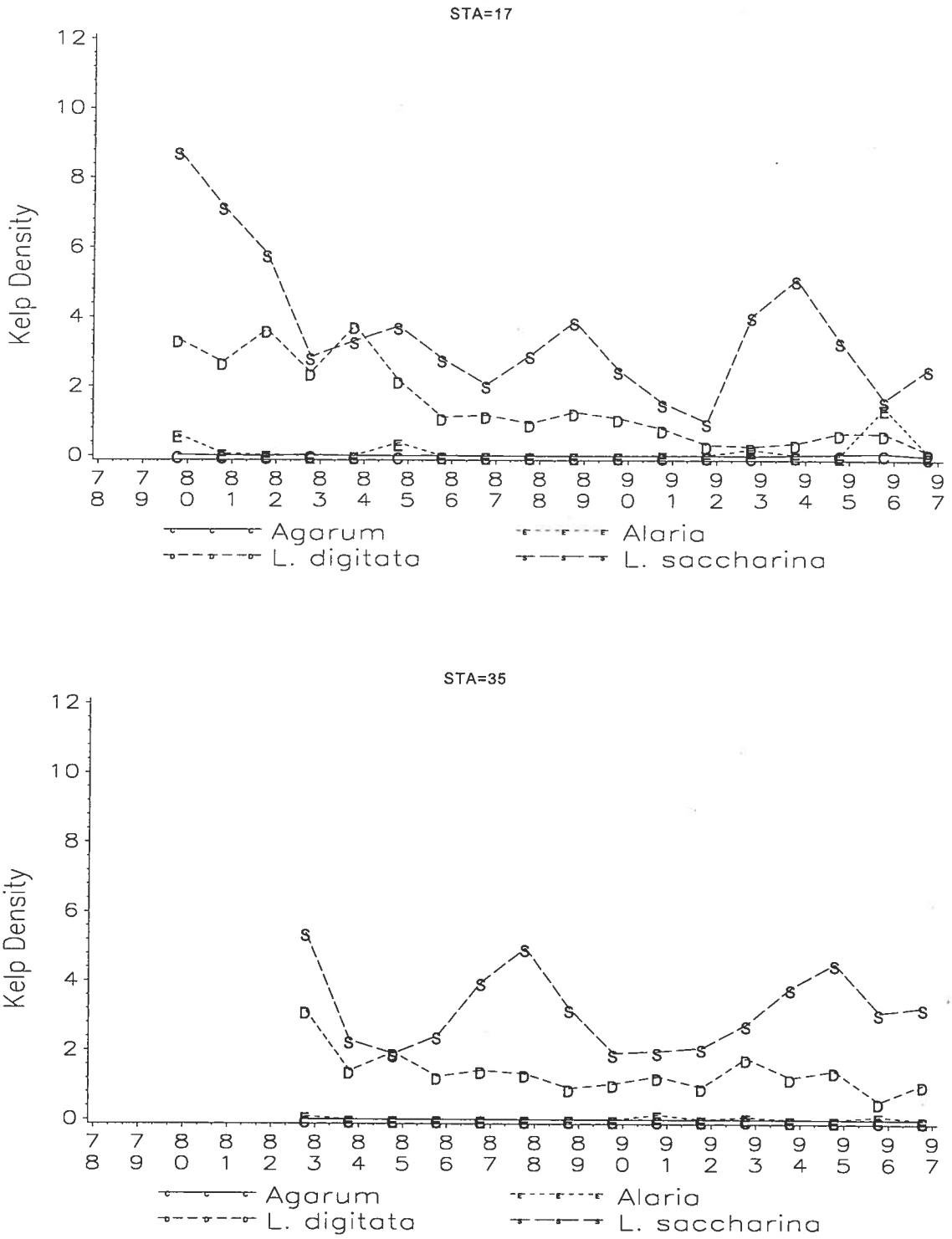
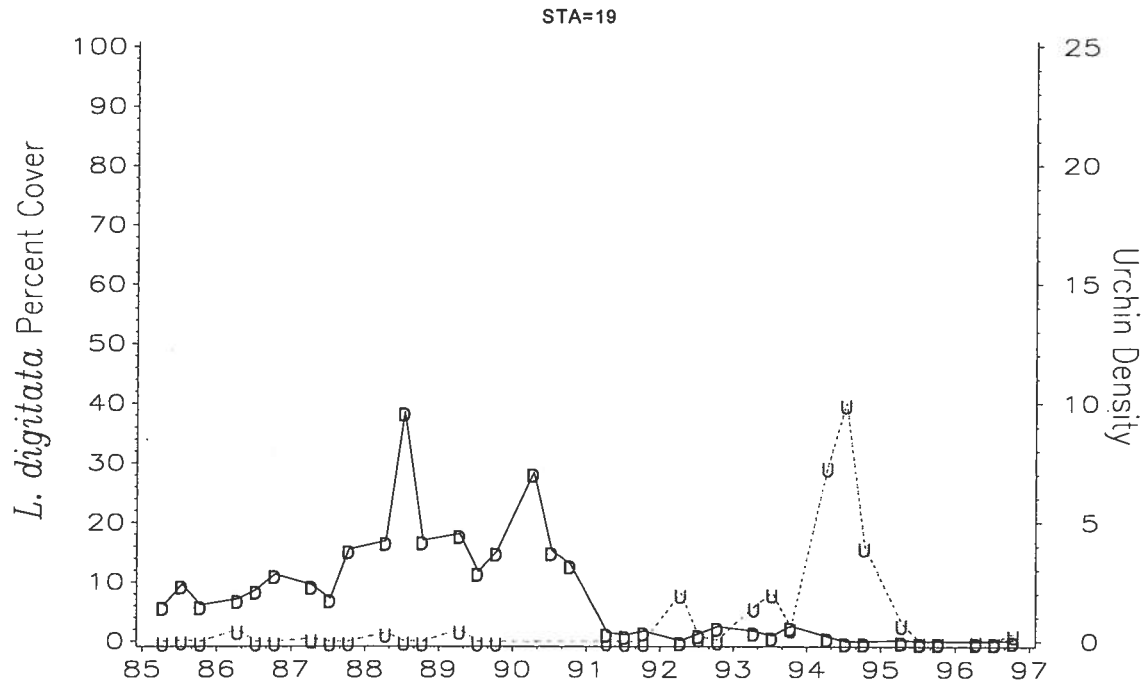


Fig. 3. Annual mean kelp densities (plants/m^2) at shallow subtidal stations, nearfield (B17) and farfield (B35), 1979-1996.



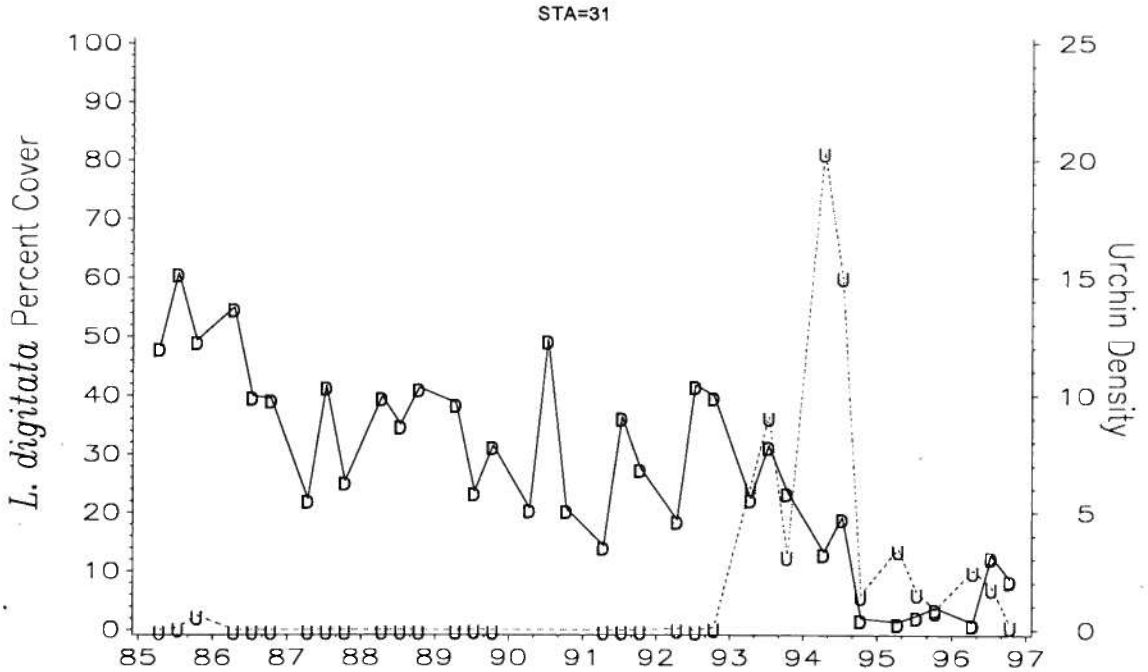


Fig. 4. Mean percent cover of *Laminaria digitata* and densities of adult *Strongylocentrotus droebachiensis* (no./m^2) for each sampling period (April, July, October) at mid-depth stations, nearfield (B19) and farfield (B31), 1985-1986.

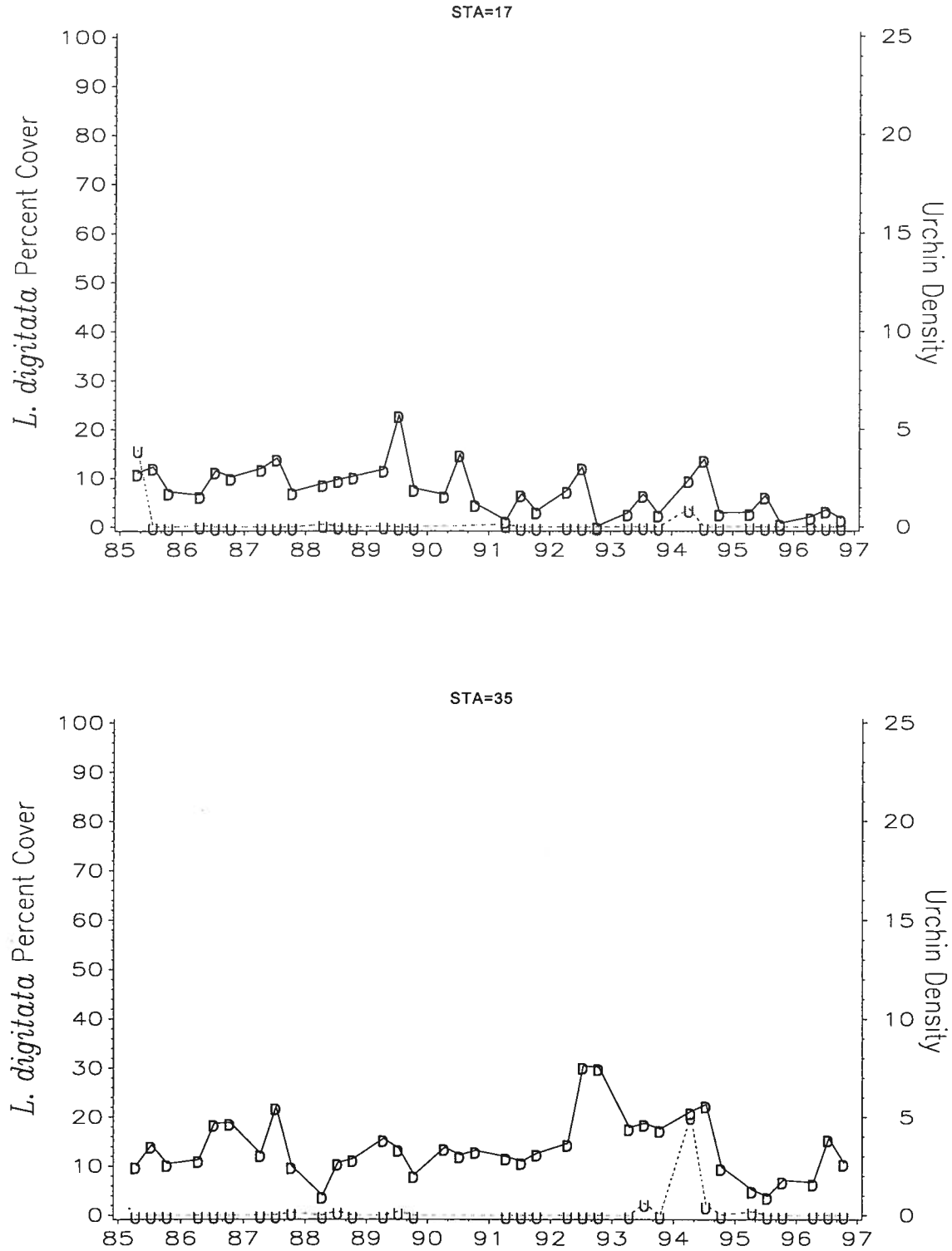


Fig. 5. Annual mean percent cover of *Laminaria digitata* and densities of adult *Strongylocentrotus droebachiensis* (no./m^2) for each sampling period (April, July, October) at shallow subtidal stations, nearfield (B17) and farfield (B35), 1985-1986.

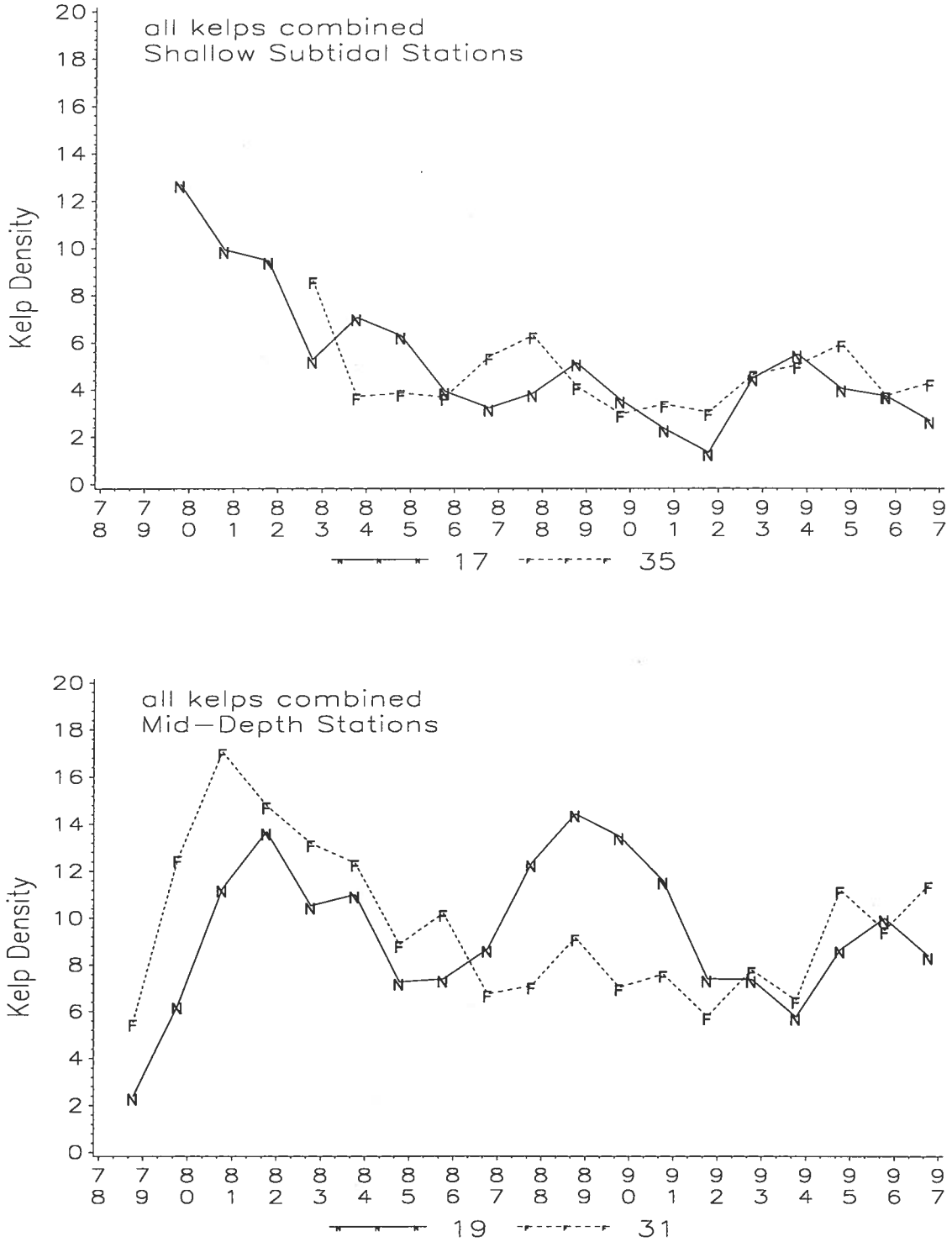


Fig. 6. Annual mean densities (plants/m^2) for all kelps combined, at shallow subtidal (nearfield B17 and farfield B35) and mid-depth (nearfield B19 and farfield B31) stations, 1978-1996.

25943

North Atlantic

North Atlantic Energy Service Corporation
P.O. Box 300
Seabrook, NH 03874
(603) 474-9521

The Northeast Utilities System

December 12, 1997

NYE-97039

Mr. Frederick Gay
NPDES Permit Coordinator
New Hampshire State Program Unit
Environmental Protection Agency
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Boston, MA 02203

Seabrook Station
On-Site Environmental Monitoring Program Procedures

Enclosed please find copies of the following on-site Seabrook Station Environmental Monitoring Program Procedures as we committed to provide to the Technical Advisory Committee (TAC) at our November 6, 1997 meeting.

- Ichthyoplankton Entrainment Sampling
- Bivalve Larvae Entrainment Sampling
- Impingement Assessment

These procedures are currently being reviewed under the Station's formal procedure review process. Any changes made to these procedures as a result of this review should be administrative or editorial in nature only and are not expected to change the scientific aspects of the procedures.

As requested at the TAC meeting, also please find enclosed 1996 screen wash data, including a listing, by date, of the screen washes for the year, screen washes for which an impingement assessment was performed and the composition of debris in assessed screen washes.

If you have additional questions, please contact me at (603) 773-7762.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

cc (with Enclosure)

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1996 Seabrook Station Screen Washes and Impingement Assessments

* Screen wash basket volume = ~ 1 cubic yard.

** Not all screen washes assessed. No value shown is an unassessed screen wash.

*** Screen wash composition (excluding fish) determined during impingement assessments only.

Date	Debris Volume * (Screen Wash Baskets)	Debris Volume ** Assessed	Composition of Debris ***	
			% Seaweed	% Shells
1-Jan-96	0.50	0.50	95	5
4-Jan-96	0.50			
6-Jan-96	0.50			
9-Jan-96	0.50	0.50	100	0
10-Jan-96	0.50			
15-Jan-96	0.75	0.75	100	0
16-Jan-96	0.13			
23-Jan-96	0.25	0.25	100	0
28-Jan-96	0.33	0.33	100	0
30-Jan-96	0.50			
6-Feb-96	0.20	0.20	100	0
13-Feb-96	0.25	0.25	100	0
20-Feb-96	0.33	0.33	100	0
24-Feb-96	1.00			
27-Feb-96	0.50	0.50	90	10
29-Feb-96	0.10			
5-Mar-96	0.50	0.50	90	10
10-Mar-96	0.25	0.25	80	20
12-Mar-96	0.05			
15-Mar-96	0.50			
18-Mar-96	0.33	0.33		
19-Mar-96	0.13			
26-Mar-96	0.33	0.33	80	20
2-Apr-96	0.33	0.33	10	90
9-Apr-96	1.00	0.50	80	20
9-Apr-96	1.00			
11-Apr-96	0.33			
16-Apr-96	0.33	0.33	90	10
18-Apr-96	0.75			
23-Apr-96	0.50	0.50	40	60
30-Apr-96	0.75	0.38	20	80
4-May-96	0.13			
7-May-96	1.00	1.00	30	70
14-May-96	0.75	0.75	20	80
21-May-96	0.50	0.50	40	60
30-May-96	0.75	0.75	20	80
4-Jun-96	2.00	0.66	10	90
4-Jun-96	1.00			
5-Jun-96	0.50			
5-Jun-96	1.00			
6-Jun-96	0.75			
6-Jun-96	0.75			
7-Jun-96	0.75			
7-Jun-96	0.50			
8-Jun-96	1.00			
9-Jun-96	1.00			

10-Jun-96	0.33			
12-Jun-96	1.00	1.00	1	99
14-Jun-96	1.00			
16-Jun-96	1.00			
17-Jun-96	1.00	0.50	1	99
18-Jun-96	1.00			
22-Jun-96	0.66			
22-Jun-96	1.00	1.00		
24-Jun-96	0.50	0.50	2	98
25-Jun-96	1.00			
3-Jul-96	1.50	0.75	1	99
9-Jul-96	1.00	1.00	5	95
12-Jul-96	2.00			
14-Jul-96	1.00			
16-Jul-96	1.00	1.00		
22-Jul-96	1.00	0.50	5	95
29-Jul-96	1.00	1.00	5	95
30-Jul-96	0.20			
2-Aug-96	0.75			
4-Aug-96	0.25			
5-Aug-96	0.66	0.66	20	80
13-Aug-96	1.00	0.50	10	90
21-Aug-96	0.75	0.75	5	95
27-Aug-96	0.75	0.75	5	95
2-Sep-96	1.00	1.00	90	10
2-Sep-96	1.50			
2-Sep-96	0.13			
4-Sep-96	0.33	0.33	90	10
7-Sep-96	0.50			
9-Sep-96	0.50	0.50	20	80
13-Sep-96	0.25	0.25	80	20
17-Sep-96	0.50	0.50	80	20
24-Sep-96	0.33	0.33	80	20
2-Oct-96	0.05	0.05	90	10
8-Oct-96	0.50	0.5	40	60
9-Oct-96	0.58			
10-Oct-96	0.50			
11-Oct-96	0.50			
15-Oct-96	0.50	0.50	90	10
20-Oct-96	6.00			
21-Oct-96	15.50	0.50	0	100
22-Oct-96	4.00			
23-Oct-96	1.08			
24-Oct-96	1.50			
25-Oct-96	0.25			
26-Oct-96	0.40			
29-Oct-96	0.25	0.25	100	0
1-Nov-96	0.25			
3-Nov-96	0.25	0.63	100	0
5-Nov-96	0.25	0.13	100	0
10-Nov-96	0.50			
11-Nov-96	0.33	0.17	100	0
12-Nov-96		0.33	100	0
13-Nov-96	0.33			
15-Nov-96	0.25			
17-Nov-96	0.50			
18-Nov-96	1.50	0.75	100	0

19-Nov-96	0.58			
20-Nov-96	0.50			
22-Nov-96	0.25			
26-Nov-96	0.13	0.13	100	0
28-Nov-96	0.25			
1-Dec-96	0.25			
2-Dec-96	0.50			
3-Dec-96	0.75			
4-Dec-96	0.25	0.25	100	0
7-Dec-96	0.50			
8-Dec-96	0.50			
10-Dec-96	0.50	0.50	100	0
12-Dec-96	0.25			
13-Dec-96	0.25			
15-Dec-96	1.00			
16-Dec-96	0.50	0.50	100	0
17-Dec-96	0.25			
23-Dec-96	0.50	0.50	100	0
25-Dec-96	0.25			
30-Dec-96	1.00	1.00	80	20
g:\fishdata\debris96.xls				

SEABROOK STATION

Licensing Procedure

Ichthyoplankton Entrainment Sampling

ZN1120.01

Rev. 00

Level of Use
General

Procedure Owner:
Ron Sher

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1. PURPOSE

1.1 Objective

This procedure describes the process for the collection of weekly entrainment samples of ichthyoplankton (fish eggs and larvae) from the circulating water system. Ichthyoplankton entrainment sampling is a requirement of Seabrook Station's NPDES Permit and is performed weekly (48 times per year).

1.2 Discussion

Entrainment sampling is part of Seabrook Station's Environmental Studies Program which is a requirement of the Station's NPDES Permit. Environmental studies which evaluate the number of ichthyoplankton (fish eggs and larvae), entrained by the Station's circulating water system (CWS), determine the potential impact to the population of these organisms due to Station entrainment. Ichthyoplankton entrainment samples are collected four times each month for a total of 48 samples per year. Each weekly collection consists of a sample collected with the 0.505 mm mesh net and a sample collected with a 0.333 mm mesh net. About 100,000 gallons of water from the discharge of each CW pump is passed through each of the 0.505 and 0.333 mm mesh ichthyoplankton nets during a 24-hour sample period. Ichtyoplankton samples are normally collected Wednesday to Thursday of each week.

Each 24-hour sample will be divided into four 6-hour subsamples. Subsamples are necessary to ensure that the entrainment sample is adequately preserved, and that specimens are **not** damaged in the collection cup. In addition, collection of subsamples will allow comparison of day and night samples. Sixteen paired day-night ichthyoplankton comparisons will be made each year. Day-night samples will be collected twice a month in February-August and October-November, when larval fish are most abundant. Day-night subsamples will be collected beginning at about 1800h, 2400h, 0600h and 1200h.

Entrainment sampling is in two trains (A and B). Train A will use a 0.505 mm mesh nets in each of the samplers to collect an entrainment sample. Simultaneously, 0.333 mm mesh nets will be used in the two samplers of Train B to collect an additional entrainment sample.

The plankton net is placed in a 30-gallon drum which is suspended in a 55-gallon drum. Water diverted from the CWS enters the 55-gallon drum from the bottom and overflows the 30-gallon drum into the plankton net. After passing through the plankton net, the water discharges through the bottom of both drums. The collected ichthyoplankton are washed from the plankton nets into sample collection jars and preserved. Weekly samples are delivered to the Normandeau Associates Hampton lab for analysis. Ichthyoplankton entrainment sampling is performed weekly (4 times per month). Entrainment sampling can be performed only when at least one CW pumps is operating, when sufficient flow is available to supply ocean water to entrainment sampling equipment.

Ichthyoplankton sampling should be performed before bivalve larvae sampling (during those months of the year, mid-April through October (28 weeks), when the sampling programs overlap).

Figure 3 provides a description of the Entrainment Analytic Procedure.

1.3 Frequency

Ichthyoplankton entrainment samples are collected four times each month for a total of 48 samples per year. Day-night samples will be collected twice a month in February-August and October-November, when larval fish are most abundant. Day-night subsamples will be collected beginning at about 1800h, 2400h, 0600h and 1200h.

2. PREREQUISITES

2.1 Requirements

Entrainment sampling can be performed only when at least one circulating water system pump is in operation, when sufficient flow is available to supply ocean water to entrainment sampling equipment.

2.2 Initial Conditions

One of the following three valves, minimum must be OPEN in order to proceed (valve is open when handle is pointed toward pump):

CL-V-59, Seawater Supply from 1-CW-P-39A
CL-V-60, Seawater Supply from 1-CW-P-39B
CL-V-61, Seawater Supply from 1-CW-P-39C

[These valves are located at the discharges of the circulating water pumps at approximately (+) 13' and are normally open]. If they are closed CONTACT the Operations Department (ext. 4079) to request that these valves be opened. Do **not** attempt to open these valves yourself.

2.3 Tools and Consumables

2.3.1 Sample collection cups for end of plankton nets, with 0.505 min and 0.333 min mesh openings.

2.3.2 32 oz. plastic sample jars for ichthyoplankton samples.

2.3.3 37% formaldehyde. Expiration Date: 1 year from opening.

3. PRECAUTIONS

None

4. INSTRUCTIONS

NOTE

If for any reason entrainment samples **cannot** be acquired, notify Ron Sher (ext. 7729), or Al Legendre (ext. 7773), or John Hart (ext. 7762).

4.1 Entrainment Sampling Preparations

4.1.1 If CW-V-130, entrainment sampling isolation valve, is **not** already open, NOTIFY the Control Room (x-3380 or x-3480) that you will be starting plankton entrainment sampling and will be opening CW-V-130.

_____/_____ 4.1.2 OPEN/CHECK OPEN CW-V-130, Entrainment Sampling Isolation Valve.

_____/_____
NSO

4.2 Entrainment Sampling Equipment Instructions

NOTE

Entrainment sampling drum assemblies are set up as two trains (A and B), each with two drums. Train A is normally used for entrainment sampling with the 0.505 mm mesh net and Train B is used for sampling with the 0.333 mm mesh net. The following procedures (steps 4.2.1 through 4.3.5) are written for sampling with Train A. Sampling in train a should be started before Train B. The instructions for sampling with Train B are identical to Train A with the exception of some valve designations. These exceptions are presented in parentheses.

4.2.1 Train A (0.505 mm mesh net) Entrainment Sampling Equipment Instructions. Sampling in Train A should be established before sampling in Train B is started.

4.2.2 OPEN/CHECK OPEN CW-V-132 (B Train: CW-V-135) and CW-V-133 (B Train: CW-V-136), Entrainment Sampling Outlet Isolation Valves.

4.2.3 CLOSE outer drum assembly drains by inserting the drain plugs on the steel rods towards the back of each drum.

CAUTION

If the next 2 steps are **not** performed in rapid succession the entrainment barrels will over flow.

4.2.4 Slowly THROTTLE OPEN CW-V-131 (B Train: CW-V-134), Entrainment Sampling Inlet Valve.

4.2.5 FLUSH system for at least 2 minutes or until water is visibly clear.

4.2.6 Slowly CLOSE CW-V-131 (B Train: CW-V-134).

4.2.7 ALLOW drums to drain to fish pit.

NOTE

Ensure nets are clean before proceeding. If residue from last sample is evident, rinse nets with salt water from salt water supply, CW-V-0211.

4.3 Ichthyoplankton Sample Net Set-Up

4.3.1 SUSPEND the two 0.505 mm ichthyoplankton nets from the hooks above each drum (B Train: 0.333 mesh nets). These nets should **not** be confused with the finer mesh bivalve nets (0.075 mm).

4.3.2 FASTEN a 0.505 mm mesh collection cup to the "Cod" (small) end of the net (B Train: 0.333 mesh collection cup).

4.3.3 CLOSE CW-V-132 and CW-V-133 (B Train: CW-V-135, CW-V-136)..

4.3.4 Slowly FILL both drums until the water level is at least 2 inches from the top of the inner drums by THROTTLING OPEN CW-V-131 (B Train: CW-V-134).

4.3.5 CLOSE CW-V-131 (B Train: CW-V-134) when water has reached the desired level.

4.3.6 LOWER the plankton nets into the inner drums, DISPLACE any trapped air and "hoop" the net ring around the outside of the inner drum (See Figure 1).

4.3.7 RESET the button on the flow totalizer CW-FL-6052 (B Train: CW-FL-6053), to re-zero the gallons throughput.

4.4 Ichthyoplankton Sample Collection

CAUTION

If the next 3 steps are **not** done in rapid succession the plankton nets may become dislodged or drums overflow. Avoid overflowing the drums.

NOTE

Final flow through the drums should be approximately 70 gpm as read on CW-FL-6052, entrainment sampling flow totalizer for Train A (Train B: CW-FL-6053). A total of 4 subsamples of approximately 6 hours duration will be collected from each train on each sampling day. The total volume collected will be about 100,000 gallons. Steps 4.3.1 through 4.5.13 are for the collection of one 6-hour subsample. These steps will be repeated three more times in the course of a 24-hour sample.

4.4.1 SLOWLY THROTTLE OPEN CW-V-131 (B Train: CW-V-134) allowing water to rise above the nets.

4.4.2 THROTTLE OPEN drum drain valves CW-V-132 and CW-V-133 (B Train: CW-V-135, CW-V-136). NOTE as start time and RECORD on Entrainment Sampling Data Sheet (Form A).

4.4.3 MAINTAIN level of drums to about 2 to 6 inches above inner drum by adjusting outlet valves CW-V-132 or CW-V-133 (B Train: CW-V-135 or CW-V-136) or input valve (CW-V-131)(B Train: CW-V-134).

4.4.4 If at any point the water level goes below the level of the net ring go back to step 4.4.1.

4.4.5 MONITOR the water level in the drums periodically to prevent overflow.

4.4.6 REPEAT steps 4.2.2 through 4.4.5 for Train B using the 0.333 mm mesh nets.

NOTE

Totalizer reading is in gallons.

4.4.7 After approximately 6-hours of collection on both Trains A and B, COLLECT the next subsample.

4.5 Ichthyoplankton Sample Removal from Nets

4.5.1 REMOVE the nets from the drums and HANG them on the hooks over the drums. RECORD the time of sampling and the volume sampled from the totalizer on the Entrainment Sampling Data Sheet (Form A) when the net is removed from the water.

4.5.2 REMOVE the sample from the nets in the A Train first, and then repeat the procedures for the B Train. Specific procedures for the B Train are indicated in parentheses.

4.5.3 HANG nets on hooks above the A-Train drums (B Train: use hooks above B-Train drums).

4.5.4 ATTACH garden hose to salt water supply CW-V-0211.

4.5.5 OPEN CW-V-0211.

4.5.6 RINSE down the nets into the 0.505 mm mesh collection cup, (B Train: 0.333 mm mesh collection cup).

4.5.7 Be sure that any material caught in net seams in step 4.5.6 is also rinsed to the sample collection jar.

4.5.8 When the biomass has settled in the collection cup, rinse the sides of the collection cup and collar of the cod end to the bottom of the cup to ENSURE that all sample material is in the cup.

4.5.9 TRANSFER the contents of both 0.505 mm collection cups (B Train: 0.333 mm) to the 32 oz. sample jar. Make up to no more than 1 inch from the top of the 32 oz sample jar with salt water.

NOTE

All ichthyoplankton entrainment samples must be preserved with formaldehyde. Approximately 50 ml of volume (no more than 1-inch of space from top) must be left in the 32 oz. Sample jar, after rinsing, to accommodate addition of buffered formaldehyde. See Section 4.7 for the preservation of samples.

4.5.10 If the jar has >50% biomass (by volume) two 32 oz. sample jars must be used. FOLLOW the remaining steps, after splitting the sample into two sample jars.

4.5.11 PLACE a label with sample number that matches the outside label, on the inside of the 32 oz. sample jar, and CLOSE the sample collection jar.

4.5.12 On the outside label (Figure 2) ENTER "SEABRK" under PROJ. ENTER "ICH" under METHOD. Record the date under DATE.

- ENTER "0.505" for Train A, or "0.333" for Train B under STA
- ENTER "1" for first subsample under REP.
- ENTER "2" for second subsample under REP.
- ENTER "3" for third subsample under REP.
- ENTER "4" for fourth subsample under REP.

4.5.13 RECORD the end time of subsample collection under TIME.

4.5.14 RECORD all information on Entrainment Sampling Data Sheet (Form A).

4.5.15 CLOSE CW-V-0211.

4.6 Next Ichthyoplankton Net Set-Up

4.6.1 RESET the 0.505 mm mesh nets in Train A and the 0.333 mm mesh nets in Train B for the collection of the next subsample following steps 4.3.1 to 4.5.13. RECORD the time when the nets are reset back in the samplers and RESET the Totalizers to 0 on both Train A and Train B.

4.6.2 After the flow to the sampling nets is stabilized, FOLLOW step 4.7.1 for the preservation of subsamples.

4.6.3 After 24-hours of sampling and the collection of four subsamples from each sampling train, TERMINATE the collection process. At this time the four subsamples from each Sampling Train (A and B) should have a sample volume of about 25,000 gallons in each subsample.

4.6.4 Slowly CLOSE CW-V-131, and CW-V-134, and RECORD the stop time on the Entrainment Sampling Data Sheet.

4.6.5 If bivalve entrainment sampling is **not** scheduled to be performed, REMOVE drain plug from rear of drums to allow drums to drain, RINSE nets and inside of both drums with potable water from PW-V-66, and hang nets from hooks above drums.

4.6.6 CLOSE/CHECK CLOSE CW-V-130.

4.6.7 NOTIFY Control Room (extension 3380 or 3480) that plankton entrainment sampling is completed and CW-V-130 is closed.

4.7 Ichthyoplankton Sample Preservation

C A U T I O N

Carefully transfer subsample to sample jar which already contains buffered formaldehyde to prevent spills.

4.7.1 ADD subsample to sample jar which already contains 43 (forty-three) ml of bifford formaldehyde solution.

4.7.2 ENSURE all information is filled in on the entrainment sampling data sheet (Form A).

4.7.3 Make a copy of data sheet and provide to Ron Sher, Environmental Compliance Department.

4.7.4 Deliver sample jars and sample data sheet to the Hampton Lab.

5. REFERENCES

5.1 NPDES Permit NH0020338

5.2 ON1038.07, Circulating Water Chlorination System Operation

5.3 OS1090.03, Operation ODI on Operating Valves

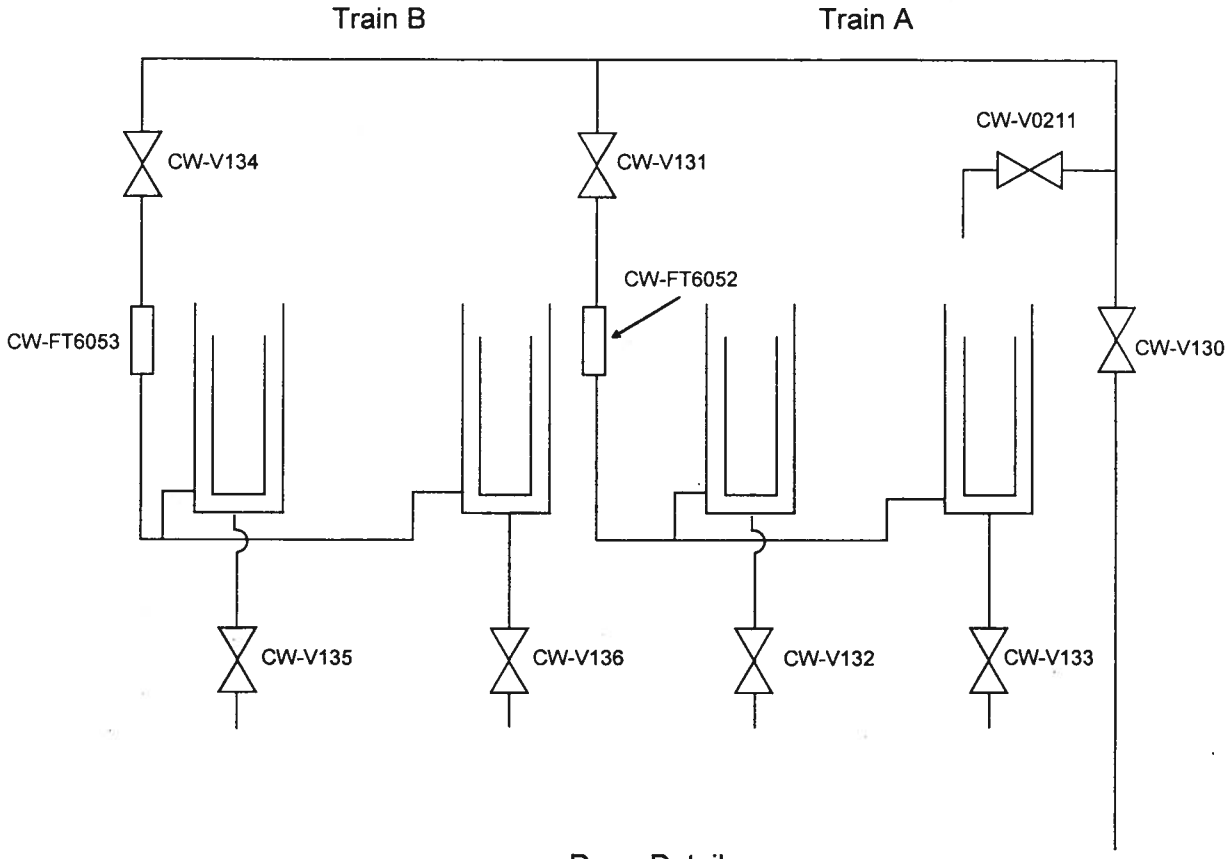
5.4 ON1038.01, Circulating Water System Startup

5.5 RTS 96RL00002012

6. SUMMARY OF CHANGES

6.1 Rev. 00: Initial Issue.

Figure 1: Diagram of Entrainment Sampling Equipment



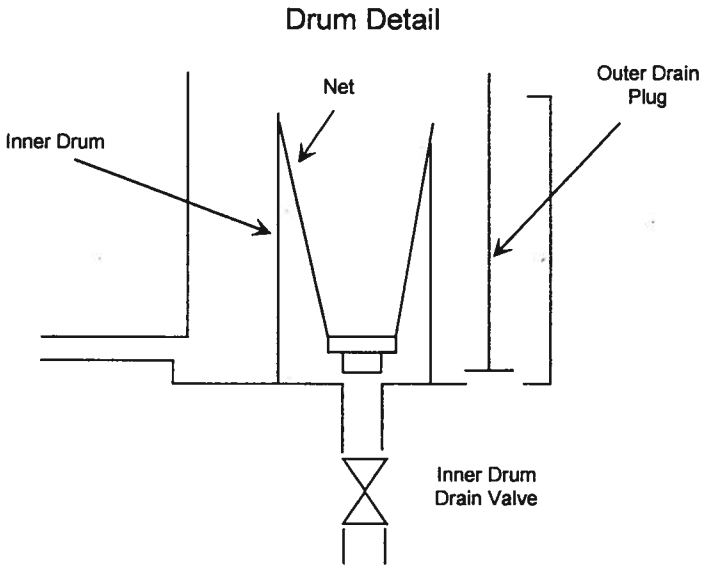


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Figure 2: Example of Sample Jar Internal and External Labels

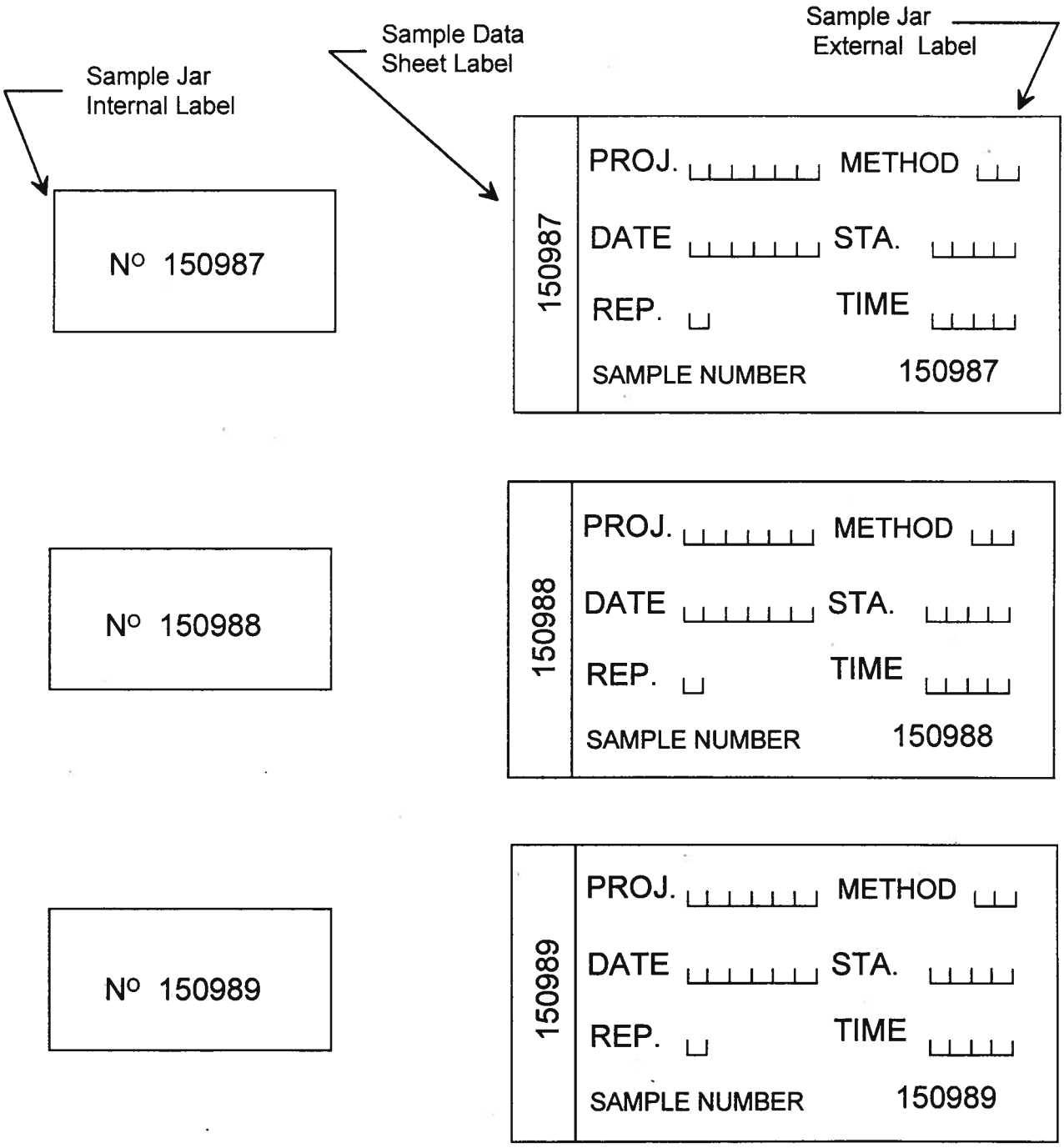

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Figure 3: Ichthyoplankton Entrainment Analytic Procedure

The annual entrainment estimate for each mesh size will be calculated as follows:

$$E_p = (D_{s,p})\ (V_p)$$

$$E_m = ;_{p=1..4}\ E_p$$

$$E_a = ;_{m=1..12}\ E_m$$

where,

E_p = entrainment estimate for a sample period (usually one week),

$D_{s,p}$ = density of ichthyoplankton in a sample for period p,

V_p = volume of cooling water pumped by the plant in a sample period (usually one week).

E_m = monthly entrainment estimate,

E_a = annual entrainment estimate.

Differences in the entrainment estimate for each mesh size will be evaluated through paired t-tests for key species. Community analyses including Multiple Analysis of Variance (MANOVA) will be used to determine if the species composition entrained by the two mesh sizes are different.

Similar techniques will be used to investigate diel differences. Paired t-tests will be used to determine if there are significant differences in the mean densities of key species between day and night. MANOVA will be used to investigate differences in the species composition between the day and night samples.

Form A: Entrainment Sampling Data Sheet

Date Samples Collected _____ Collectors Name _____

Sample Number (Place adhesive label here)	Mesh Size	Sample Start Time	Sample End Time	Sample Duration (minutes)	Sample Volume (totalizer reading gallons)	Flow Rate (gpm)	Formaldehyde Added (43 ml.)
	0.505mm						
	0.505mm						
	0.505mm						
	0.505mm						
	0.333mm						
	0.333mm						
	0.333mm						
	0.333mm						

Samples Delivered to Normandeau Associates by: _____ Time: _____ Date: _____

Samples Received By: _____ Time: _____ Date: _____

Provide copy of completed form to Ron Sher, Environmental Compliance.

PROCEDURE BASIS INFORMATION

Rev. 00: Initial Issue.

SEABROOK STATION

Licensing Procedure

Impingement Assessment Procedure

ZN1120.03

Rev. 00

Level of Use
Continuous

Procedure Owner:
Ron Sher

Impingement Assessment Procedure

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1. PURPOSE

1.1 Objective

This procedure describes the process for conducting the weekly screen wash impingement assessment. Impingement assessments are a requirement of Seabrook Station's NPDES Permit and are conducted every week of the year. Two assessments will be regularly scheduled each week. The first assessment, made on Tuesday of each week, will include all screenwash material from the previous screenwash to Tuesday morning. This will usually be a 6-day period, although it is possible that unscheduled screenwashes will have occurred during the 6-day period. The second assessment will generally occur on Wednesday and will represent a 24-hour assessment. It is the goal of the program to monitor all screen washes, including unscheduled screen washes. In the case of an unscheduled screen wash, the Environmental Compliance Department shall NOTIFY personnel from Normandeau Associates (NAI), Seabrook Station's Environmental Studies contractor, who will be on-site within 24-hours to assess the screen wash debris. In the unlikely event that a screen wash is **not** enumerated, the number of impinged organisms will be estimated based on the volume of screen wash material in the unscheduled wash, and the volume in the next regularly scheduled wash (see Figure 1, Impingement Analytical Procedures).

1.2 Discussion

Weekly impingement assessments are part of Seabrook Station's Environmental Studies Program which is a requirement of the Station's NPDES Permit. Fish and lobsters are impinged (drawn into) the Circulating Water System along with seaweed and other debris. Weekly impingement assessments are performed in the Circulating Water Pumphouse to determine the number and size of fish and lobsters that are impinged by the Station's Circulating Water System.

2. PREREQUISITES

None

3. PRECAUTIONS

3.1 Fish spines and other sharp objects in screen wash debris can be hazardous. When performing a screen wash assessment, heavy rubber gloves shall be worn to protect hands when removing fish from screen wash debris. Following the removal of fish from debris it is appropriate to use a thinner latex glove for species identification and counting.

4. INSTRUCTIONS

NOTE

1. If for any reason the weekly impingement assessment **cannot** be made, contact Ron Sher (ext. 7729), Al Legendre (ext. 7773) or John Hart (ext. 7762).

2. The Operations Department (Work Control) notifies the Environmental Compliance Department by cc:mail following all screen washes. The notification includes the time and date of the screen wash and the volume of screen wash debris in increments of screen wash baskets (one cubic yard). Operations personnel ENTER the same information in the screenwash log in the pumphouse.

4.1 The regularly scheduled screen washes are generally performed on Tuesday and Wednesday of each week, however, conditions may require that screen washes be conducted on other days of the week. When an unscheduled screen wash occurs, it will be necessary to record the volume of screen wash debris in case the screenwash is **not** enumerated. The volume of screenwash debris in the unenumerated screen wash will be recorded in Section III of the data sheet for the next regularly scheduled screen wash. The volume of screen wash debris of the unenumerated screen wash can be used to estimate the number of fish impinged using a ratio of fish to debris in that screen wash using the reference (assessed) screen wash.

NOTE

If the screen wash debris has **not** been removed from the screen wash basket, contact the Operations Department (ext. 4078) and request that the debris be removed from the basket.

4.2 Impingement Assessment Procedure

4.2.1 RECORD your name and date and the total volume of screen wash debris in Section I of the Fish/Lobster Impingement Data Sheet.

4.2.2 DETERMINE the volume of screen wash debris from the screen wash log in the Pumphouse. If the volume of screen wash debris is greater than two baskets, consult Table 1 for the number of subsamples. If the volume of debris is more than four baskets, see Step 4.2.3.

a. SEPARATE the volume of the screen wash debris sequentially into the number of subsamples specified in Table 5-1. For example, if four subsamples are required, split the entire pile in half and randomly select one of the two halves using a coin toss. Split the selected half into two more subsamples. Select one of the remaining subsamples for assessment using a coin toss.

b. RECORD on the data sheet (Form A) in decimal form the scaling factor (from Table 1) used to estimate the total number of fish impinged.

c. Enumerate all the fish in one of the randomly selected subsamples following the procedures in steps 4.2.4 through 4.2.12.

4.2.3 It is possible that during severe weather, more than four baskets of screen wash debris will be impinged, and it may **not** be possible to stockpile the material in the screen wash collection area. At this time, the Environmental Compliance Department will declare a "High Impingement Event" and the screen wash material will be stockpiled in containers or dumpsters at a designated area outside the screenwash collection area. Normandeau Associates Personnel will be on-site as soon as possible, but no later than 24-hour after the declaration of the High Impingement Event to assess the screen wash debris. Plant personnel will record the total volume of screen wash debris in the screen wash log in the Pumphouse.

4.2.4 Separate all fish and lobsters from the screen wash debris to be assessed.

4.2.5 If it is **not** possible to identify a specific fish, PUT the fish in a plastic bag with a tag (RECORD your name, date and your opinion of fish species on the tag) and PLACE the tag in the Pumphouse freezer. RECORD the unidentifiable fish on the Fish/Lobster Impingement Data Sheet (Form A) as species code = 2000000.

4.2.6 Measure the total length (carapace length for lobsters) to the nearest mm, a maximum of twenty fish per species in the assessed screen wash debris.

a. If more than 20 fish of a given species are collected it will be necessary to subsample for length measurements. Spread out all the fish of a given species in rows on a flat surface ensuring that all sizes are mixed together thoroughly. Select the first specimen to be subsampled by using a random number table.

NOTE

RANDOM NUMBER TABLES FOR THE SELECTION OF FISH FOR LENGTH MEASUREMENTS

REFER to the random number tables provided in the Pumphouse Storage Desk to be used for the selection of the random starting point for fish length measurements when more than 20 fish of a given species are collected. To select the starting point, first determine the total number of individuals of a species collected, and then select the table with the next highest number of fish. For example, if 36 fish are collected, select the table for up to 40 fish. ENTER this table at the first random number and if it is less than or equal to the number of fish collected, use it as the starting point. If it is **not**, move to the next number. For example, the first number in the selected random number table is 39. It is greater than the number of fish collected, so reject this number and move to the next number 28. This number is appropriate, so the starting point for the selection of random fish is the 28th fish. Cross off each random number used, including numbers that were rejected, so that they will **not** be used again.

NOTIFY Ron Sher, Environmental Compliance (ext. 7729) when you have reached the last row of any random number table so more tables can be generated.

b. Proceed from the first fish selected taking every i^{th} specimen in succession for the subsample until 20 fish have been selected, where "I" is determined by dividing the total number of fish by 20. If "I" is **not** a whole number, round up to the next whole number. The purpose of this step is to ensure that every specimen has an equal chance of being included in the subsample, regardless of size.

4.2.7 If the number of fish in a species in the assessed screen wash debris is greater than 20, RECORD the number of fish **not** measured in, NO. OF FISH **NOT** MEASURED on the Fish/Lobster Impingement Data Sheet.

4.2.8 SEPARATE seal remains from screen wash debris and PUT in plastic bag with a tag describing the contents (e.g. three seal bones), date and your name. PLACE the bag in the Pumphouse freezer.

4.2.9 RECORD a description of seal remains in screen wash debris in Section IV of the Fish/Lobster Impingement Data Sheet AND NOTIFY Ron Sher (ext. 7729), Al Legendre (ext. 7773) or John Hart (ext. 7762).

4.2.10 RECORD the makeup of screen wash debris (to the nearest ten percent) of shells and seaweed in Section III of the Fish/Lobster Impingement Data Sheet.

4.2.11 NOTIFY the Operations Department (ext. 4079) that the impingement assessment has been completed and the screen wash debris can be cleaned-up.

4.2.12 LEAVE the screen wash debris for utilities personnel to clean up.

4.3 Data Sheet coding instructions:

SECTION I

EMPLOYEE NUMBER:	ENTER your employee number.
DATE:	ENTER the date in mm/dd/yy format.
TIME:	ENTER the time of the screen wash in 24-hour clock format from the screen wash log located on the desk in the screen wash room.
TOTAL VOLUME OF SCREEN WASH DEBRIS:	ENTER the volume of screen wash debris (in baskets) from the screen wash log located on the desk in the screen wash room.
SCALING FACTOR:	ENTER in decimal form, the scaling factor for the amount of screen wash debris assessed, from Form B.

SECTION IIi

SPECIES:	ENTER the common name and species code for the impinged fish.
LENGTHS:	Record the total length to the nearest mm for a maximum of 20 randomly selected fish per species.
NO. OF FISH **NOT** MEASURED:	If more than 20 fish are collected ENTER the number of fish per species that are **not** measured.

SECTION III

ENTER a percentage estimate of the amount of seaweed and shells in the screen wash debris.

SECTION IV

ENTER a description of any seal remains present in the screen wash debris.

4.4 COPY the Fish/Lobster Impingement Data Sheet and send a copy to Regulatory Compliance Senior Scientist, Ron Sher (mail code 01-48). Retain orignian copy of the data sheet.

5. REFERENCES

5.1 NPDES Permit NH0020338

5.2 ON1017.02, "Circulating Water Screen Wash Operation

5.3 RTS 97RL00003041

6. SUMMARY OF CHANGES

6.1 Rev. :Original Issue.

Figure 1: Impingement Analytic Procedures

The annual impingement estimate will be the sum of the 52 weekly impingement collections made during year. This can be represented as:

$$I_a = ;_{w=1...52} I_w$$

$$I_w = I_s + I_{24} + I_u$$

where,

I_a = annual impingement,

I_w = weekly impingement

I_s = six-day impingement

I_{24} = 24-hour impingement, and

I_u = impingement from unscheduled washes.

It is the goal of the program to enumerate all unscheduled washes. In the unlikely event that an unscheduled wash **cannot** be enumerated, the number of impinged organisms will be estimated based on the ratio of screenwash debris to organisms in the next regularly scheduled wash. This can be represented as:

$I_x = (I_e\ D_x)/D_e$ where,

I_x = number of impinged organisms in the unenumerated screen wash,

I_e = number of impinged organisms in the next regularly scheduled screen wash,

D_x = volume of debris in the unenumerated screen wash, and

De = volume of debris in the enumerated screen wash.

Form A: Sample Fish/Lobster Impingement Data Sheet

SEABROOK STATION FISH/LOBSTER IMPINGEMENT DATA SHEET

PROJECT 1 7 4 5 5 | EMPLOYEE NUMBER | DATE | TIME (24-HOUR) | TOTAL VOLUME OF SCREENWASH DEBRIS | SCALING FACTOR | Page ___ Of ___

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

LENGTHS (no decimals) | SPECIES NAME _____ | SPECIES CODE | NUMBER OF FISH NOT MEASURED

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Section III Screen Wash Debris Makeup _____ %Seaweed _____ % Shells

Section IV. Describe any seal remains present in screen wash debris.

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Form B: Number of Subsamples and Scaling Factors for Screenwashes

NUMBER OF BASKETS OF SCREEN WASH DEBRIS	NUMBER OF SUBSAMPLES	NUMBER OF SUBSAMPLES ASSESSED	SCALING FACTOR
<2.0	0	All debris assessed	1
2.0 to 4.0	2	1	2
4.0 to 8.0	4	1	4
> 8.0	8	1	8

PROCEDURE BASIS INFORMATION

Rev. 00: Initial Issue.

SEABROOK STATION

Licensing Procedure

Bivalve Larvae Entrainment Sampling

ZN1120.02

Rev. 00

Level of Use
General

Procedure Owner:
Ron Sher

Bivalve Larvae Entrainment Sampling

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1. PURPOSE

1.1 Objective

This procedure describes the process for the collection of weekly entrainment samples of bivalve (soft-shell clam) larvae from the circulating water system. Entrainment sampling is a requirement of Seabrook Station's NPDES Permit and is conducted every week from mid-April through October.

1.2 Discussion

Entrainment sampling is part of Seabrook Station's Environmental Studies Program which is a requirement of the Station's NPDES Permit. Environmental studies which evaluate the number of bivalve (soft-shell clam) larvae, entrained by the Station's circulating water system (CWS), determine the potential impact to the population of these organisms due to Station entrainment. Approximately 2,000 gallons of water from the CW pump discharge is passed through 0.075 mm mesh bivalve larvae plankton nets. Entrainment sampling equipment is in two trains (A and B). Each train consists of two double-barrel systems. The plankton net is suspended in a 30-gallon drum which, in turn, is suspended in a 55-gallon drum. Water diverted from the CWS enters the 55-gallon drum from the bottom and overflows the 30-gallon drum into the plankton net. After passing through the plankton net, the water discharges through the bottom of both drums. The collected bivalve larvae are washed from the plankton nets into sample collection jars and preserved. Weekly samples are delivered to the Normandeau Associates Hampton lab for analysis. Entrainment sampling for bivalve larvae is performed every week from mid-April through October (28 sample weeks). Entrainment sampling can be performed only when at least one CW pumps is operating when sufficient flow is available to supply ocean water to entrainment sampling equipment. Bivalve larvae entrainment sampling may be performed before or after ichthyoplankton sampling.

Figure 3 provides a description of Bivalve Larvae Entrainment Analytic Procedure.

2. PREREQUISITES

2.1 Requirements

Entrainment sampling can be performed only when at least one circulating water system pump is in operation, when sufficient flow is available to supply ocean water to entrainment sampling equipment.

2.2 Initial Conditions

One of the following three valves, minimum must be OPEN in order to proceed (valve is open when handle is pointed toward pump):

CL-V-59, Seawater Supply from 1-CW-P-39A

CL-V-60, Seawater Supply from 1-CW-P-39B

CL-V-61, Seawater Supply from 1-CW-P-39C

[These valves are located at the discharges of the circulating water pumps at approximately (+) 13' and are normally open]. If they are closed, CONTACT the Operations Department (ext. 4079) to request that at least one of these valves be opened. Do **not** attempt to open these valves by yourself.

2.3 Tools and Consumables

2.3.1 Sample collection cups for end of plankton nets with 0.075 mm mesh openings.

2.3.2 32 oz. Plastic sample jars for ichthyoplankton samples.

2.3.3 Table Sugar

2.3.4 37% buffered formaldehyde - obtained from vendor. Expiration Date: 1 year from opening

3. PRECAUTIONS

None

4. INSTRUCTIONS

NOTE

If for any reason entrainment samples **cannot** be acquired, notify Environmental Compliance, Ron Sher (ext. 7729), or Al Legendre (ext. 7773) or John Hart (ext. 7762).

4.1 Entrainment Sampling Preparations

4.1.1 If CW-V-130, entrainment sampling isolation valve is **not** already open, NOTIFY the Control Room (x-3380 or x-3480) that you will be starting entrainment sampling and will be opening CW-V-130.

_____/_____ 4.1.2 OPEN/CHECK OPEN CW-V-130, Entrainment Sampling Isolation Valve.

_____/_____
NSO

NOTE

Entrainment sampling drum assemblies are set up as two trains (A and B), each with two drums. Train A is the normal train to use. Train B components may be used as a backup.

4.2 Train A Entrainment Sampling Equipment Instructions

NOTE

Three replicates of bivalve larvae samples are taken during each sampling week (Mid-April through October for a total of 28 sample weeks). Ichthyoplankton samples are taken throughout the year (48 sample weeks).

4.2.1 OPEN/CHECK OPEN CW-V-132 and CW-V-133, Entrainment Sampling Outlet Isolation Valves.

4.2.2 CLOSE outer drum assembly drains by inserting the drain plugs on the steel rods at the back of each barrel.

CAUTION

If the next 2 steps are **not** performed in rapid succession the entrainment barrels will over flow.

4.2.3 Slowly THROTTLE OPEN CW-V-131, Entrainment Sampling Inlet Valve.

4.2.4 THROTTLE OPEN CW-V132 and CW-V-133, Entrainment Sampling Outlet Isolation Valves.

4.2.5 FLUSH system for at least 2 minutes or until water is visibly clear.

4.2.6 Slowly CLOSE CW-V-131.

4.2.7 ALLOW drums to drain to fish pit.

NOTE

Ensure nets are clean before proceeding. If residue from last sample is evident, rinse nets with salt water from salt water supply, CW-V-0211.

4.3 Bivalve Larvae Sample Net Set-Up

4.3.1 SUSPEND the two 0.075 mm bivalve larvae nets from the hooks above each drum. These nets should **not** be confused with the coarser mesh ichthyoplankton nets (0.505 mm and 0.333 mm).

4.3.2 FASTEN a collection cup to the "Cod" (small) end of the net.

4.3.3 CLOSE CW-V-132 and CW-V-133.

4.3.4 Slowly FILL both drums until the water level is at least 2 inches above the top of the inner drums by throttling OPEN CW-V-131

4.3.5 CLOSE CW-V-131 when the water has reached the desired level.

4.3.6 LOWER the plankton nets into the inner drums, DISPLACE any trapped air and "hoop" the net ring around the outside of the inner drum (See Figure 1).

4.3.7 RESET the button on the flow totalizer CW-FT-6052, to re-zero the gallons throughput.

4.4 Bivalve Larvae Sample Collection

CAUTION

If the next 3 steps are **not** done in rapid succession the plankton nets may become dislodged or drums overflow. Avoid overflowing the drums.

4.4.1 SLOWLY THROTTLE OPEN CW-V-131 allowing water to rise above the nets.

4.4.2 THROTTLE OPEN drum drain valves CW-V-132 and CW-V-133. NOTE as start time and RECORD on Entrainment Sampling Data Sheet (Form A).

NOTE

Final flow through the drums should be approximately 100-400 gpm as read on CW-FL-6052, entrainment sampling flow totalizer for Train A.

4.4.3 MAINTAIN level of drums to about 2 to 6 inches above inner drum by adjusting outlet valves (CW-V-132 or CW-V-133) or inlet valve (CW-V-131).

4.4.4 If at any point the water level goes below the level of the net ring go back to step 4.4.1.

4.4.5 MONITOR the water level in the drums periodically to prevent overflow.

NOTE

Totalizer reading is in gallons.

4.4.6 When the totalizer displays approximately 2,000 gallons slowly CLOSE CW-V-131. NOTE as stop time and RECORD on Entrainment Sampling Data Sheet (Form A).

4.4.7 ALLOW water to drain from drum.

4.5 Bivalve Larvae Sample Removal from Nets

NOTE

Bivalve larvae can only be rinsed into the sample jars with salt water.

4.5.1 REMOVE the nets from the drums and HANG them on hooks above A-Train drums.

4.5.2 ATTACH garden hose to salt water Supply CW-V-0211.

4.5.3 OPEN CW-V-0211.

4.5.4 RINSE down the nets into the 0.075 mm sample collection cup.

4.5.5 When the biomass has settled in the collection cup, rinse the sides of the collection cup and collar of the cod end to the bottom of the cup to ensure that all sample material is in the cup.

NOTE

All bivalve larvae samples must be preserved with formaldehyde. Approximately 10 ml of volume must be left in the 16 oz. sample jar, after rinsing, to accommodate addition of formaldehyde. See Section 4.8 for preservation of the samples.

4.5.6 TRANSFER the contents of both 0.075 mm collection cups to the 16 oz. sample jar.

4.5.7 If collection jar has >50% biomass (by volume) two sample jars must be used. FOLLOW the remaining steps for both collection jars after splitting the sample into two sample jars.

4.5.8 TRANSFER the biomass from both sample collection cups and sieves to one labeled 16 oz. sample jar using salt water in a squeeze bottle to wash them in.

4.6 Sample Jar Labeling

4.6.1 PLACE a label with sample number that matches the outside label, on the inside of the sample jar, and CLOSE the sample collection jar.

4.6.2 On the outside label (Figure 2) ENTER "SEABRK" under PROJ.

- ENTER "BL" under METHOD.
- RECORD the date under DATE.
- ENTER "1" for first replicate under REP.
- ENTER "2" for second replicate under REP.
- ENTER "3" for third replicate under REP.

4.6.3 RECORD the end time of replicate collection under TIME.

4.7 Next Bivalve Larvae Net Set-Up

4.7.1 REPEAT sampling process beginning at step 4.3.1 for a total of three bivalve larvae samples, placing each sample in a separate 16 oz. sample jar (3 samples total).

4.7.2 RECORD all information on Entrainment Sampling Data Sheet (Form B).

4.7.3 CLOSE CW-V-0211.

4.7.4 REMOVE drain plug from rear of drums to allow drums to drain and from PW-V-66. RINSE nets and inside of both drums with potable water.

4.7.5 HANG rinsed nets from hooks above drums to dry.

NOTE

If ichthyoplankton samples will be collected next, preserve bivalve samples (step 4.8) and proceed to step 4.3 of "Ichthyoplankton Entrainment Sampling Procedure", ZN1120.01.

If ichthyoplankton samples will **not** be collected next, proceed to step 4.7.6.

4.7.6 CLOSE/CHECK CLOSE CW-V-130.

4.7.7 NOTIFY Control Room (extension 3380 or extension 3480) that entrainment sampling is completed.

4.8 Bivalve Larvae Sample Preservation

CAUTION

Carefully transfer sample to sample jar, which already contains buffered formaldehyde, to prevent spills.

4.8.1 ADD subsample to sample jar which already contains 3 (three) ml of buffered formaldehyde solution and 1/8 teaspoon of sugar.

4.8.2 ENSURE all information is filled in on the Entrainment Sampling Data Sheet (Form B).

4.8.3 Make a copy of the data sheet and provide to Ron Sher, Environmental Compliance Department.

4.8.4 DELIVER sample jars and sample data sheets to the Hampton Lab.

5. REFERENCES

5.1 NPDES Permit NH0020338

5.2 ON1038.07, Circulating Water Chlorination System Operation

5.3 OS1090.03, Operation ODI on Operating Valves

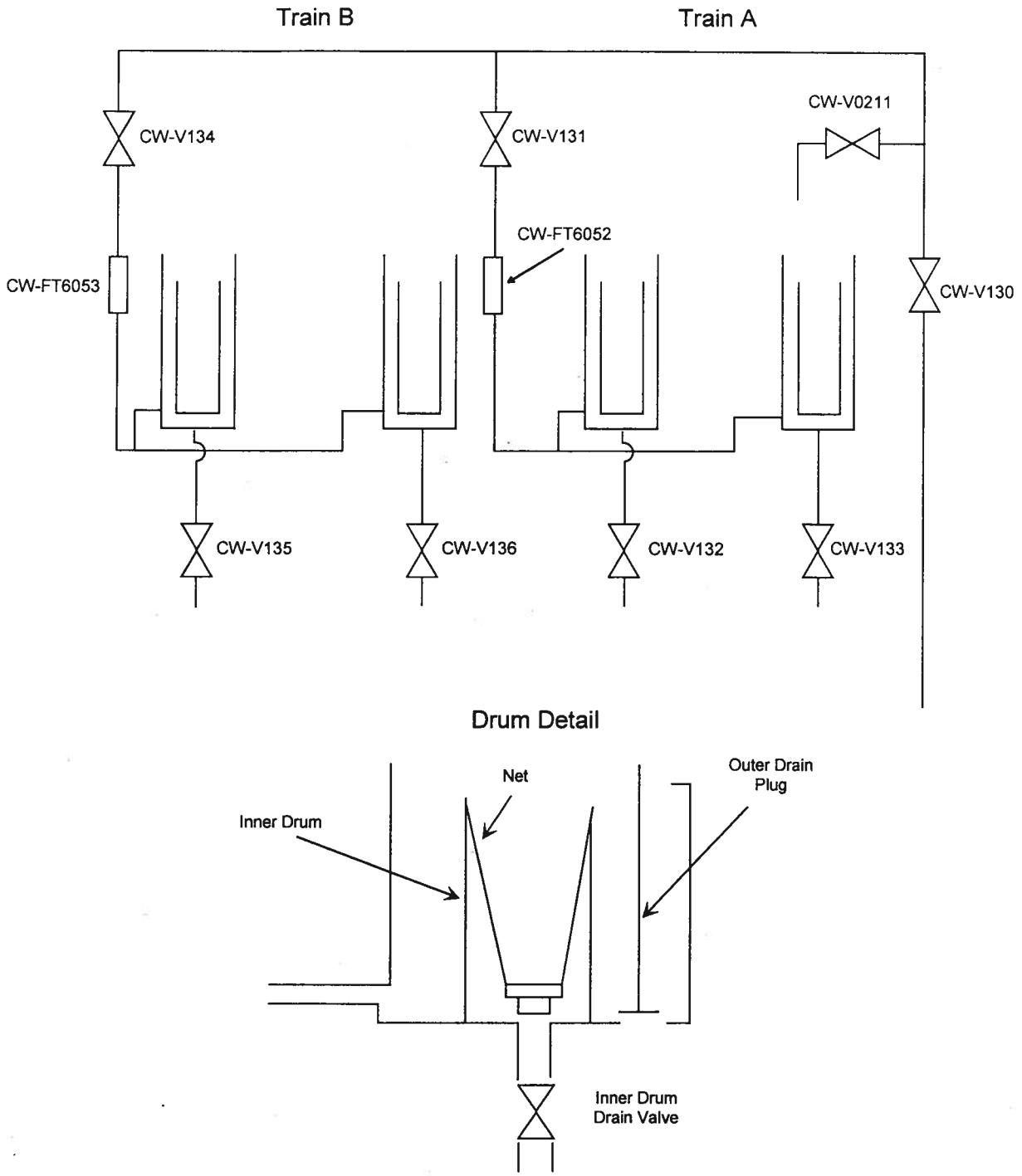
5.4 ON1038.01, Circulating Water System Startup

5.5 RTS 97RL00001028

6. SUMMARY OF CHANGES

6.1 Rev. 00: Original Procedure. Initial Issue.

Figure 1: Diagram of Entrainment Sampling Equipment



G:\Word\Images\Images_P.ZN\112002.ds4

Figure 2: Example of Sample Jar Internal and External Labels

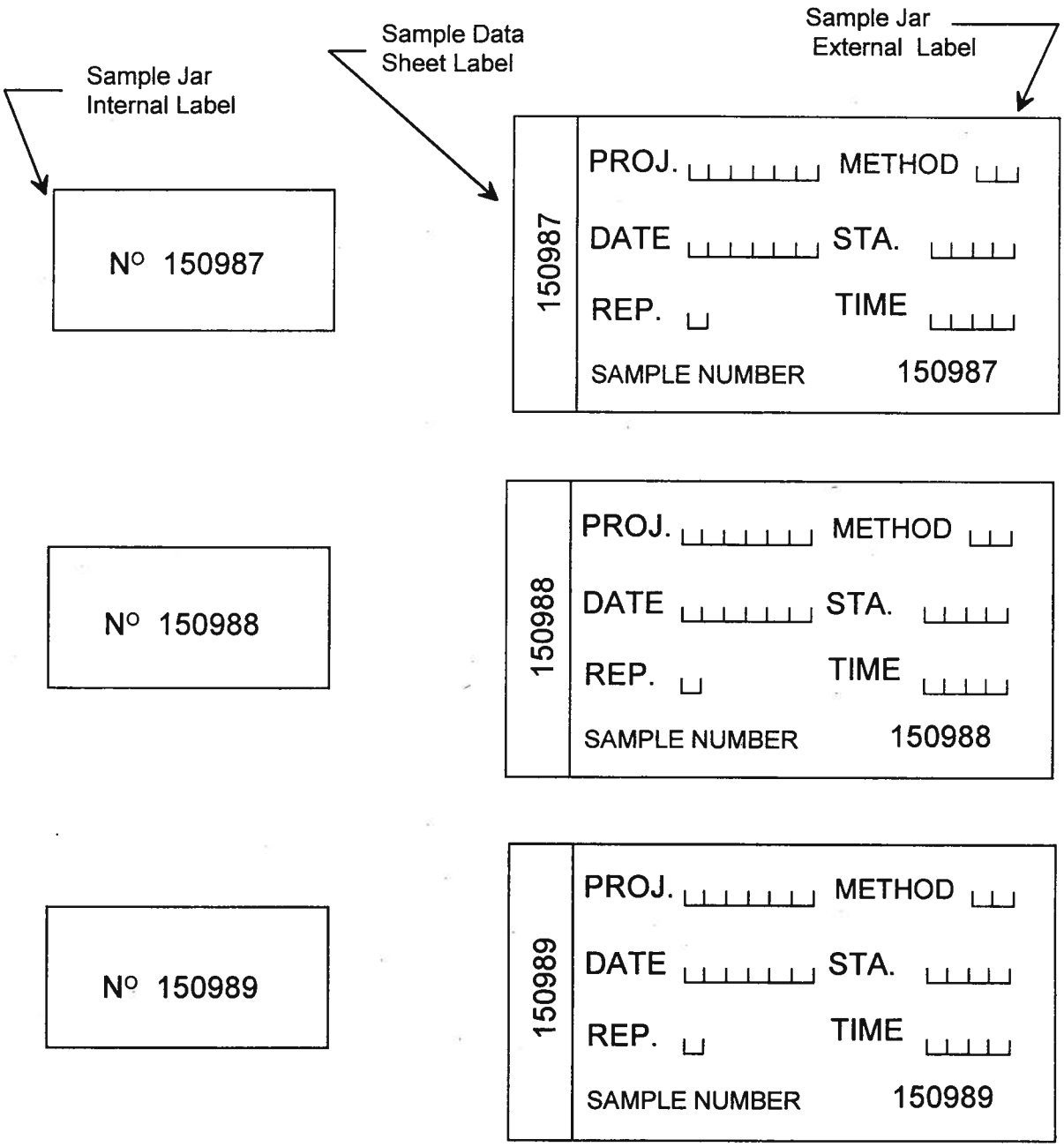


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Figure 3: Bivalve Larvae Entrainment Analytic Procedure

The annual bivalve larvae entrainment estimate will be calculated as follows:

$$E_p = (D_{s,p})\ (V_p)$$

$$E_m = ;_{p=1..4.}\ E_p$$

$$E_a = ;_{m=4..10}\ E_m$$

where,

E_p = entrainment estimate for a sample period (usually one week),

$D_{s,p}$ = density of bivalve larvae in a sample for period p,

V_p = volume of cooling water pumped by the plant in a sample period (usually one week).

E_m = monthly entrainment estimate,

E_a = annual entrainment estimate (mid-April through October).

Form A: Entrainment Sampling Data Sheet

Date Samples Collected _____ Collector's Name _____

SAMPLE NUMBER (PLACE ADHESIVE LABEL HERE)	SAMPLE START TIME	SAMPLE END TIME	SAMPLE DURATION (MINUTES)	SAMPLE VOLUME (TOTALIZER READING GALLONS)	FLOW RATE (GPM)	FORMALDEHYDE AND SUGAR ADDED

Samples Delivered to Normandeau Associates by: _____ Time: _____ Date: _____

Samples Received by: _____ Time: _____ Date: _____

Provide copy of completed form to Ron Sher, Environmental Compliance.

PROCEDURE BASIS INFORMATION

Rev. 00: Initial Issue.

PROCEDURE BASIS INFORMATION

Rev. 00: Initial Issue.

25944

North Atlantic

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The Northeast Utilities System

March 6, 1998

NPDES Permit No. NH0020338
NYE-98003

AR# 97030151

RECEIVED
MAR 12 1998
NH STATE PROGRAM UNIT

Planning and Administration (SPA)
U. S. Environmental Protection Agency
P. O. Box 8127
Boston, MA 02114

Seabrook Station
Zooplankton Biomass Conversion White Paper

North Atlantic Energy Service Corporation (North Atlantic) encloses herein a white paper (Enclosure 1) entitled, "Zooplankton Biomass Conversion," prepared by Dr. Bernard J. McAlice of the Seabrook Station Ecological Advisory Committee (SEAC). North Atlantic committed to provide this white paper in the Revised Long-Term Monitoring Program Proposal submitted to the Environmental Protection Agency and the New Hampshire Department of Environmental Services[1].

The white paper concludes that zooplankton biomass entrained by Seabrook Station and converted into available nutrients does not alter nutrient or phytoplankton dynamics in the vicinity of the discharge, nor does the detrital rain of dead zooplankton impact the benthos.

During the preparation of the enclosed white paper, North Atlantic identified incorrect minimum and maximum water quality values in Table 2-1 (page 2-8) of the 1996 Seabrook Station Environmental Monitoring Report.[2] These incorrect values were apparently carried over from the previous year's report. This condition appears to be an isolated incident. A review of all other tables and figures in the Water Quality Section of the 1996 Report revealed no such errors.

---

[1] North Atlantic Letter NYE-97035 dated November 20, 1997, "Revised Long-Term Monitoring Program Proposal," J. Hart (North Atlantic) to C. DeLoi (EPA) and E. Schmidt (NHDES).

[2] North Atlantic Letter NYE-98002 dated February 12, 1998, "1996 Seabrook Station Environmental Monitoring Report," J. Hart (North Atlantic) to EPA.

A corrected copy of page 2-8 is enclosed (Enclosure 2) and should be used to replace page 2-8 in the 1996 Report.

Should you require additional information regarding this matter, please contact me at (603) 773-7762.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

John B. Hart
Environmental Compliance Manager

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ENCLOSURE 1 TO NYE-98003

Zooplankton Biomass Conversion at Seabrook Station

Prepared by Bernard J. McAlice

Associate Professor of Oceanography, Emeritus University of Maine
and
Seabrook Station Ecological Advisory Committee Member

Zooplankton are entrained and killed in the cooling water system of Seabrook Station. The question arises as to whether the conversion of these organisms into their elemental chemical constituents will play a significant role in modifying nutrient dynamics in the offing of the cooling water discharge. I address this question here, using something close to a worst case scenario.

A typical high daily flow through the cooling system is 600 MGD (millions of gallons per day). (NAI 1998). Let us use 650 MGD.

$$650 \times 10^6 \text{ gal day}^{-1} \times 3.77\times10^{-3}\text{m}^3\text{gal}^{-1} = 2.45 \times 10^6\text{m}^3\text{day}^{-1} = 28.3 \text{ m}^3\text{sec}^{-1}.$$

The sampling program at Seabrook Station does not generate zooplankton biomass numbers, but abundance data only. Zooplankton dry biomass in productive coastal waters and estuaries varies from <1 mg m^{-3} up to as much as 300 mg m^{-3} (Kennish, 1990). For this evaluation, the zooplankton dry biomass was assumed to be 100 mg dry weight m^{-3}.

Nitrogen is the nutrient generally considered most likely to be limiting in most marine systems. Nitrogen as a percentage of dry biomass varies from about 1% for some gelatinous zooplankters up to about 11% for crustaceans (Parsons et al., 1984). We will use 10% for a mixed assemblage strongly dominated by crustaceans, principally copepods, and make the very liberal assumption that dead plankters are broken down into their elemental chemical components while still in the circulating water system.

So: 100 mg dry weight m^{-3} x 10% N = 10 mg N m^{-3}, or 10 ug N $liter^{-1}$ at the discharge, nearly the same as the minimum values for total N of 10.5 ug N $liter^{-1}$ reported by NAI (1998, Table 2-1) for "All Years" at Stations P2, P5, and P7, and an order of magnitude greater than the minima for the same stations during the "Operational" period.

But these possibly N-enriched parcels of discharged water do not retain their integrity, and are mixed with and diluted by the receiving waters. Assume that the linear diffuser array acts as a single narrow slot-like opening, 325 m long, and that the discharge emerges from the pipe opening as a curtain-like plume rising through a water column having a mean depth of 16 m into a current of only 1/4 knot (12.9 cm sec^{-1}).

The receiving water then presents 325 m x 16 m x 12.9 x 10^{-2}m sec^{-1} = 671 m^3sec^{-1}. The discharge yields 10 x 10^3 ug N m^{-3} x28.3 m^3 sec^{-1} = 28.3 x 10^4 ug N sec^{-1}.

Assuming that the discharge mixes fully with the receiving volume, we have:

28.3 x 10^4 ug N sec^{-1} / 671 m^3 sec^{-1} = 4.2 x 10^2 ug N m^{-3}, or 0.42 ug N $liter^{-1}$, which is of the same order as seasonal lows for total N reported by NAI (1998, Table 2-1, Figure 2-12). If quantities of dead zooplankton were being quickly converted to inorganic nutrients, one could predict that three consequences would ensue. First, operational levels of nutrients should be greater than pre-operational levels. Second, enrichments should be most noticeable for the more reduced species. Third, enrichment would be greatest at the station closest to the discharge, where dilution would be least. Analysis of Variance of the Seabrook nitrogen and phosphorus data show no such results (NAI 1998, Table 2-2).

Phosphorus content of crustacean zooplankters is about one-tenth of the nitrogen content, and minimum levels of both orthophosphate and total phosphorus at Seabrook sampling stations which are an order of magnitude greater than any phosphorus addition that could result from conversion of zooplankton biomass.

I conclude that conversions of zooplankton biomass to available nutrients, even were it to occur almost instantaneously in the cooling water system, would not alter the nutrient or phytoplankton dynamics in the vicinity of Seabrook Station.

What of the benthos? The station discharges about 24.5 kg N day^{-1} in the form of dead zooplankton. Let this rain down uniformly over an area of, say, 3.2 km on a side, or 10 km^2, giving an input of 2.4 mg m^{-2} day^{-1}. Some of this would be used in situ, and some released to the overlying water column. A reasonable number for release rates of N from shallow coastal sediments is 40 mg m^{-2} day^{-1} (Valiela, 1984), an order of magnitude greater than our assumed input. Were the input to be concentrated in a smaller area, say 1 km^2, it would be of the same order of magnitude as the outward flux, and over time one might expect to see some eutrophication if one knew where to look. Concentrated precipitation of dead but undecayed zooplankton could lead to localized hypoxia and dentrification, but none of these effects have been seen in the vicinity of Seabrook Station.

The assumption that the deposition of dead zooplankton occurs over a 1 km^2 area is extremely conservative and was made deliberately. Daily net-drift data collected from mid-depth current meters off Hampton Beach deployed from 1973 through 1976 indicated that typical net drift rates were at least 1.9 to 3.7 km day^{-1} with numerous periods of much greater net drift (NAI 1977).

Therefore, I conclude that a detrital rain to the benthos of dead zooplanktors or their decay products is not now occurring in such quantity as to pose a threat to the system.

Literature Cited

Kennish, M.J. 1990. Ecology of Estuaries. Vol. II. Biological aspects. CRC Press, Inc. Boston. 391 pp.

Normandeau Associates, Inc. 1977. Summary Document: Assessment of Anticipated Impacts of Construction and Operation of Seabrook Station on the Estuarine, Coastal and Offshore Waters, Hampton-Seabrook, NH.

_____. 1998. Seabrook Station 1996 Environmental Monitoring in the Hampton-Seabrook Area.

Parsons, T.R., M. Takahashi, and B. Hargrave. 1984. Biological Oceanographic Processes. Pergamon Press, New York. 330 pp.

Valiela, I. 1984. Marine Ecological Processes. Springer-Verlag. New York. 546 pp.

ENCLOSURE 2 TO NYE-98003

Table 2-1. (Continued)

Errata: page 2 1996 figures corrected February 1998

PARAMETER	PREOPERATIONAL ALL YEARS[a] $\bar{x}$	CV	MIN	MAX	PREOPERATIONAL RECENT YEARS[b] $\bar{x}$	CV	MIN	MAX	OPERATIONAL $\bar{x}$	CV	MIN	MAX	1996 $\bar{x}$	MIN	MAX
SURFACE NUTRIENTS (µg/L)															
Orthophosphate															
P2	12.9	27.4	0.5	34.0	14.9	14.7	0.5	34.0	14.9	14.6	4.7	32.6	15.8	13.0	31.0
P5	12.1	22.7	0.5	66.0	14.6	12.2	0.5	42.0	14.5	15.3	4.8	31.4	15.5	13.0	31.0
P7	15.9	10.2	0.5	38.0	15.6	11.4	0.5	38.0	15.6	14.6	5.3	37.3	17.1	13.0	36.0
Total Phosphorus															
P2	25.8	18.8	5.0	95.0	29.2	11.8	5.0	60.0	30.3	24.9	11.8	64.5	28.5	10.0	85.0
P5	27.5	22.6	7.0	82.0	29.7	5.9	10.0	60.0	30.1	24.9	13.9	59.8	30.1	10.0	87.5
P7	29.1	12.2	8.0	70.0	31.0	13.2	10.0	70.0	31.5	25.7	10.8	64.8	31.9	10.5	71.5
Nitrate															
P2	40.0	20.9	5.0	200.0	44.0	24.5	5.0	200.0	44.7	26.9	2.2	175.8	41.5	0.3	185.5
P5	39.8	19.9	5.0	200.0	42.2	26.2	5.0	200.0	39.7	23.4	2.2	158.3	46.4	0.3	188.0
P7	42.1	24.4	5.0	200.0	47.4	22.5	5.0	200.0	44.7	13.9	2.2	180.3	51.2	0.3	185.0
Nitrite															
P2	2.0	30.9	0.5	8.0	2.1	16.2	0.5	7.0	2.3	10.5	0.5	6.0	2.7	0.3	6.0
P5	2.1	26.0	0.5	9.0	2.0	13.6	0.5	9.0	2.1	21.1	0.5	5.9	2.5	0.3	8.0
P7	1.9	32.3	0.5	9.0	2.2	17.5	0.5	9.0	2.6	16.5	0.5	9.6	2.8	0.3	7.5
Ammonia[c]															
P2	6.4	10.7	5.0	20.0	--	--	--	--	10.7	62.8	2.7	35.4	16.4	3.0	65.0
P5	6.1	25.0	5.0	20.0	--	--	--	--	9.8	62.7	2.6	25.3	14.8	3.0	50.0
P7	7.6	18.8	5.0	30.0	--	--	--	--	10.4	59.7	2.7	36.3	15.5	3.0	80.0

[a]Mean of annual means.

Water quality parameters: P2 = 1979-1989; P5 = 1979-1981, 1987-1989; P7 = 1982-1989

Nutrients: P2 = 1978-1984, 1987-1989; P5 = 1978-1981, 1987-1989; P7 = 1982-1984, 1987-1989

[b]1987-1989; preoperational period specified in ANOVA (Table 2-2), mean of annual means.

[c]Because analytical methods for ammonia changed in April 1988, preoperational period for ammonia is April 1988 - December 1989.

25945

North Atlantic

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The Northeast Utilities System

AUG 7 1996

NPDES Permit No. NH0020338
NYE-96016

Mr. Carl DeLoi
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Environmental Protection Agency
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Evaluation of Seabrook Station Surface Panels
Monitoring Program After Five Years of Plant Operation

North Atlantic Energy Service Corporation (North Atlantic) has enclosed the 1995 Seabrook Station Environmental Studies Program Surface Panels Report Section and technical review paper entitled, "Evaluation of Seabrook Station Surface Panels Program After Five Years of Plant Operation." Based on the information provided herein, North Atlantic requests that all surface panel monitoring be discontinued since no impacts have been observed during the first five years of Seabrook Station operation. The Seabrook Ecological Advisory Committee has reviewed and endorsed the Surface Panels Section and technical review paper.

The Surface Panels Program was initiated in 1975 to monitor the interaction of Seabrook Station and the local marine fouling community. The Surface Panels Program has two major objectives which, as discussed below, have been demonstrated during the five years of Seabrook Station operation. The first objective was to identify the species which could settle on (foul) Seabrook Station structures (e.g. cooling water intake tunnel and condenser) and impair their operability, while the second objective was to determine whether the thermal plume from Seabrook Station would have an impact on the fouling community.

The first Surface Panels Program objective was demonstrated in that potential fouling organisms were identified prior to the beginning of Seabrook Station operation (August 1990) and as result, plant structures and operational considerations were designed accordingly. Seabrook Station currently maintains an in-plant Fouling Panels Program that assesses changes in fouling potential and provides data necessary to maintain an effective fouling control program by continuous low-level chlorination.

The second Surface Panel Program objective, with respect to showing that the thermal plume has not impacted the fouling community, has also been demonstrated. Furthermore, there are no natural or artificial communities of fouling organisms within the influence of the discharge plume. The enclosed review paper also shows that other studies in the current Seabrook Environmental Program will continue to monitor fouling organisms on bottom panels and on natural hard substrata.

In a November 16, 1995 submittal[1] North Atlantic first proposed elimination of the Surface Panels Program. North Atlantic also discussed this proposal at the November 1995 Seabrook Station TAC Meeting and a February 26, 1996 meeting with the EPA in Boston. At that time North Atlantic explained that it would submit the enclosed 1995 Surface Panels Report Section and technical review paper once all 1995 surface panel samples were analyzed. Therefore, North Atlantic restates its request for approval to discontinue the Surface Panels Program this year.

The enclosed 1995 Surface Panels Section will also be included in the Seabrook Station 1995 Environmental Studies Report (as Section 7.0) to be submitted later this year.

It should be noted that North Atlantic's environmental studies contractor is collecting 1996 surface panels samples and will need to analyze these samples in the near future if regulatory approval is not granted to discontinue the Surface Panels Program.

Should you require additional information regarding this matter, please contact Mr. Anthony M. Callendrello, Licensing Manager, at (603) 474-9521, extension 2751.

Very truly yours,

NORTH ATLANTIC ENERGY SERVICE CORP.

Bruce L. Drawbridge
Executive Director
Nuclear Station Safety and Oversight and
Senior Site Officer

---

[1] North Atlantic Letter NYE-95028, dated November 16, 1995, "1996 Seabrook Station Environmental Studies Program Modification" B. L. Drawbridge (North Atlantic) to C. DeLoi (EPA)

cc (with enclosures)

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SEABROOK STATION 1995 ENVIRONMENTAL STUDIES REPORT

SURFACE PANELS SECTION

Prepared for

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SUMMARY

The fouling community settling and developing on surface panels has shown predictable seasonal patterns throughout the study. Trends observed during the operational and preoperational periods were similar. Most measures of community structure (biomass, abundance, number of taxa), and abundances and frequencies of individual taxa indicate fouling community settlement (on panels exposed for one month) and development (on panels exposed for periods of 1-12 months) showed no significant differences between preoperational and operational periods. Some parameters measured on the year-end fouling community (panels exposed for one year) indicated changes during the operational period that were not consistent between nearfield and farfield areas. The wood-boring mollusk, *Teredo* sp. occurred in wood blocks for the first time since 1980, at both nearfield and farfield stations. This organism has been present in the bivalve larvae study each year since 1984, and adults have been observed on panels during the preoperational period in 1976, 1979 and 1980. None of the findings in 1995 or in previous operational years indicate that Seabrook Station operation has any effect on the local fouling community.

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7.0 SURFACE PANELS

7.1 INTRODUCTION

The surface fouling panels program was designed to study species settlement patterns and fouling community development in the discharge plume area and the corresponding farfield area. The main objectives of the panels program were: (1) to describe the temporal patterns of the dominant organisms that comprise the fouling community, and to determine if any of these organisms have the ability or potential to affect the operation of Seabrook Station, and (2) to describe the balanced indigenous fouling community in the vicinity of Seabrook Station and determine if the discharge from Seabrook Station has affected this community. The program is based on the hypothesis that the local fouling community is not adversely influenced by exposure to the thermal plume. Short-term panels, submerged for one month, provided information on the temporal sequence of settlement activity, while monthly sequential panels, collected after one to twelve months exposure and quarterly sequential panels collected after three, six, nine and 12 months, provided information on species growth and patterns of community development.

7.2 METHODS

7.2.1 Field Methods

Fouling panels (10.2 cm x 10.2 cm roughened plexiglass plates, bolted to pine blocks of equal size) were collected monthly from January through December at two mid-depth stations (nearfield B19, depth 12.2 m and farfield B31, depth 9.4 m, Figure 7-1). The designation mid-depth was based on the surface to bottom depth in relation to more shallow stations sampled for other programs in this study (i.e., benthos, macroalgae). Panel depths below the water surface ranged from 3 to 6 m depending on the tidal stage. Collections were made at Stations B19 and B31 from 1978 to 1984 and from July 1986 through 1995. Historically, collections were also made at Station B04 from 1978 to 1984 and 1986-1993, and at Station B34 from 1982-1984 and 1986-1993. Information on these stations is presented in NAI and NUS (1994).

Three different exposure strategies were employed at each station: short-term (ST) panels, exposed for one month; monthly sequential (MS) panels, exposed for increasing time periods from 1-12 months and quarterly sequential (QS) panels exposed three, six, nine and 12 months. Two replicate short-term panels and one monthly sequential panel were collected monthly at each of the stations. In addition to the one MS panel, two QS panels were collected in March, June, September and December for a total of three panels. In December, an additional MS panel was collected at each station.

7.2.2 Laboratory Methods

In the laboratory, each panel was dismantled and the panel face photographed. Fouling material was scraped off the wood block and panel support apparatus and rinsed over a 0.25 mm mesh sieve prior to storage or processing. Wood blocks from all MS and QS panels were dried, split, and examined for the presence of wood-boring organisms.

All noncolonial species collected monthly on both ST replicates and one December MS replicate were identified and enumerated. When high abundances of Mytilidae, *Hiatella* sp. and *Anomia* sp. occurred, organisms were enumerated from subsamples generated using a Folsom plankton splitter (NAI 1990). Colonial animals, diatoms and macroalgae on ST panels were quantified by determining the percent frequency of occurrence on the panel face (Mueller-Dombois and Ellenberg 1974; Rastetter and Cooke 1979; NAI 1990). Colonial animals, diatoms, and macroalgal species were recorded as "P" (present, but not quantified) when found in the sample, but not directly on the panel face. For MS and QS panels, the percent frequency of occurrence of selected dominant animals (colonial and noncolonial), and diatom and macroalgal species was estimated using the procedure cited above. Counts were estimated for noncolonial species and recorded as an abundance class. Abundance classes, assigned 1 through 5, consist of ranges of numbers of individuals (1-10, 11-100, 101-1,000, 1,001-10,000, >10,000, respectively). Colonial and noncolonial dominants, diatoms, and macroalgae were recorded as "P" (present, but not quantified) when found in the sample, but not directly on the panel face. These laboratory methods for MS panels were initiated in 1987.

Random samples of ≥200 Mytilidae and ≥100 *Jassa marmorata* Holmes 1903 individuals found on MS and QS panels and in the residue were measured and recorded in 0.1

mm increments (NAI 1990). All *J. marmorata* and Mytilidae individuals less than 1.0 mm were recorded as <1.0 mm and estimated at 0.5 mm in calculations of mean lengths.

Dry-weight biomass from one of each pair of ST replicates and all MS and QS panels was determined after taxonomic processing by drying all faunal and floral material to a constant weight at 105°C.

7.2.3 Analytical Methods

Analysis of Variance

Recruitment on ST panels, measured on a monthly basis by the number of taxa, the abundance of noncolonial organisms, and total biomass, indicated the potential for fouling community development. Monthly biomass levels on MS panels give an indication of community development. Multiway analyses of variance (variables Preop-Op, Year, Station and Month) were used to compare fouling community settlement patterns (as exemplified by number of taxa, total abundance, total biomass and abundance and size of selected dominant species on ST panels) as well as community development (biomass, dominant species on MS panels) between preoperational (1978-1984 and 1986-1989 for ST panels and MS biomass, 1987-1989 for other MS variables) and operational (1991-1995) years at paired nearfield (B19) and farfield (B31) Stations (the two preoperational periods, 1978-1984 and 1987-1989, were treated as one period and were not statistically compared). Operational/preoperational and nearfield/farfield differences in monthly means for fouling community parameters and abundances of dominant taxa were evaluated using a multi-way analysis of variance procedure (ANOVA), using a before-after-control-impact (BACI) design to test for potential impacts of plant operation. A fixed effects ANOVA model was used to test the null hypothesis that spatial and temporal abundances during the preoperational and operational periods were not significantly ($p>0.05$) different. The data collected for the ANOVAs met the criteria of a Before-After/Control-Impact (BACI) sampling design discussed by Stewart-Oaten et al. (1986), where sampling was conducted prior to and during plant operation and sampling station locations included both potentially impacted and non-impacted sites. The ANOVA was a two-way factorial with nested effects that provided a direct test for the temporal-by-spatial interaction. The main effects were period (Preop-Op) and station (Station); the interaction term (Preop-Op X Station) was also included in the model. Nested temporal effects were years

within operational period (Year (Preop-Op)) and months within year (Month (Year)), which were added to reduce the unexplained variance, and thus increased the sensitivity of the F-test. For both nested terms, variation was partitioned without regard to station (stations combined). The final variance not accounted for by the above explicit sources of variation constituted the Error term. Preoperational periods for each analysis are listed on the appropriate figures and tables. Log (x+1) transformed monthly mean values were used in the ANOVAs for ST noncolonial total abundance and all selected taxa abundances *(Jassa marmorata* and Mytilidae), or frequencies of occurrence *(Tubularia* sp.). Non-transformed monthly means were used in the multiway analyses of variance for ST and MS biomass and short-term number of taxa. A significant difference in the interaction (Preop-Op X Station) was investigated by comparing the least square means with a paired t-test (SAS 1985).

t Test

Community development was also assessed by examining biomass, species richness, and abundance on surface panels exposed for one year. A comparison was made between preoperational (generally 1982-1984 and 1986-1989, which was treated as one period) and operational (1991-1995) periods at each station using paired t tests (SAS 1985). Selected dominant species (Mytilidae and *Jassa marmorata)* lengths from MS and QS panels were also compared using paired t tests to determine if average annual lengths varied between the nearfield and farfield station pair in 1995.

7.3 RESULTS

7.3.1 Short-Term Panels

Short-term panels provided information on the seasonal cycles of settlement activity. Seasonal cycles in number of taxa in 1995 and during the operational period were similar to the preoperational trend (Figure 7-2). The number of taxa typically increased during May and June and remained high throug``h September at both B 19 and B3 1. In 1995, number of taxa remained high through November at both stations, with the exception of July at B31. Monthly numbers of taxa during the operational period were generally similar to the preoperational period, although several months (May, June, August, October and November at

B19 and June, August and October through December at B31) averaged higher than the upper 95% confidence limit of the preoperational monthly means. During 1995, the monthly number of taxa was often higher than the preoperational period upper confidence limit, including April, June and August through November at B19 and August through December at B31. During several months, February at B19, and January, February and July at B31, the number of taxa in 1995 was lower than the lower 95% confidence limit of the preoperational period. The annual mean number of taxa in 1995, although higher than either the preoperational or operational period mean (Table 7-1), was within the range of previously observed values (NAI 1992). Based on ANOVA, the number of taxa was significantly higher during the operational period than the preoperational period (Table 7-2). ANOVA results indicated that the number of taxa at B19 was significantly higher than the number of taxa at B31 (Table 7-2). The interaction term (Preop-Op X Station) was not significant, indicating that the between-station difference occurred during the preoperational and operational periods, and was unlikely related to plant operation.

Seasonal patterns of faunal abundance for non-colonial species at mid-depth Stations B19 and B31 during the operational years, including 1995, were similar to those during preoperational years. Historically, abundances remained low from January to May, increased in June and July, then declined from August to December (Figure 7-2). Mean abundances at both stations during 1995 were greater than the preoperational and operational period means, primarily due to the elevated abundances during June through November (except July at B3 1), which were above the preoperational 95 % confidence limits (Table 7- 1, Figure 7-2). ANOVA results indicated that the interaction of the main effects (Preop-Op X Station) was significant; a significant increase in abundance between preoperational and operational periods occurred at Station B19, but there was no significant difference at B31 (Table 7-2, Figure 7-3). Historically, there has been an increase in total abundances every three to four years (Figure 7-4). These periodic increases have been observed at both stations. Abundances in 1994 and 1995 were lower than in 1993, suggesting that a similar pattern is being repeated in the operational period. The significant ANOVA results, which only test operational and preoperational averages, are not indicative of plant effects.

Seasonal settling patterns for the entire fouling community (motile fauna, colonial organisms, macroalgae) were also assessed by examining changes in biomass. The 1995 seasonal trend for biomass at Station B19 followed a pattern generally similar to the preoperational and operational periods, except that August and October values were unusually

high (Figure 7-2). Biomass remained low through July in 1995, peaked in August and October and then declined steadily through December. The unusually high biomass values in August and October 1995 at B19 resulted in an annual mean value that was twice the means of both the preoperational or operational periods (Table 7-1).

At farfield Station B31, the operational period biomass levels remained low throughout the year. Only in November were mean operational period biomass levels above the 95% confidence levels established during the preoperational period. During 1995 at Station B31, biomass levels remained low through July, peaking in August (4g/panel) and remaining at or above preoperational period means through October (Figure 7-2). November and December values were consistent with operational and preoperational periods. Annual mean biomass for 1995 at both stations was higher than preoperational and operational means (Table 7-1) because of the higher than normal August and October peaks observed at both stations. ANOVA results indicated, however, there were no significant differences for the main effects (Preop-Op and Station), and the interaction of the main effects (Preop-Op X Station) was not significant (Table 7-2).

Several dominant taxa on short-term panels were monitored to determine their seasonal settlement patterns. Historically, Mytilidae (mainly *Mytilus edulis* Linné 1758 spat) was the most abundant noncolonial taxon. Seasonally, the recruitment pattern for Mytilidae during 1995 at Stations B19 and B31 closely followed the operational and preoperational seasonal trends (Figure 7-5). Low to moderate settlement occurred from January to May. Settlement increased in June and remained high until late fall, following the pattern of larval availability (Section 4.0). The 1995 monthly abundances at Station B19 were higher than the operational and preoperational averages during July, August and October (Figure 7-5). Monthly abundances at Station B31 in 1995 were higher than operational and preoperational means during June, August and October. Annual mean abundances at Stations B19 and B31 in 1995 were higher than their respective preoperational and operational averages (Table 7-1). ANOVA results indicated that there was a significant interaction between the main effects (Preop-Op X Station). Similar to noncolonial abundance, Mytilidae abundance showed a significant increase between the preoperational and operational periods at B19, but no significant increase occurred at B31 (Figure 7-3). Mytilidae abundance, a major contributor to the observed trends in total abundance, has undergone a three to four-year abundance cycle unrelated to plant operation (Figure 7-4).

The amphipod *Jassa marmorata* (formerly known as *J. falcata* and revised by Conlan (1990)) is a common fouling organism (Barnard 1957). This species lacks a larval stage, so recruitment occurs through dispersal of juveniles or adults through the water column (Bousfield 1973). Throughout the study period, *J. marmorata* abundances at B19 and B31 were low during the early part of the year with a small late-summer increase (Figure 7-5). This seasonal recruitment pattern also occurred in 1995. However, abundances at both stations were above the upper 95% confidence limits of the preoperational period means from August through November. Annual mean abundances in 1995 were higher than the preoperational and operational means (Table 7-1). Based on ANOVA, there were no significant differences between the preoperational and operational periods, but abundances were significantly higher at B31 than B19 (Table 7-2). The interaction term was not significant, indicating that the pattern between stations was consistent between the preoperational and operational periods, and there was no effect due to the operation of Seabrook Station.

Hydroids of the genus *Tubularia* are dense summer colonizers. They are important as habitat formers and provide a substrate (Field 1982) and food source (Clark 1975) for epifaunal taxa. During the preoprational period, *Tubularia* sp. increased rapidly beginning in June and reached peak cover in September (Figure 7-5). During 1995, peak percent cover occurred at both B19 and B31 from August through October when percent frequencies were 100% and above the upper 95% confidence limits of the preoperational years. Because of the extended and extremely elevated peak period at both stations, 1995 annual means were higher than either preoperational or operational means (Table 7-1). There was no significant difference for the main temporal effect (Preop-Op; Table 7-2). Percent frequency was significantly higher at Station B19 than Station B31 for the entire study period (Table 7-2). The interaction of the main effects (Preop-Op X Station) was not significant indicating no effect due to the operation of Seabrook Station (Table 7-2).

7.3.2 Monthly Sequential Panels

Monthly sequential panels provide information on cumulative growth and successional patterns of development within the fouling community. Seasonal patterns of community development were assessed by examining monthly biomass levels. At Stations B19 and B31 during the operational and preoperational periods, monthly biomass on monthly sequential panels remained low from January to June, increasing from July to a peak in late fall/winter

(Figure 7-6). During 1995, biomass followed this same general pattern, although Station B31 experienced a slight decline in October. On an annual basis, the 1995 mean biomass at both stations was lower than either preoperational or operational means (Table 7-1). Historically there has been high year-to-year variability in mean biomass as is indicated by the high coefficient of variation (CV) at each station during the preoperational period (Table 7-1). There were no significant differences between the preoperational and operational periods, between stations, and no significant interaction of these main effects (Table 7-3).

Seasonal patterns of abundance of the community dominants in 1995 were similar to those observed during the preoperational period in most cases. Mytilidae spat settled heavily on panels in June at both stations (Figure 7-6). Percent frequency of occurrence during 1995 reached high levels in July that were maintained through December at both stations. During the operational period Mytilidae monthly percent frequencies of occurrence were similar to monthly means during the preoperational period.

Mytilidae spat measurements from monthly sequential panels in 1995 were compared to determine if mean lengths differed between the nearfield-farfield station pair. Mytilidae annual mean lengths averaged 3.0 at Station 19 and 2.9 mm at Station 31 in 1995 (Table 7-4), and were not statistically different based on a paired *t*-test ($t=0.1$, $p>0.9$).

Jassa marmorata percent frequency at Station B19 during the preoperational period was quite variable seasonally. This variability has continued throughout the operational period (Figure 7-7). However, in general, frequency of occurrence at B19 has been low from January to June followed by an increase in August through October and a slight decrease at the end of the year. Percent frequency followed this pattern at B19 during the operational period, and in 1995. The farfield Station B31 exhibited a more distinct mid-year peak in both the preoperational and operational periods. In 1995, there was little decline in frequency at B31 at the end of the year. The operational period was similar to the preoperational period although there were several instances in 1995 (August at B19; September, November and December at B31) when percent frequency was above preoperational confidence limits (Figure 7-7). The average length of *J. marmorata* individuals colonizing monthly sequential panels was 3.6mm at B19 and 3.5mm at B31 in 1995 (Table 7-4). A *t*-test indicated that there were no significant differences in length between the nearfield (B19) and farfield (B31) stations ($t=0.1$, $p>0.8$).

In 1995, *Balanus* sp. (including *Balanus* spp. *and Semibalanus balanoides* L.) was first found at Stations B19 and B31 in April, similar to previous years (Figure 7-7). Monthly percent frequencies in 1995 were high (>60%) at both stations during June through August, in contrast to the lower preoperational monthly means. With few exceptions, the operational monthly means at both stations were greater than the preoperational means but within the established 95% confidence limits.

During the preoperational period, *Tubularia* sp. generally first occurred in April at both stations, with the seasonal pattern of occurrence quite variable from year to year, as evidenced by the wide 95% confidence intervals (Figure 7-7). In 1995, *Tubularia* sp. first appeared during the summer at both stations. At B19, frequencies were higher than the preoperational 95% confidence limits during September and November. At Station B31, *Tubularia* sp. occurred only in July and October through December. During the operational period, *Tubularia* sp. has occurred later in the year (July at both B19 and B31) than during preoperational years.

Fifteen specimens of the woodboring "shipworm", *Teredo* sp., were found on the MS and QS panel blocks at Station B19 in October, November and December and at Station B31 in October and December (NAI 1996). *Teredo* sp. individuals have been recorded from MS panels several times in the past, at Station B19 in 1976 (NAI 1977) and 1979 (NAI 1981a) and at Station B31 in 1980 (NAI 1981b).

7.3.3 Quarterly Sequential Panels

Quarterly sequential (QS) panels provide additional information on growth and successional patterns of development within the fouling community, and through panel replication, allow assessment of within-station variability. Comparisons can be made with the preoperational period by using the monthly preoperational mean from the MS panel program for those months sampled in the QS program (Figure 7-7). Quarterly biomass levels were used to assess patterns of community development.

During 1995, biomass levels were first measurable in June and increased in September at both Stations B19 and B31; biomass continued to increase in December at B19 while decreasing at B31 (Figure 7-8). This seasonal trend paralleled those observed in ST

panels (Figure 7-2) and MS panels (Figure 7-6) both in 1995 and during the preoperational period. The annual average biomass in 1995 was higher than observed for MS panels (Table 7-1) and higher than in 1994 (NAI 1995). The nearfield and farfield biomass values were similar in 1995.

The number of taxa on QS panels in 1995 averaged 19.5 at Station B19 and 18.5 at Station B31 (Table 7-1), similar to the number observed in 1994. The number of taxa on QS panels averaged higher than on ST panels, reflecting the longer exposure period of the QS panels. There were 22 taxa present on the December QS (12-month exposure) panels at both stations, compared to 19 at Station B19 in 1994 and 14 at Station B31. The increase in number of taxa observed in December 1995 compared to 1994 was also noted in the long-term panels (Section 7.3.4).

No *Laminaria* sp. blades were collected on QS panels in 1995 (Table 7-1), as in 1994. While *Laminaria* sp. blades were present on the December MS (12-month exposure period) panels at both stations, they occurred in relatively low numbers.

Seasonal patterns of abundance of dominant animals on QS panels were examined in 1995. Mytilidae were not present during March but were present during the last three quarters with percent frequencies between 50% and 100% at both stations (Figure 7-8). Seasonal patterns in 1995 were similar to those observed during the preoperational period. In 1995, *Jassa marmorata* frequency of occurrence was low in March and June, but reached 25% or higher for the rest of the year at both stations. *J. marmorata* first appeared in June at both stations and reached a high in September at B19 and in December at B31. Frequencies in September and December 1995 were higher than the preoperational average at both stations (Figure 7-9). In 1995, *Balanus* sp. first appeared and peaked in June at both stations followed by a decline (Figure 7-9). Peak percent frequencies in 1995 (approximately 35% at B19 and 55% at B31) were lower than those observed during 1994 but higher than during the preoperational period. *Tubularia* sp. appeared and peaked in September at both Stations B19 (35%) and B31 (20%) (Figure 7-9). While peak occurrences were higher than observed during the same months preoperationally, they were lower than the peaks observed on MS panels in 1995 (Figure 7-7). The quarterly sampling regime misses the mid-summer months when the preoperational average has been highest on MS panels (Figure 7-7).

Mytilidae spat and *Jassa marmorata* measurements from QS panels in 1994 were compared to determine if mean lengths differed between the nearfield/farfield station pair. Mytilidae annual mean lengths averaged 4.2 mm at Station B19 and 3.3 mm at Station B31 (Table 7-5). This difference was not significant ($t=-0.32$, $p>0.7$). Average lengths of *J. marmorata* individuals colonizing QS panels averaged 2.6 mm at Station B31 and 2.8 mm at Station B19. There was no significant difference in length between the two stations ($t=0.30$, $p>0.7$).

7.3.4 One Year Panels

Community development was also assessed by examining biomass, species richness (number of taxa) and abundance on surface panels exposed for one year. Year-end biomass in 1995 at B19 was similar to the preoperational mean, whereas biomass at B31 was lower than the preoperational mean (Table 7-6). The values at both stations were elevated from the 1994 operational period lows (NAI 1995). Mean year-end biomass during the operational period was not significantly different from the preoperational mean at either Station B19 or B31 (Table 7-6).

The number of noncolonial taxa in 1995 was higher than the preoperational mean at Stations B19 and B31 (Table 7-6). The operational mean was significantly greater than the preoperational mean at Station B19, while there were no significant differences between the preoperational and operational means at Station B31. The number of noncolonial taxa at B19 was similar to 1994 and, at B31, was double that found in 1994 (NAI 1995). At both stations, the number of taxa in 1995 was lower than the average for the operational period (Table 7-6).

Non-colonial abundance in 1995 was higher than both the preoperational and operational mean abundance at B19 (Table 7-6). At B31, abundance in 1995 was higher than the preoperational mean, but similar to the operational mean. There were no significant differences between the preoperational and operational means at either station. Mean noncolonial abundance at the farfield station was higher than at the nearfield station during the operational period, consistent with the relationship between the preoperational means.

Laminaria sp. blade counts on one-year panels have been low during most years of this study. At nearfield Station B19, *Laminaria* sp. did not occur during three of the seven

preoperational years (NAI 1991, 1992, 1993) and has not occurred during any operational year until 1995 (Table 7-6). *Laminaria* sp. did occur during each preoperational year and early operational years at farfield Station B31, but was absent during 1993 and 1994 (NAI 1995; NAI and NUS 1994). Differences between operational and preoperational means were significant only at farfield Station B31.

7.4 DISCUSSION

The surface panels program was established to document the temporal and spatial patterns in the recruitment and development of the fouling community and to monitor the effects of Seabrook Station's operation on the community. The characteristics of Seabrook Station's thermal plume have been estimated from hydrothermal modeling studies (Teyssandier et al. 1974) and confirmed in recent field studies (Padmanabhan and Heckler 1991). Results from field studies generally confirmed initial model results, indicating that the discharge plume area was relatively small under the conditions tested. For example, the isotherm of a surface temperature increase of 3°F (1.7°C) covered a relatively small 32-acre area in the vicinity of the discharge area. Water temperatures were elevated at most by 2-3°F (under the conditions tested) in the approximate area where panels at nearfield Station B19 are deployed.

The community settling and developing on surface panels has shown predictable seasonal patterns throughout the study, as evidenced by both measures of community structure (biomass, abundance, and number of taxa) and abundance or percent frequency of occurrence of dominant taxa. During 1995, abundance varied seasonally on ST panels and biomass varied seasonally on both ST and MS panels. Biomass exhibited similar trends at nearfield and farfield stations on both ST and MS panels. Temporal patterns of total and Mytilidae (the most abundant taxon) abundance differed significantly between the nearfield and farfield stations (Table 7-2, Figure 7-4). Historically (Figure 7-3), there has been a pattern of fluctuating total and Mytilidae abundances repeated over a several-year period, suggesting that this difference is not indicative of plant effects. The number of taxa on ST panels was higher during the operational period than preoperationally. This pattern was consistent between stations and is, therefore, not related to the operation of Seabrook Station. In most cases, the operational means closely followed the historical patterns established during the preoperational period (Table 7-7), indicating that settlement and development of the local fouling community remains unaffected by the operation of Seabrook Station.

The year-end values for parameters measured for surface panels exposed for twelve months provide information on long-term successional development of the fouling community and reflect cumulative effects of biological processes such as recruitment, growth, and competition. One parameter, number of non-colonial taxa, showed a difference during the operational period that was not consistent between the nearfield-farfield station pair (Table 7-7). The mean number of non-colonial taxa was significantly higher at Station B19 (nearfield) during the operational period. Although the number of taxa was higher at the farfield station, this difference was not significant. The same pattern was observed in 1994 (NAI 1995) and a similar trend was observed in 1993 (NAI and NUS 1994), where significant differences were noted at both stations. The algal species *Laminaria* sp. was present in 1995 at both stations, although it continued to occur at low levels, reflecting the declining trend that began during the preoperational years (NAI, 1991, 1992, 1993, 1995, NAI and NUS 1994). However, the differences in abundance of *Laminaria* between the preoperational and the operational periods were significant only at the mid-depth farfield Station B31. There is no indication that this effect is due to Seabrook Station operation, since the decline occurred at both nearfield and farfield stations and began prior to the operation of Seabrook Station.

The quarterly sequential panel program was initiated in 1994 to provide information on within-station variability of settlement and development. Given the varying exposure period (3,6,9, and 12 months), the program parallels that of the community development (1-12 months exposure, MS) program. The methodology used is similar to the MS program, relying on percent frequencies for dominant taxa. Quarterly biomass values were similar to those observed in the MS program in 1995. The atypical fall decrease observed in MS and QS biomass levels in 1994 was not observed in 1995 when biomass returned to a more typical seasonal pattern. Selected species Mytilidae, *Balanus* sp. and *Jassa marmorata* collected in the QS program showed similar seasonal patterns and frequencies to the MS program, as would be expected. *Tubularia* sp. frequencies typically display a seasonal pattern in the MS program that is not consistently detected by the QS program. QS panel analyses demonstrate within-station variability was high for all parameters, a factor which should be taken into account in interpretation of MS and ST results.

The occurrence of the shipworm *Teredo sp.* in 1995 in QS and MS wooden blocks that support surface panels is not unexpected for the Seabrook area. Occasional specimens have been collected previously during the surface panels study, including 1976 and 1979 at

Station B19 and 1980 at Station B31 (NAI 1977, 1981a, b). Additionally, teredinid veliger larvae have been observed in bivalve larvae samples every year since 1984.

Teredo navalis is the most common teredinid reported for the Gulf of Maine (Grave 1928; Turner 1966), and is cosmopolitan in its distribution, being found in most semi-tropical to boreal ocean environments (Gosner 1971). Along the east coast of North America, it occurs from Newfoundland to Florida (Culliney 1975). While *T. navalis* is most abundant in temperate and semi-tropical waters south of Cape Cod, periodic outbreaks have been reported in more northern boreal waters, including the Gulf of Maine (Dow and Baird 1953). The mode of dispersion is through the larval stage; veliger larvae are planktonic for 2-3 weeks following release from the adult and can travel in ocean currents for hundreds of kilometers (Scheltema 1971; Nair and Saraswathy 1971).

Based on the historic documentation of *Teredo* in the Gulf of Maine by other researchers and in the Hampton-Seabrook area specifically during preoperational study years of these monitoring studies, and the fact that *Teredo sp.* was identified at both nearfield and farfield stations in 1995, the most recent occurrence in 1995 QS and MS panels is not indicative of an impact from Seabrook Station operation.

Overall, results in 1995 agree with those from previous years. There is no evidence that operation of Seabrook Station has had an effect on the local fouling community.

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TABLE 7-1. MEANS (PER PANEL) AND COEFFICIENT OF VARIATION (%) FOR SELECTED PARAMETERS AND SPECIES ABUNDANCES AT STATIONS B19 AND B31 DURING THE PREOPERATIONAL[b] AND OPERATIONAL PERIODS (1991-1995), AND 1995 MEANS. SEABROOK OPERATIONAL REPORT, 1995.

			PREOPERATIONAL[b]		1995	OPERATIONAL	
PARAMETER/ TAXON	PANEL[a] TYPE	STATION	MEAN[c]	CV	MEAN[c]	MEAN[c]	CV
Total no. of taxa	ST	B19	11.3	30.4	15.1	13.6	13.3
		B31	10.8	25.2	12.3	12.4	4.8
Total noncolonial abundance	ST	B19	53.7	17.2	101.7	79.5	11.8
		B31	69.9	18.2	74.4	67.4	14.1
Total biomass (g)	ST	B19	0.8	40.8	1.7	0.8	74.5
		B31	0.6	67.5	0.9	0.6	54.4
Mytilidae	ST	B19	30.4	22.6	60.1	45.0	18.8
		B31	39.6	21.1	54.0	39.9	23.5
Jassa marmorata	ST	B19	3.0	29.0	8.6	2.9	37.9
		B31	3.9	30.4	12.1	4.2	41.3
Tubularia spp.	ST	B19	1.9	51.2	3.6	2.2	21.2
		B31	1.1	73.6	3.2	1.0	89.0
Biomass (g)	MS	B19	207.8	106.6	172.1	197.2	49.3
		B31	236.8	90.0	141.1	193.6	36.3
Biomass (g)	QS	B19	--	--	237.8	194.6	--
		B31	--	--	259.6	208.3	--
Total number of taxa	QS	B19	--	--	19.5	20.8	--
		B31	--	--	18.5	17.3	--
Laminaria sp.	QS	B19	--	--	0	0	--
		B31	--	--	0	0	--

[a]ST = short term MS = monthly sequential QS = quarterly sequential
[b]Preoperational = 1978-1984; Jul 1986-Dec 1989
[c]Geometric mean for total abundance, Mytilidae, *J. marmorata* abundance and percent frequency of occurrence for *Tubularia* sp. Preop. and Op. means are means of annual means.

TABLE 7-2. RESULTS OF ANALYSIS OF VARIANCE COMPARING MONTHLY TOTAL NUMBER OF TAXA, NONCOLONIAL FAUNAL ABUNDANCE, TOTAL BIOMASS, AND SELECTED SPECIES ABUNDANCE OR PERCENT FREQUENCY ON SHORT TERM PANELS AT THE MID-DEPTH STATION PAIR (B19 AND B31) DURING PREOPERATIONAL (1978-1989) AND OPERATIONAL (1991-1995) PERIODS. SEABROOK OPERATIONAL REPORT, 1995.

PARAMETER	STATIONS	SOURCE OF VARIATION	df	S	F[f]	MULTIPLE COMPARISONS[g]
Number of taxa	B19, B31	Preop-Op[a]	1	305.10	47.58***	Op>Preop
		Year (Preop-Op)[b]	14	128.96	20.11***	
		Month (Year)[c]	166	86.11	13.43***	
		Station[d]	1	50.55	7.88**	B19>B31
		Preop-Op X Station[e]	1	11.12	1.73 NS	
		Error	180	6.41		
Noncolonial faunal abundance	B19, B31	Preop-Op	1	0.39	4.51*	Op>Preop
		Year (Preop-Op)	14	1.57	18.10***	
		Month (Year)	166	2.43	27.99***	
		Station	1	0.05	0.57 NS	
		Preop-Op X Station	1	0.69	7.97**	B19Op B31Preop B31Op B19Preop
		Error	180	0.09		
Biomass	B19, B31	Preop-Op	1	0.43	0.47 NS	
		Year (Preop-Op)	12	2.56	2.79**	
		Month (Year)	146	2.79	3.05***	
		Station	1	3.02	3.30 NS	
		Preop-Op X Station	1	0.01	0.01 NS	
		Error	158	0.92		
Mytilidae	B19, B31	Preop-Op	1	0.50	4.81*	Op>Preop
		Year (Preop-Op)	14	2.14	20.85***	
		Month (Year X Preop)	166	2.86	27.49***	
		Station	1	0.08	0.79 NS	
		Preop-Op X Station	1	0.56	5.38*	B19Op B31Preop B31Op B19Preop
		Error	180	0.10		

PARAMETER	STATIONS	SOURCE OF VARIATION	df	S	F[f]	MULTIPLE COMPARISONS[g]
Jassa marmorata	B19, B31	Preop-Op	1	<0.01	0.01 NS	
		Year (Preop-Op)	14	0.87	9.79***	
		Month (Year X Preop)	166	0.82	9.18***	
		Station	1	0.92	10.34**	B31>B19
		Preop-Op X Station	1	0.05	0.53 NS	
		Error	180	0.09		
Tubularia sp.	B19, B31	Preop-Op	1	0.01	0.04 NS	
		Year (Preop-Op)	14	0.91	6.32***	
		Month (Year X Preop)	166	0.75	5.23***	
		Station	1	2.06	14.32***	B19>B31
		Preop-Op X Station	1	0.08	0.53 NS	
		Error	180	0.14		

[a]Preop-Op = 1991-1995 v. previous years (1978-84; July 1986-December 1989) regardless of station
[b]Year nested within preoperational and operational periods regardless of station
[c]Month nested within year regardless of station
[d]Station regardless of year or period
[e]Interaction between main effects Station and Preop-Op
[f]NS = Not significant ($p>0.05$)
* = Significant ($0.05 \geq p > 0.01$)
** = Highly significant ($.01 \geq p > 0.001$)
*** = Very highly significant ($0.001 \geq p$)
[g]Ranked in decreasing order
LS means multiple means test used for significant interaction term

TABLE 7-3. ANOVA RESULTS COMPARING MONTHLY SEQUENTIAL PANEL BIOMASS AT THE MID-DEPTH (B19, B31) STATION PAIR DURING PREOPERATIONAL (1978-1989) AND OPERATIONAL (1991-1995) PERIODS. SEABROOK OPERATIONAL REPORT, 1995.

STATIONS	SOURCE OF VARIATION	df	MS	F[f]
Mid-depth	Preop-Op[a]	1	4,756.22	0.42 NS
B19, B31	Year (Preop-Op)[b]	14	276,118.10	24.61***
	Station[c]	1	6,395.16	0.57 NS
	Month (Year)[d]	156	129,656.88	11.55***
	Preop-Op X Station[e]	1	38,260.42	3.41 NS
	Error	170	11,221.74	

[a]Preop-Op = 1991-1995 v. previous years (1978-84; July 1986-December 1989)
[b]Year nested within preoperational and operational periods regardless of station
[c]Station regardless of year or period
[d]Month nested within year regardless of station
[e]Interaction between main effects
[f]NS= Not significant (.05>p)
* = Significant (.01<p≤.05)
** = Highly significant (.001<p≤.01)
*** = Very highly significant (p≤.001)

TABLE 7-4. NEARFIELD/FARFIELD COMPARISON OF ANNUAL MEAN AND STANDARD ERROR OF *JASSA MARMORATA* AND MYTILIDAE SPAT LENGTHS (mm) FROM MONTHLY SEQUENTIAL PANELS COLLECTED IN 1995. SEABROOK OPERATIONAL REPORT, 1995.

		MYTILIDAE SPAT		*JASSA MARMORATA*	
STATION		MEAN LENGTH (mm)	STANDARD ERROR	MEAN LENGTH (mm)	STANDARD ERROR
Mid-depth	B19	3.0	0.97	3.6	0.48
	B31	2.9	0.94	3.5	0.43

TABLE 7-5. NEARFIELD/FARFIELD COMPARISON OF ANNUAL MEAN AND STANDARD ERROR OF MYTILIDAE SPAT AND *JASSA MARMORATA* LENGTHS (mm) FROM QUARTERLY SEQUENTIAL PANELS COLLECTED IN 1995. SEABROOK OPERATIONAL REPORT, 1995.

	MYTILIDAE SPAT		*JASSA MARMORATA*	
STATION	MEAN LENGTH (mm)	STANDARD ERROR	MEAN LENGTH (mm)	STANDARD ERROR
B19	4.2	2.23	2.8	0.55
B31	3.3	1.93	2.6	0.55

TABLE 7-6. DRY WEIGHT BIOMASS, NONCOLONIAL NUMBER OF TAXA, ABUNDANCE, AND *LAMINARIA* SP. COUNTS ON SURFACE FOULING PANELS SUBMERGED FOR ONE YEAR[a] AT STATIONS B19 AND B31. MEAN AND STANDARD DEVIATION FOR THE PREOPERATIONAL PERIOD (1982-1984 AND 1986-1989) AND MEAN FOR 1995, AND THE OPERATIONAL PERIOD (1991-1995). SEABROOK OPERATIONAL REPORT, 1995.

	STATION	PREOPERATIONAL MEAN	PREOPERATIONAL S.D.	1995 MEAN	OPERATIONAL[c] MEAN	OPERATIONAL[c] S.D.
BIOMASS (g/panel)	B19	661.5	476.88	601.2	749.1 NS	506.49
	B31	708.9	523.86	437.4	510.0 NS	271.47
NUMBER OF NON-COLONIAL TAXA (No./panel)	B19	21.3	4.42	24.0	29.5 *	4.80
	B31	25.9	4.60	30.0	31.0 NS	11.45
NONCOLONIAL ABUNDANCE (No./panel)	B19	13,905.1	7,046.48	77,209.0	41,111.3 NS	34,032.68
	B31	21,967.6	18,398.27	58,961.0	59,481.8 NS	35,261.04
LAMINARIA SP.[b] (No./panel)	B19	24.3	36.91	1.0	0.3 NS	0.50
	B31	39.3	29.24	9.0	6.4 *	6.43

*.01<p≤.05 when preoperational and operational means tested for equality with a single sample *t*-test (SAS 1985)
[a]December MS panel only (one replicate)
[b]not determined to species due to juvenile condition of most plants
[c]B19:1991, 1993-1995; B31:1991-1995. B19 panel lost due to weather

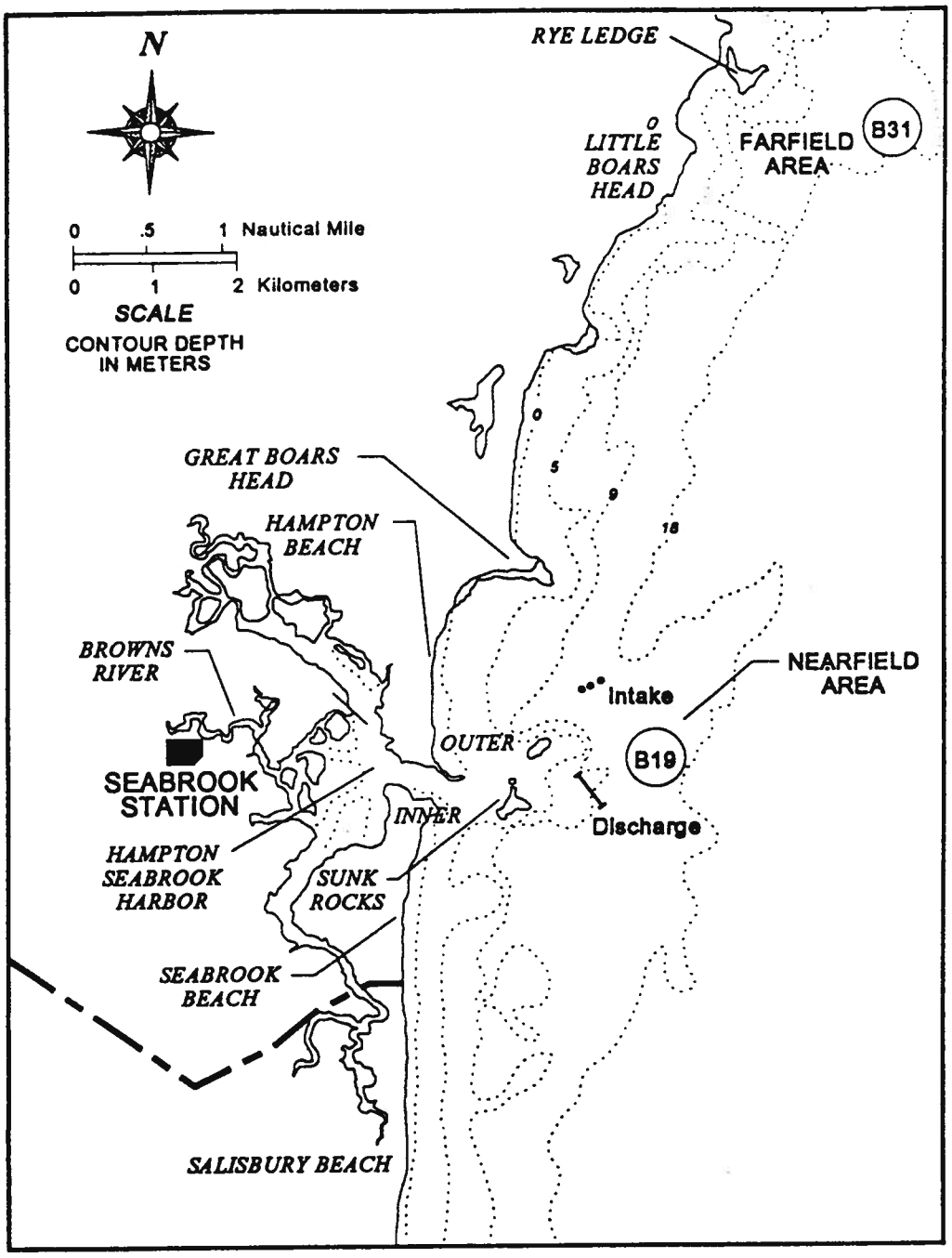
TABLE 7-7. SUMMARY OF EVALUATION OF DISCHARGE PLUME EFFECTS ON THE FOULING COMMUNITY IN VICINITY OF SEABROOK STATION. SEABROOK OPERATIONAL REPORT, 1995.

COMMUNITY	DEPTH ZONE	PARAMETER[a]	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS?	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[b]
Fouling community: Settlement[c]	Mid-depth	Abundance	no	NF:Op>Preop FF:Op=Preop
		No. of taxa	no	yes
		Biomass	yes	yes
Fouling community: Development-MS[c]	Mid-depth	Biomass	yes	yes
Fouling community: Development-year end[c]	Mid-depth	Abundance	yes	yes
		No. of taxa	no	NF:Op>Preop FF:Op=Preop
		Biomass	yes	yes
Fouling community: Settlement[c]	Mid-depth	Mytilidae	no	NF:Op>Preop FF:Op=Preop
	Mid-depth	*Jassa marmorata*	yes	yes
	Mid-depth	*Tubularia* sp.	yes	yes

[a]Abundance, number of taxa, biomass, total density, and frequency of occurrence evaluated using ANOVA, or *t*-test

[b]NF = nearfield FF = farfield

[c]Settlement = short term panels; Development = monthly sequential panels - MS; year end = one year exposure

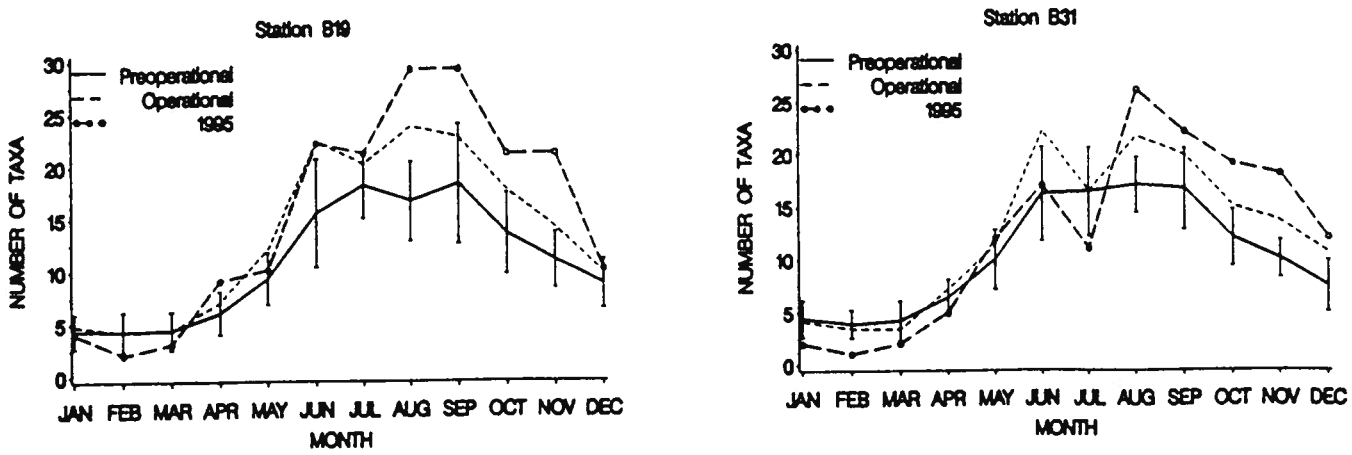


LEGEND

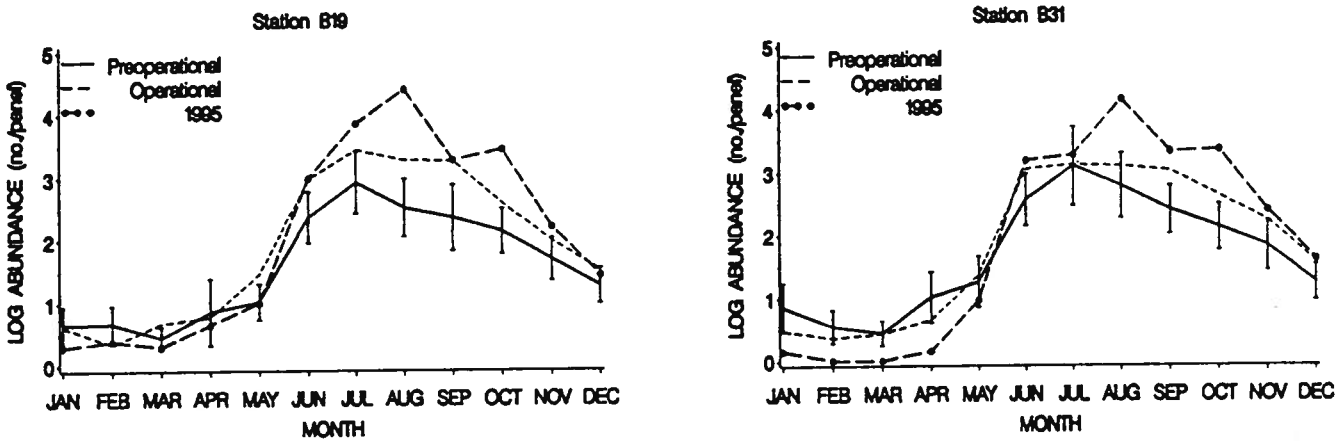
◯ = surface panels

Figure 7-1. Surface panel sampling stations. Seabrook Operational Report, 1995.

Number of Taxa



Log(x+1) Abundance



Biomass

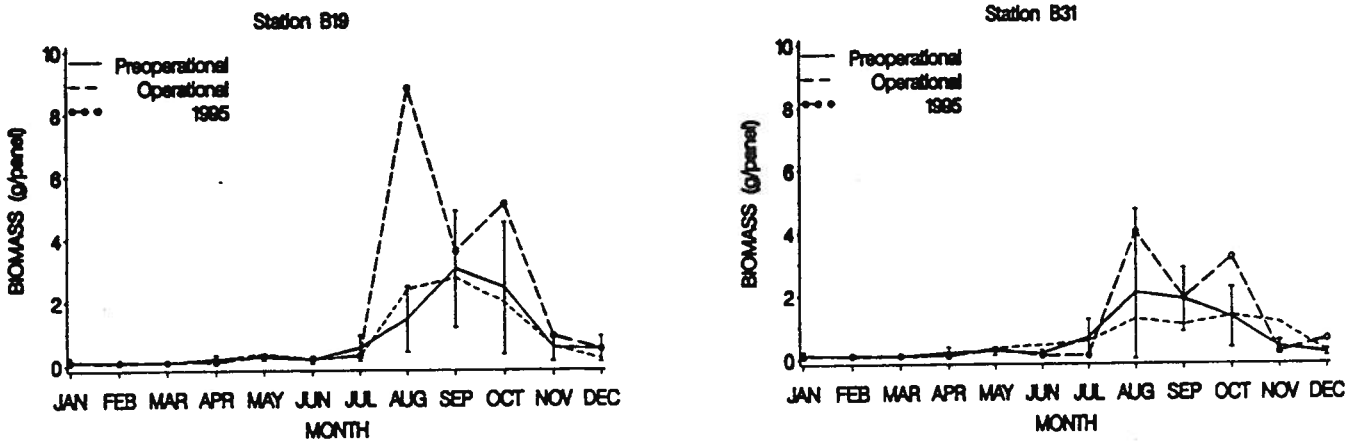
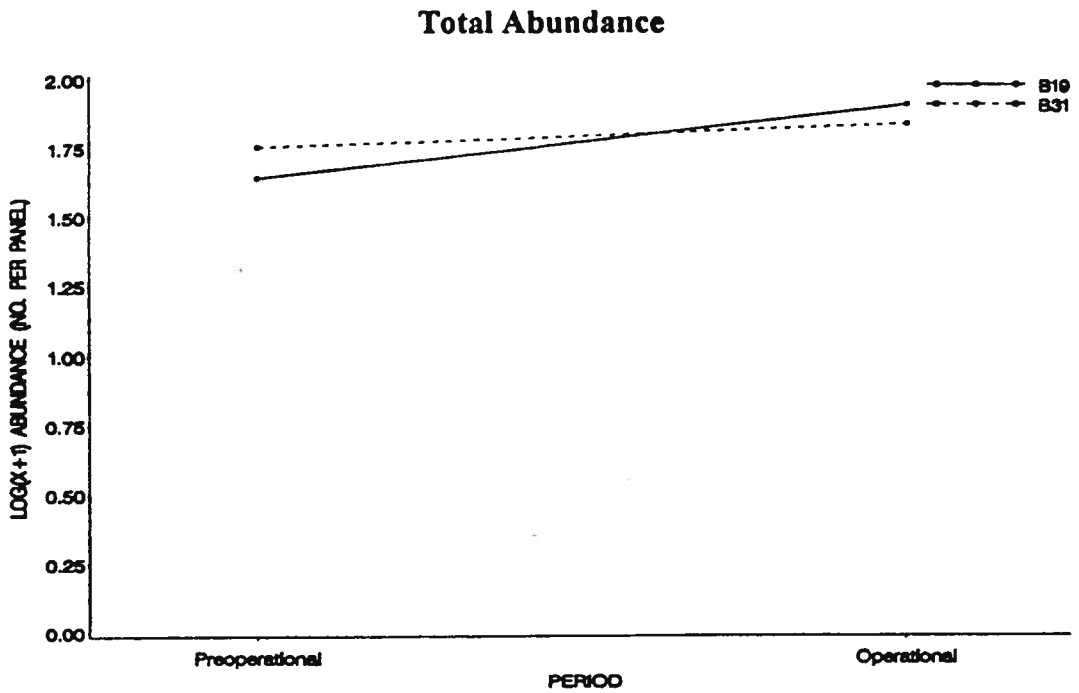


Figure 7-2. Monthly faunal number of taxa (on two relicate panels), abundance, and biomass on short-term panels at the nearfield/farfield station pair B19 and B31during the operational period (1991-1995) and 1995 compared to the means and 95% confidence limits during the preoperational period (1978-1984; July 1986-December 1989). Seabrook Operational Report, 1995.



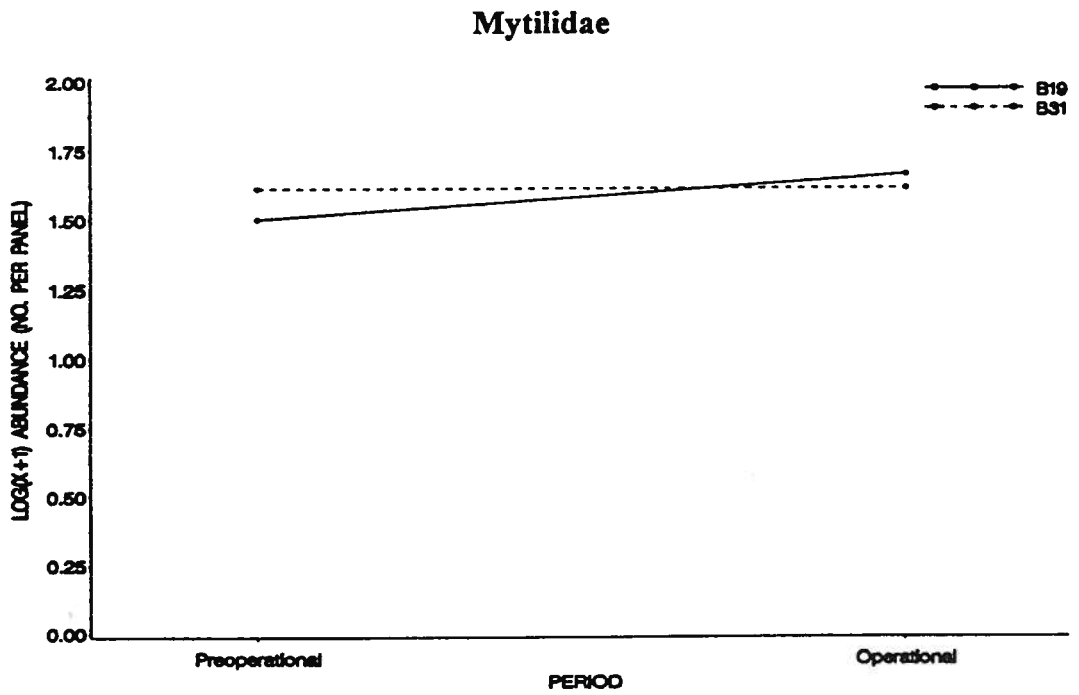
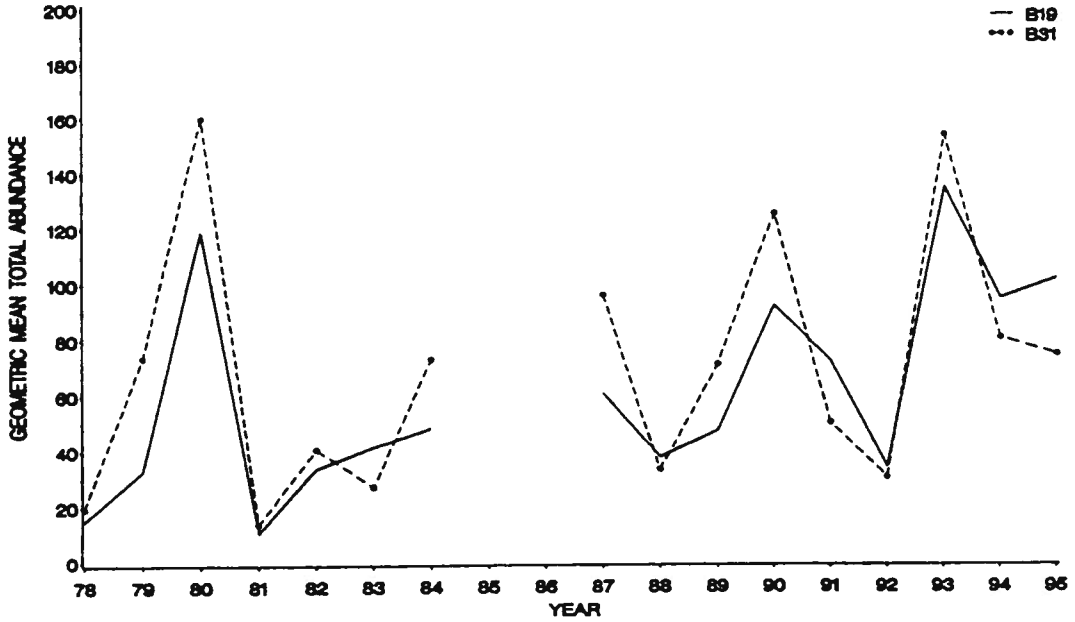


Figure 7-3. A comparison between stations of the $\log_{10}(x+1)$ no. per panel total abundance and Mytilidae abundance in short-term panels during the preoperational (1978-1985; 1987-1989) and operational (1991-1995) periods. Seabrook Operational Report, 1995.

Total Abundance



Mytilidae

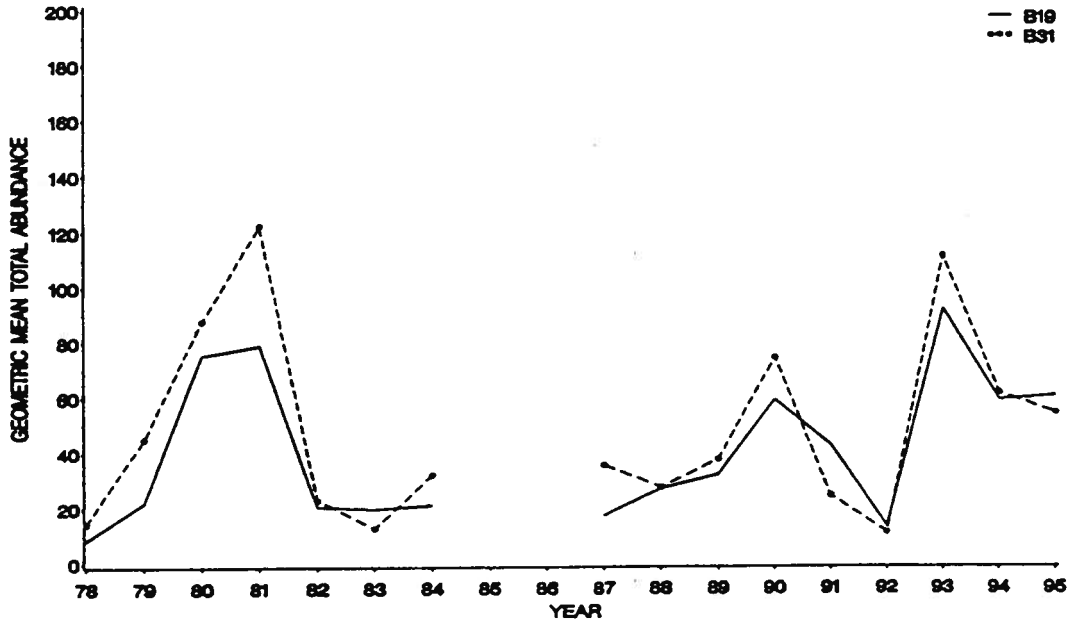
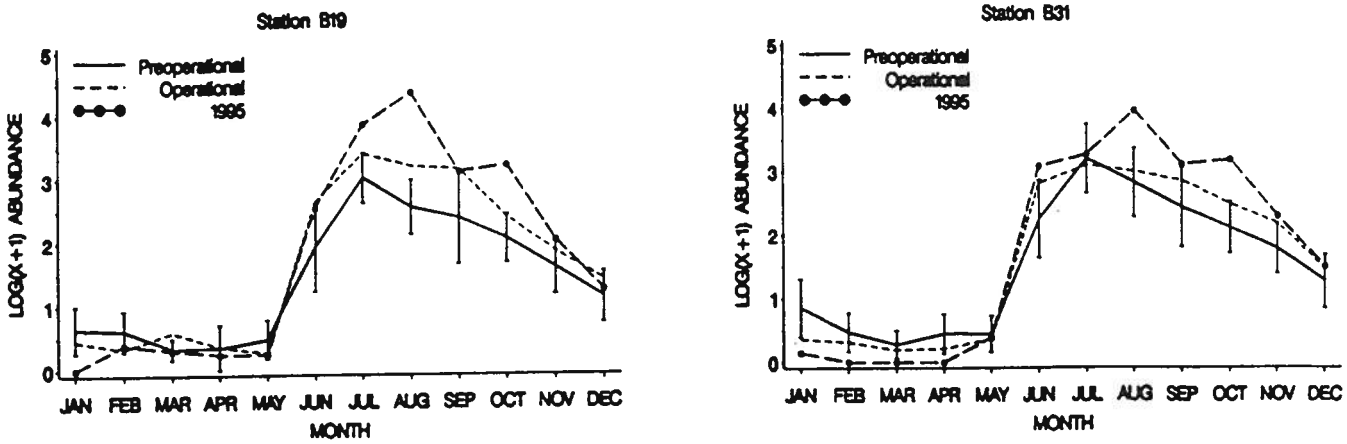
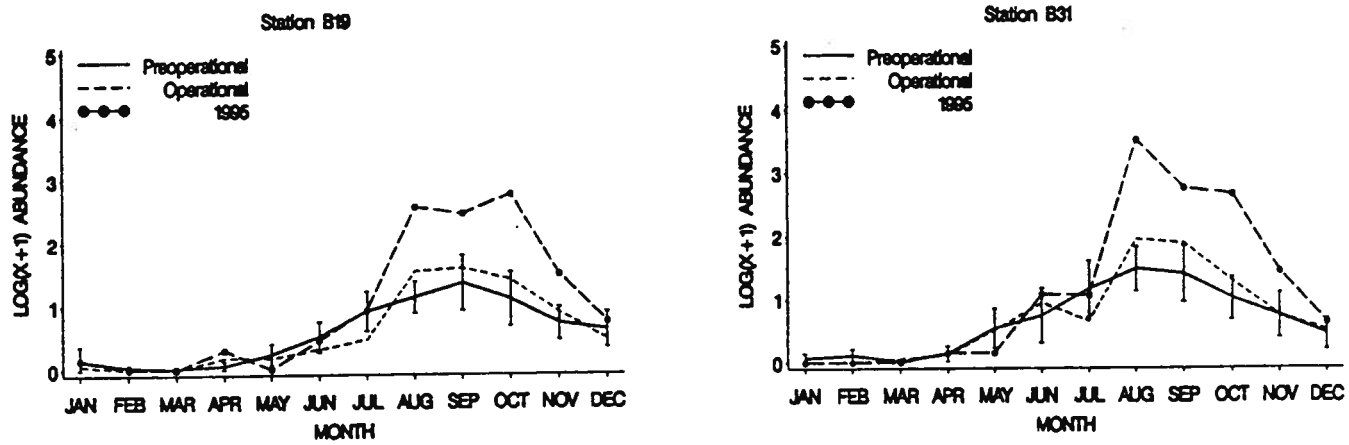


Figure 7-4. Annual geometric total abundance and abundance of Mytilidae on short-term panels at Stations B19 and B31, 1978-1995. Seabrook Operational Report, 1995.

Mytilidae



Jassa marmorata



Tubularia sp.

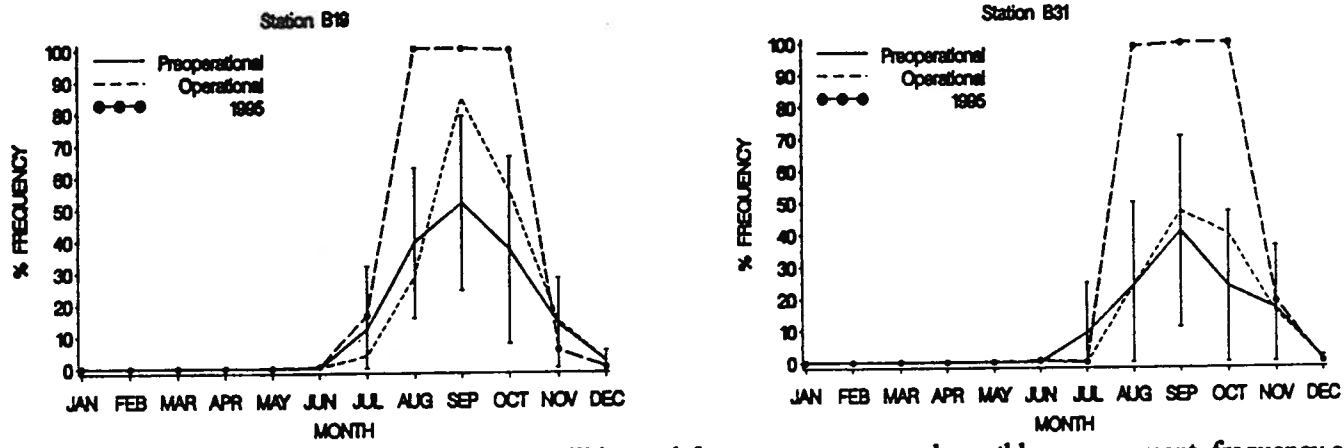
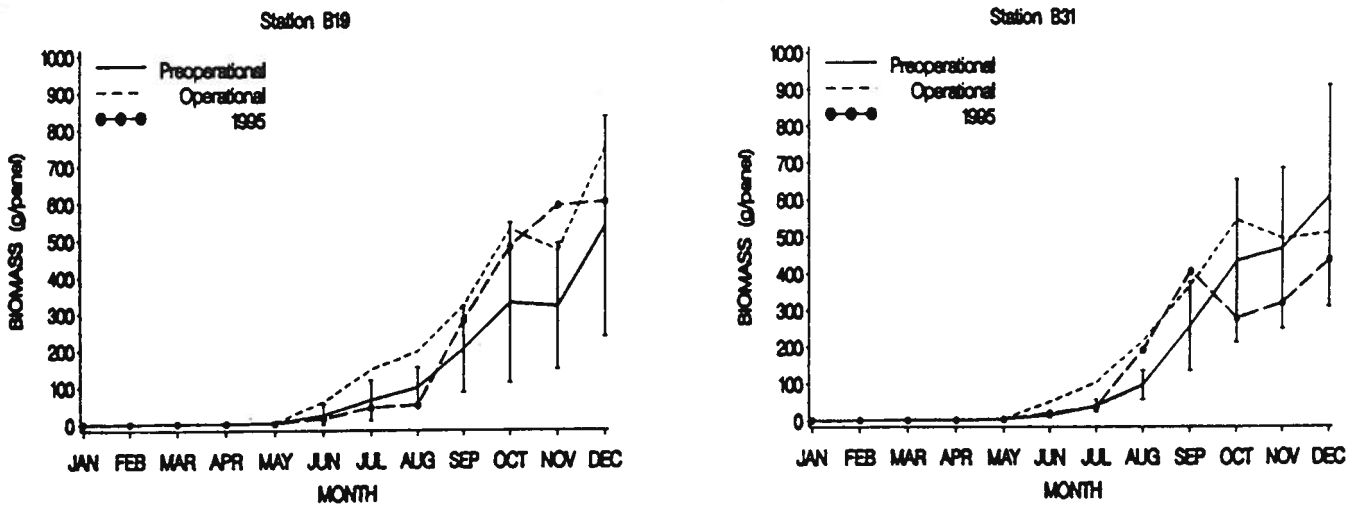


Figure 7-5. Log abundance (no. per panel) of Mytilidae and *Jassa marmorata* and monthly mean percent frequency of *Tubularia* sp. on short-term panels at nearfield Stations B19 and B31 during the operational period (1991-1995) and 1995 compared to the mean abundance or percent frequency and 95% confidence limits during the preoperational period (1982-1984; July 1986- December 1989). Seabrook Operational Report, 1995.

Biomass



Mytilidae

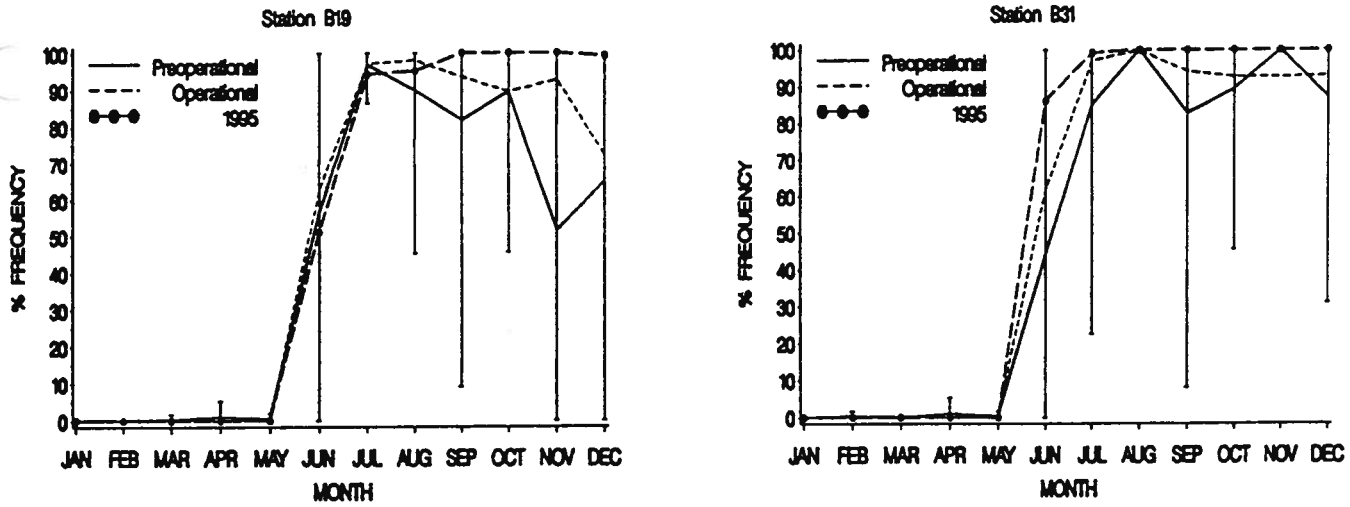
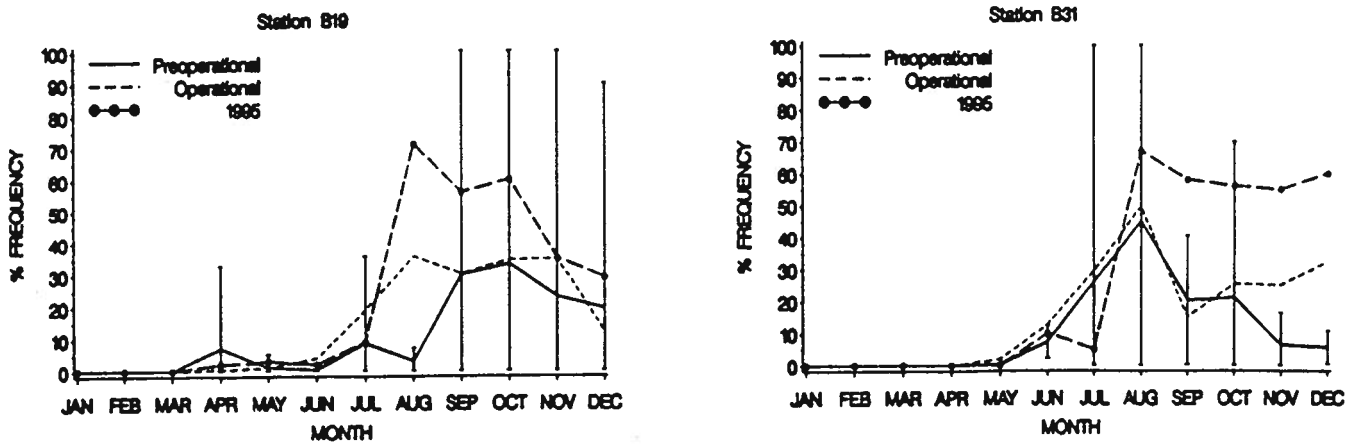
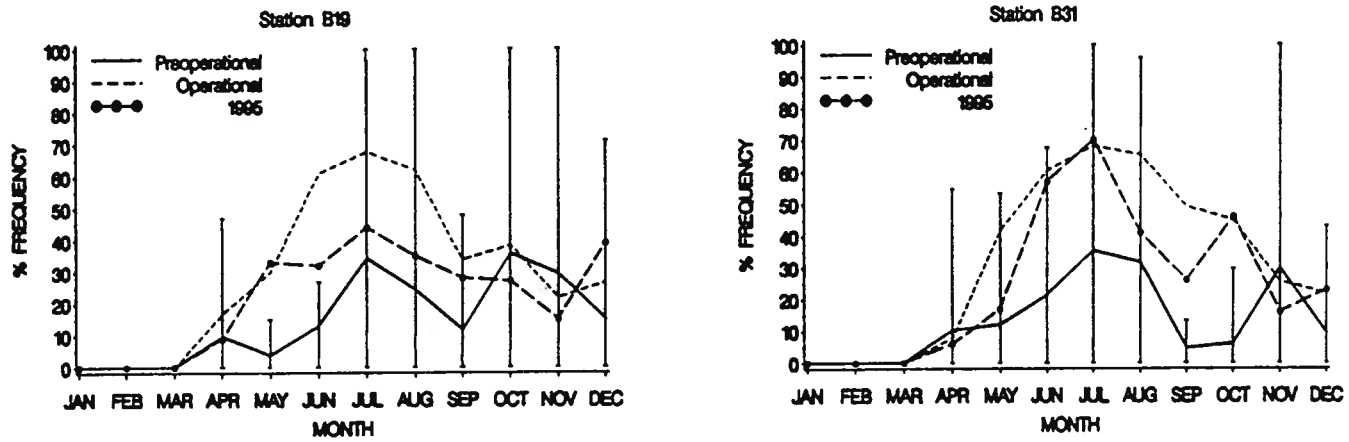


Figure 7-6. Mean biomass (g/panel) and Mytilidae spat (percent frequency of occurrence) during the operational period (1991-1995) and in 1995 compared to mean and 95% confidence limits during the preoperational period (Stations B19 and B31 from 1978-1984 and July-December 1986-1989 for biomass and 1987-1989 for Mytilidae) on monthly sequential panels. Seabrook Operational Report, 1995.

Jassa marmorata



Balanus sp.



Tubularia sp.

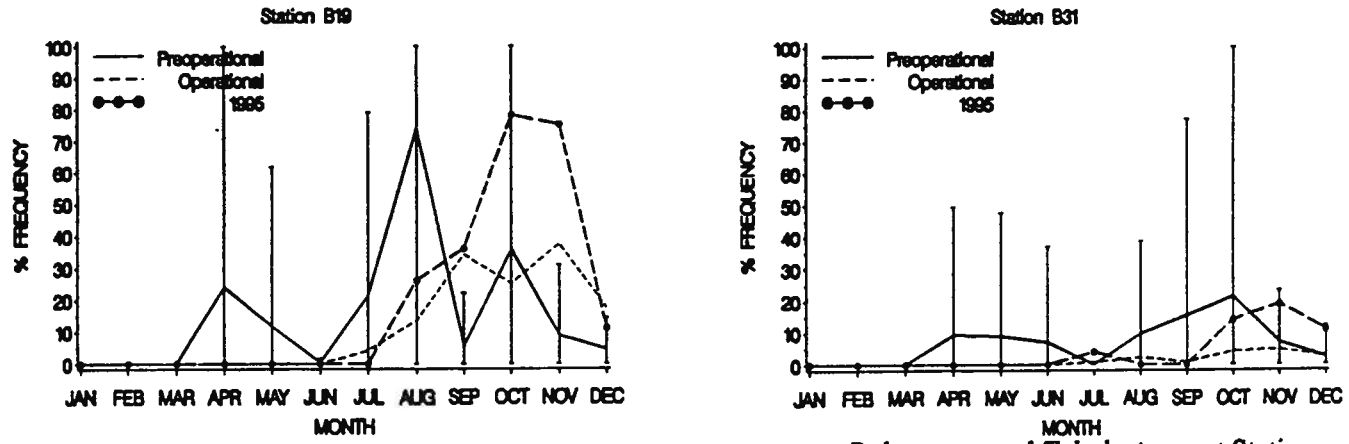
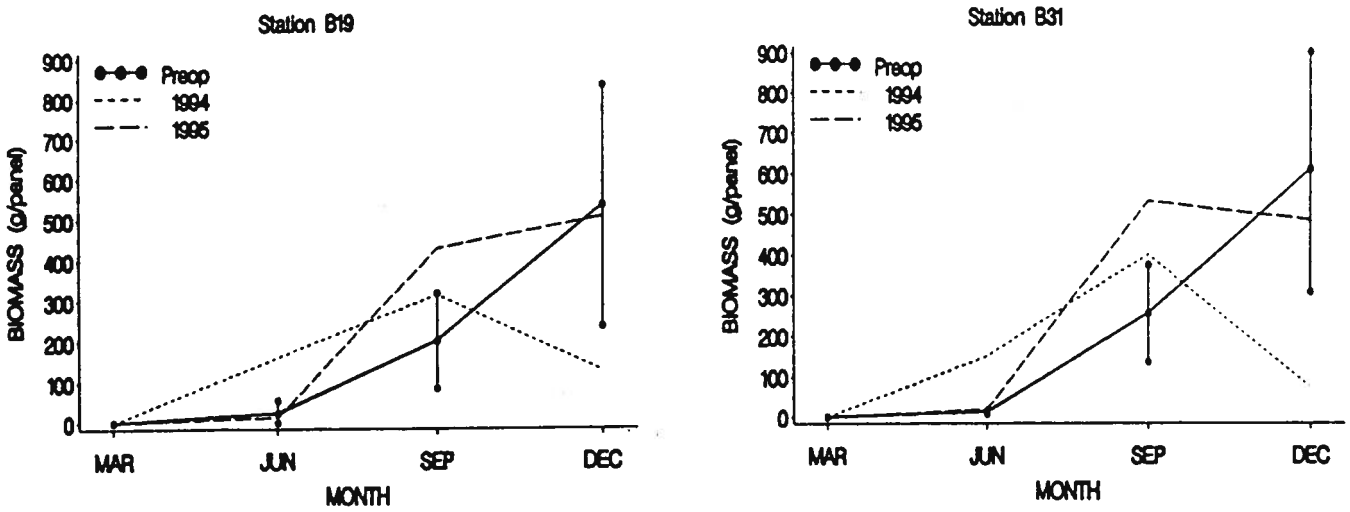


Figure 7-7. Mean percent frequency of occurrence for *Jassa marmorata*, *Balanus* sp. and *Tubularia* sp. at Stations B19 and B31 during the operational period (1991-1995) and in 1995 compared to means and 95% confidence limits during the preoperational period (1987-1989) on monthly sequential panels. Seabrook Operational Report, 1995.

Biomass



Mytilidae

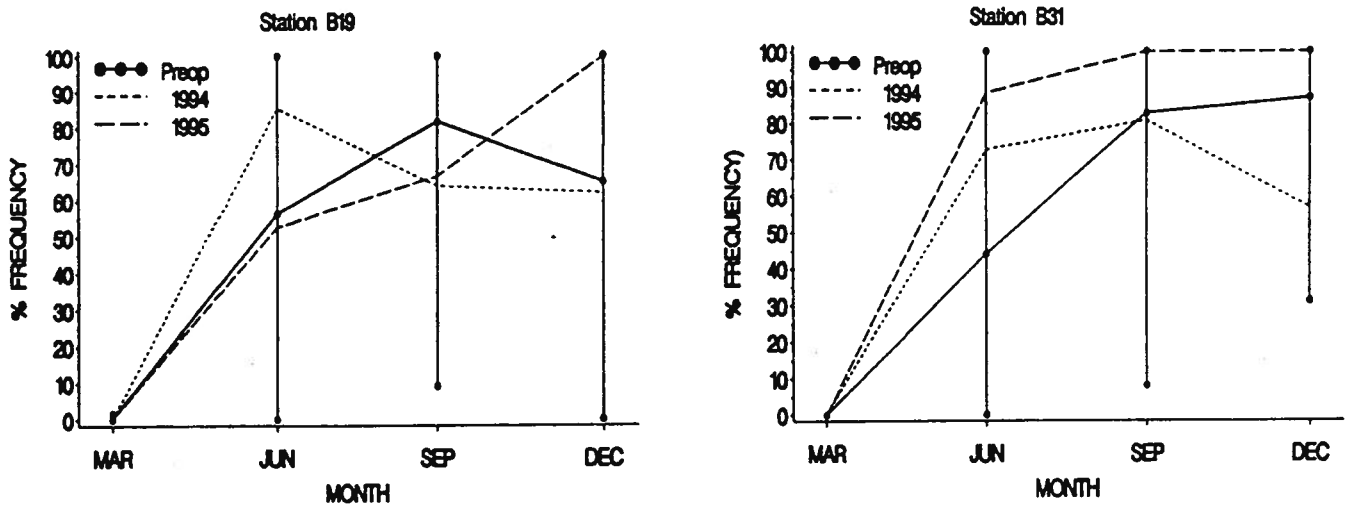
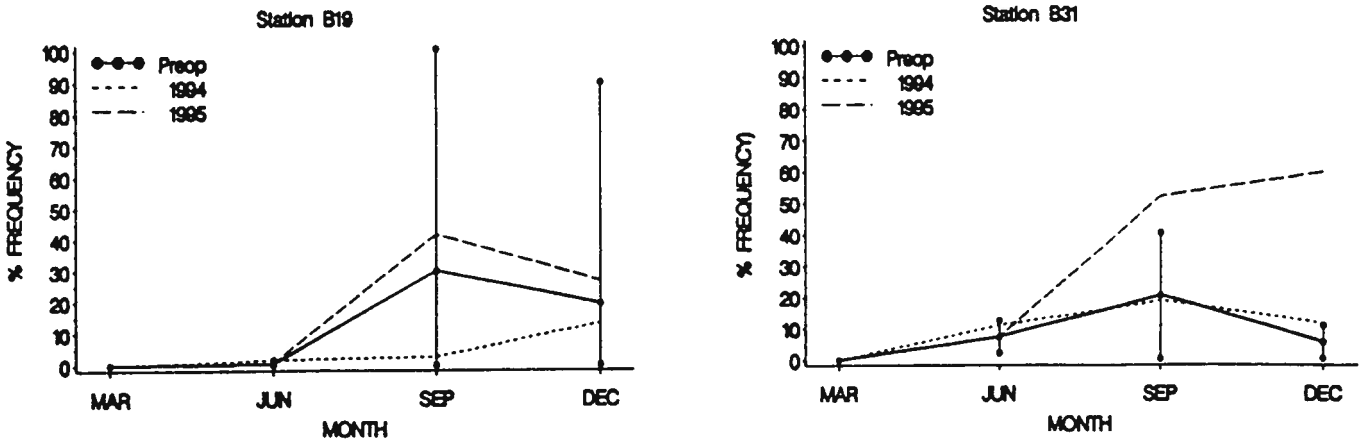
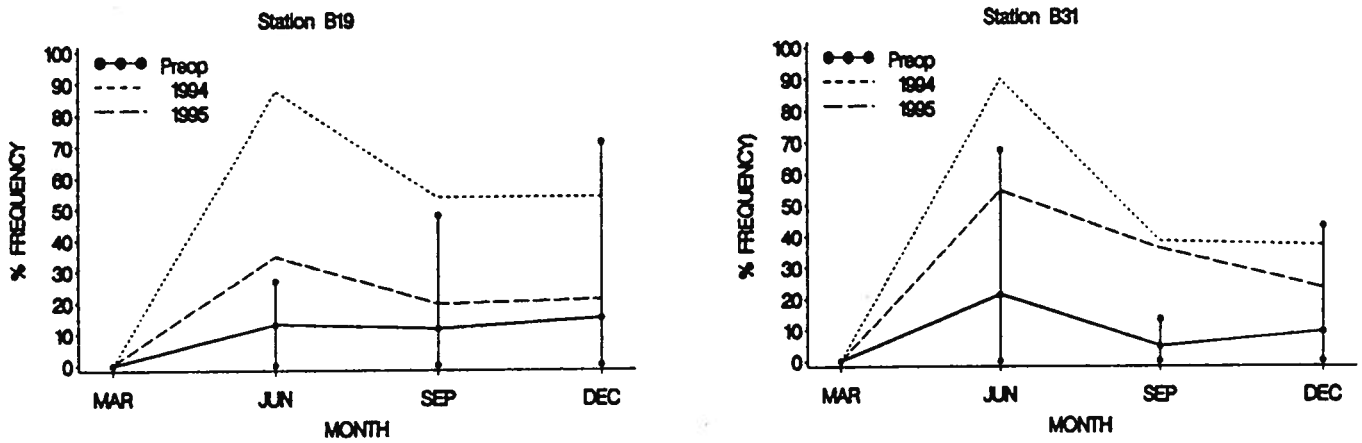


Figure 7-8. Mean biomass (g/panel) and Mytilidae spat (percent frequency of occurrence) and 95% confidence limits (n=3) during 1995 from Stations B19 and B31 on Quarterly Sequential panels compared to the monthly preoperational means (1987-1984 and 1986-1989 for biomass and 1987-1989 for Mytilidae). Seabrook Operational Report, 1995.

Jassa marmorata



Balanus sp.



Tubularia sp.

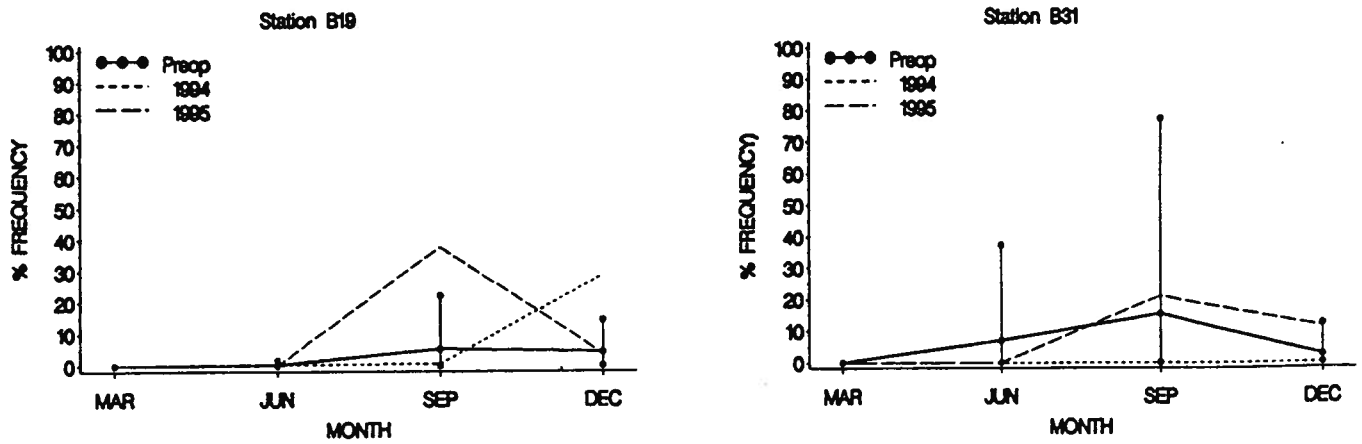


Figure 7-9. Mean percent frequency of occurrence for *Jassa marmorata*, *Balanus* sp. and *Tubularia* sp. at Stations B19 and B31 during 1994 and 1995 compared to the monthly preoperational means and 95% confidence limits (1987-1989) on Quarterly Sequential panels. Seabrook Operational Report, 1995.

EVALUATION OF SEABROOK STATION SURFACE PANELS PROGRAM AFTER FIVE YEARS OF PLANT OPERATION

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July 1996

Evaluation of Seabrook Station Surface Panels Program
After Five Years of Plant Operation

Introduction

Use of artificial substrata (e.g., exposure panels) is an effective experimental method to study marine benthos that occur on hard surfaces. Standardized substrata (size, material and surface texture, depth and orientation in the water column) are intended to simulate natural hard surfaces, while removing factors such as surface heterogeneity and orientation that produce variability naturally associated with the colonization of submerged surfaces (Osman 1977, 1982; Sutherland and Karlson 1977). The capability of deployment at specific locations ensures that panels and the developing fouling community are exposed to the desired degree of the stress of interest (Brown and Moore 1977; Schoener 1982) and the ability to take exposed panels to the laboratory permits closer examination than is possible in the field (Cairns 1982). Therefore, when appropriate, exposure panel studies have been included in many environmental monitoring programs (Cory and Nauman 1969; Hillman 1975, 1977; Osman et al. 1981; NUSCO 1987; NAI 1996a).

The surface fouling panels program initated at Seabrook Station in 1975 was designed and implemented with two objectives. The first objective was to determine the composition and characteristics of the local fouling community, identifying species that could settle on power plant structures and impair their operability. The second objective was to determine if the operation of Seabrook Station affected patterns of fouling species settlement and community development.

The Seabrook Station condenser cooling water discharge could potentially impact the local fouling community in several ways. Changes to water circulation patterns around nearby hard surfaces could affect abundance and species composition of available colonizers. Elevated temperatures could impact the exposed fouling community by affecting rates of recruitment and growth of settled organisms, changing long-term patterns of successional development. Finally, the power plant discharge could affect the distribution or behavior of motile grazers and predators which are important structuring factors in the fouling community. The purpose of this report is to evaluate the current surface panels program to: 1) determine how well the program has addressed its two objectives after over 20 years of study that include five years (1991-1995) of Seabrook Station operation; 2) identify any redundancy with other studies of the Seabrook monitoring program (such as the marine macrobenthos studies); and 3) determine if any questions remain that would merit continued surface panel monitoring.

Review of Methodology

The sampling methodology and data analyses used in the surface panels program were designed to focus on key aspects of the fouling community (e.g., community parameters, selected taxa) at sites determined to be most likely impacted by Seabrook Station operation. A synopsis of the historical development of this program was presented in NUSCO (1993).

In the present surface panels program, fouling panels (10.2 cm x 10.2 cm roughened plexiglas plates bolted to pine blocks of equal size) have been deployed at two stations: B19 in the

discussed by Stewart-Oaten et al. (1986) was used to test for potential impacts of plant operation. A significant interaction term (Preop-Op X Station) was investigated by comparing least-squares estimates of means. Paired t-tests were also used to compare preoperational/operational period differences in biomass, number of taxa and abundance on surface panels exposed for one year, and differences in average annual lengths of Mytilidae and *Jassa marmorata* between nearfield and farfield stations. Further details of sampling methodology and data analyses are provided in NAI (1996a).

Results and Discussion

Information critical to assessment of fouling community impacts related to Seabrook Station operation includes extensive physical and biological data. Hydrodynamic modeling, conducted prior to plant start-up to predict the areal extent of the thermal plume under various meteorological and marine current regimes, indicated considerable dilution of thermal effluent once the plume reached surface waters in close proximity to the discharge ($\Delta T \approx 3\text{-}4°F$), and that further dilution ($\Delta T \leq 2°F$) at the surface would occur within relatively short distances (0.5-1.0 km) from the discharge area (Teyssandier et al. 1974). Subsequent field validation studies were conducted after Seabrook Station began operation during October-November 1990. This period was chosen because there was no vertical temperature stratification, similar to conditions used in the hydrodynamic model. Conclusions from these studies were consistent with modeling predictions, and estimated the area within the 3°F ΔT isotherm to be a relatively small 32 acres

of surface water near the discharge (Padmanabhan and Hecker 1991). Based on both studies, surface panels at the nearfield B19 station were exposed to a maximum ΔT of 2-3° F (Fig. 2). Temperature increases at the nearest potentially-exposed natural hard substrate habitats were <1°F (i.e., at the intertidal and shallow subtidal sites near the Outer Sunk Rocks monitored through marine macrobenthos studies (NAI 1996b)).

Analyses of biological data collected during the surface panels program have shown very consistent patterns of fouling species settlement and community development over the entire study period, including the first five years (1991-1995) of Seabrook Station operation (NAI 1996a). Assessment of seasonal settlement patterns was based on results of the short-term panels study. While ANOVAs indicated significant differences among months and years, and between stations for community indices and abundances of dominant taxa, the Preop-Op X Station interaction term was significant for only two parameters (Total noncolonial abundance and Mytilidae abundance; Table 1). In both cases, increases from the preoperational to operational period were observed at the nearfield station (B19), while no between-period changes were observed at the farfield station (B31).

To further investigate these apparent increases in abundance since 1990 in the nearfield area, the nonparametric Wilcoxon's signed-rank test (Lehmann 1975) was used to compare nearfield and farfield monthly time-series. This test provided strong support to the ANOVA results by concluding that there were significant differences between nearfield and farfield stations (B19<B31) for total non-colonial and Mytilidae abundance during the preoperational period ($n=123$; $p=0.013$ for non-colonials and $p=0.018$ for Mytilidae), and no significant differences after 1990 ($n=59$; $p=0.428$ for non-colonials and $p=0.446$ for Mytilidae).

Periodic enhancement of mytilid abundance has been documented near effluents of other power plants in New England, but these changes were short-lived (several months), with no long-term effect on long-term benthic community structure (BECO 1995; NUSCO 1996). While these analyses indicate possible increases in Mytilidae and total abundance in the nearfield area during the operational period, time-series of annual means for these parameters for nearfield and farfield stations exhibited remarkably similar patterns (Fig. 3). For both parameters, it appears that the operational period increase at the nearfield station was largely the result of a single year of exceptionally high abundance (1993). Given the documented spatial and temporal variability in abundance patterns exhibited by Mytilidae in these studies and elsewhere (Menge 1976; Seed 1976; Fell and Balsamo 1985; King et al. 1985; Newell et al. 1991; Petraitis 1991; Seed and Suchanek 1992) and the overall dominance of this taxon on surface panels, the changes noted during the operational period are not consistent with a power plant impact.

Mytilidae abundance and total faunal density were also monitored on the nearest natural hard surfaces as part of the marine macrobenthos destructive sampling studies. These studies revealed no changes in Mytilidae abundance or total faunal density on submerged rock ledges during Seabrook operation for all four nearfield/farfield pairs, including the B19/B31 pair near surface panel study sites (NAI 1996b). Another component of the marine macrobenthos program, the subtidal bottom panels program, monitored settlement of benthic organisms, including Mytilidae, on artificial substrata placed near natural hard surfaces. Results of this study indicated increases in Mytilidae abundance during the operational period at both the nearfield (B19) and farfield (B31) stations, which is not consistent with a power plant impact. Similarly, macrozooplankton studies showed an overall increase in Mytilidae plantigrade larvae during the operational period

in both nearfield and farfield areas.

Annual development of the fouling community was assessed through analyses of monthly sequential and quarterly sequential panel data. Seasonal abundance patterns of selected taxa on monthly sequential panels were similar between preoperational and operational years. Statistical analysis of community indices (Table 1) indicated a difference between stations in preoperational-operational periods trends in one instance (no. of taxa); however, this result (i.e., an increase during the operational period at the nearfield station, with no difference at the farfield station), taken in context with the between-period similarity of most other study parameters, does not represent a change of developing fouling community beyond what is expected from natural variability. Results of the quarterly sequential panel study in 1995 were consistent with monthly sequential panel results, and through panel replication, provided information on within-station variability. For most parameters analyzed (biomass, abundance of selected taxa), variability within a collection was quite high, particularly during peak periods (NAI 1996a). Similar variability has been documented in other exposure panel studies (e.g., Brown and Moore 1977).

The 15 *Teredo* spp. individuals found in quarterly and monthly sequential wooden surface panels in 1995 was not an unexpected event for the Seabrook area. Occasional specimens have been collected previously during the surface panels study, including 1976 and 1979 at Station B19, and 1980 at Station B31 (NAI 1977, 1981a, b). Additionally, *Teredo* spp. veliger larvae have been observed in bivalve larvae samples every year since 1984.

Occurrence of *Teredo navalis*, the most common teredinid north of Cape Cod, has been well documented in the Gulf of Maine (Grave 1928; Turner 1966; Gosner 1971; Culliney 1975), at times exhibiting periodic outbreaks (Dow and Baird 1953). Based on the historic documentation

of *Teredo* in Gulf of Maine through these and other studies, and the fact that *Teredo* sp. was identified at both nearfield and farfield stations in 1995, the most recent occurrence in 1995 surface panels cannot be attributed to the operation of Seabrook Station. Similarly, overall results of surface panel, marine macrobenthos and hydrothermal studies show no indication that Seabrook Station operation has impacted the local fouling community.

Conclusions

Twenty years of surface panel studies (including five full years (1991-1995) of Seabrook operation) have demonstrated that the two original objectives of this program have been met. The temporal settlement patterns of potential foulers of power plant structures have been characterized, and none have created plant operational problems. Current biofouling control measures and the in-station fouling panels program have proven to be sufficient to maintain plant operability.

The extensive physical and fouling community database gathered since 1975 has provided all needed evidence for effective impact assessment. Environmental conditions in the vicinity of Seabrook Station discharge before and after plant operation have allowed a balanced indigenous fouling community to colonize and develop on nearby hard surfaces, with no evidence of power plant effects. Specifically, hydrothermal studies (Padmanabhan and Hecker 1991) have shown that the nearfield surface panel study area is more exposed to the thermal plume than the nearest natural hard substrate habitats (Outer Sunk Rocks). These studies indicate that there is no natural

hard benthos or fouling community affected by the thermal plume. Consistent with this physical data, 20 years of biological studies of both areas (surface panels and marine macrobenthos study sites) indicate no evidence of ecological impacts to hard benthos from Seabrook operation. In addition, the same community parameters, dominant taxa, and patterns of settlement and development studied on surface panels are also monitored by the marine macrobenthos program on the nearest natural hard surfaces (destructive and non-destructive studies) and on subtidal bottom panels (Table 2) in the vicinity of stations B19 and B31 (Fig. 1).

Based on this evaluation, we request to discontinue all surface panel monitoring because no impacts have occurred after five years of Seabrook Station operation.

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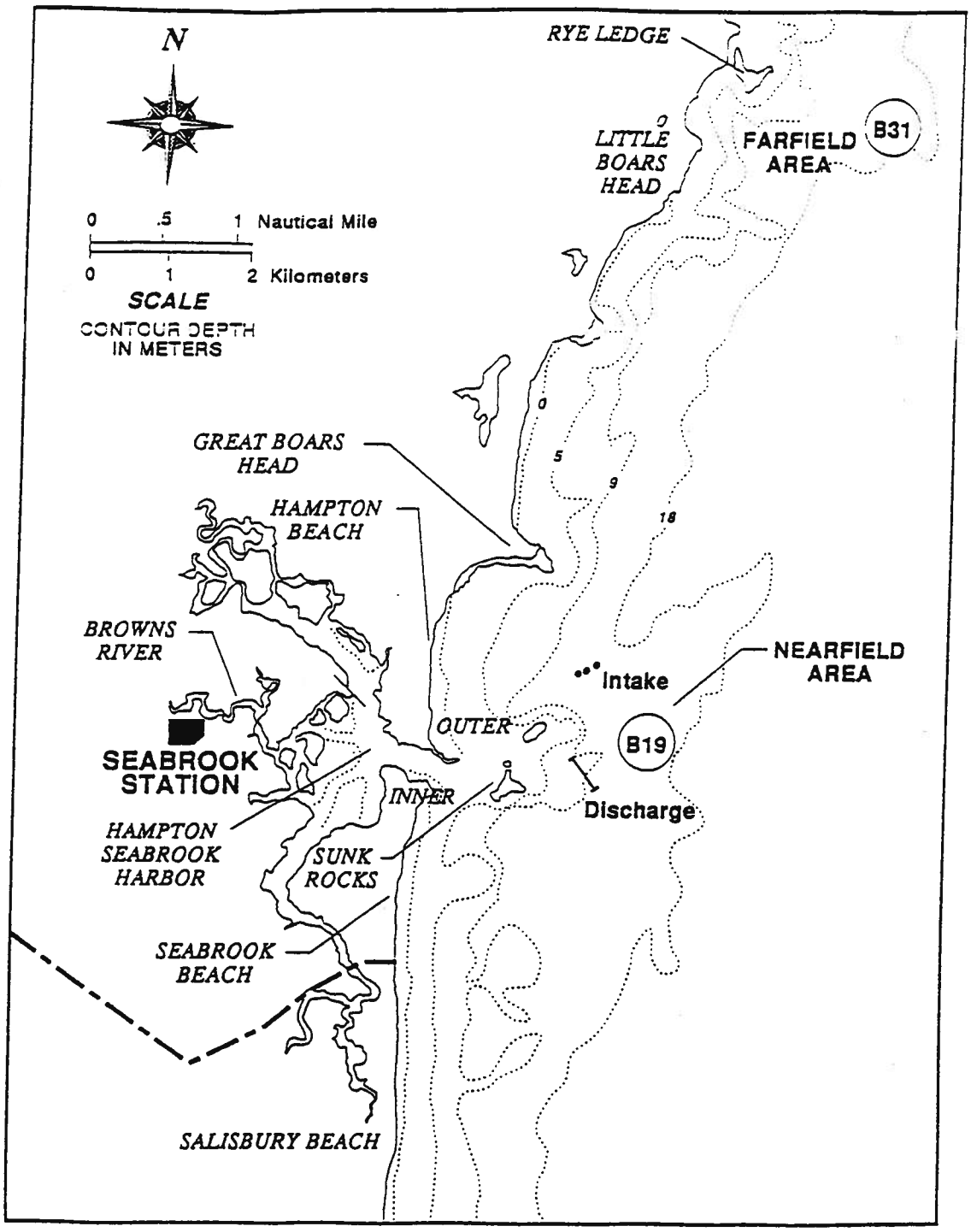


LEGEND

○ = surface panels

Fig. 1. Surface panel sampling stations. From NAI (1996a)

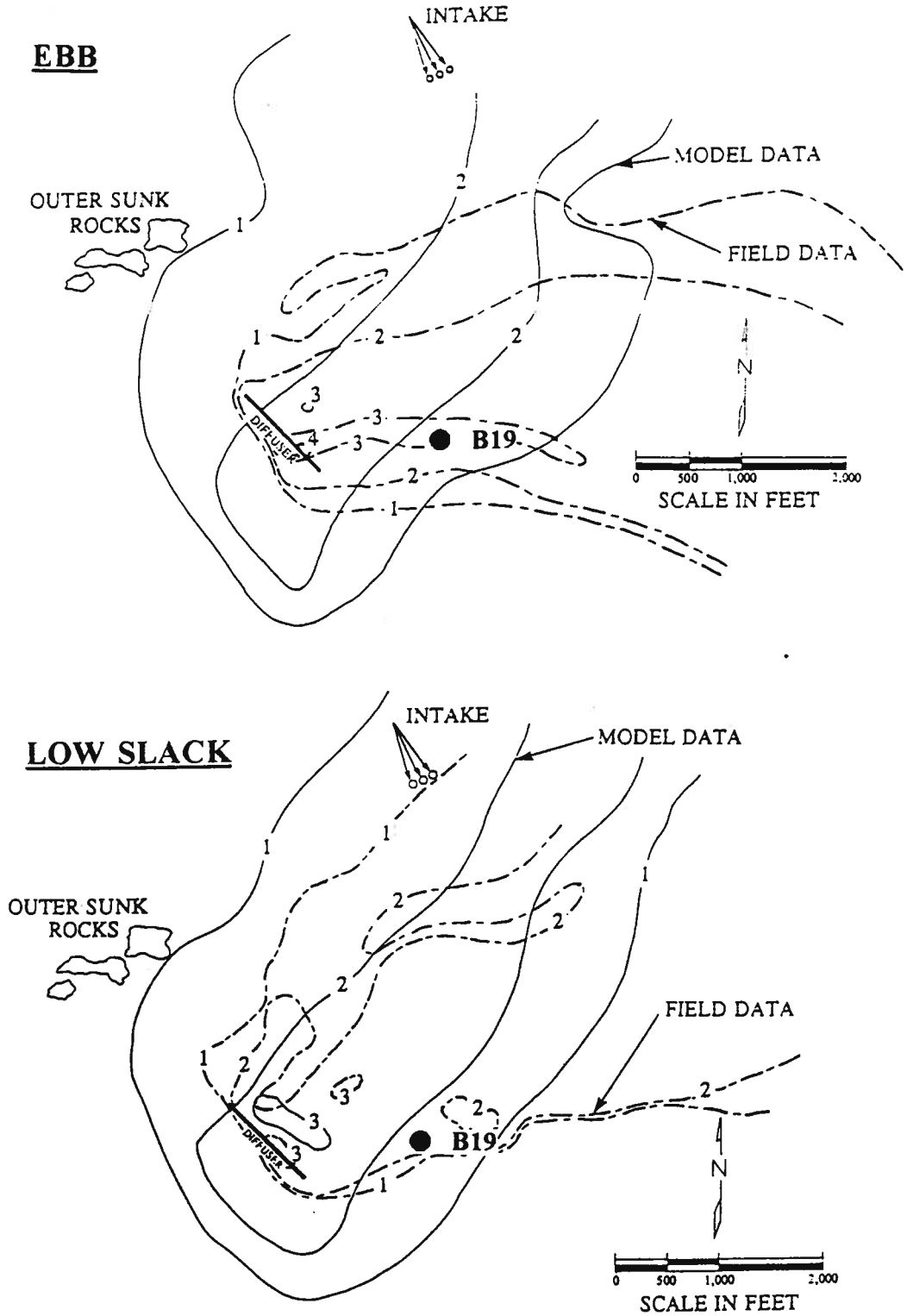
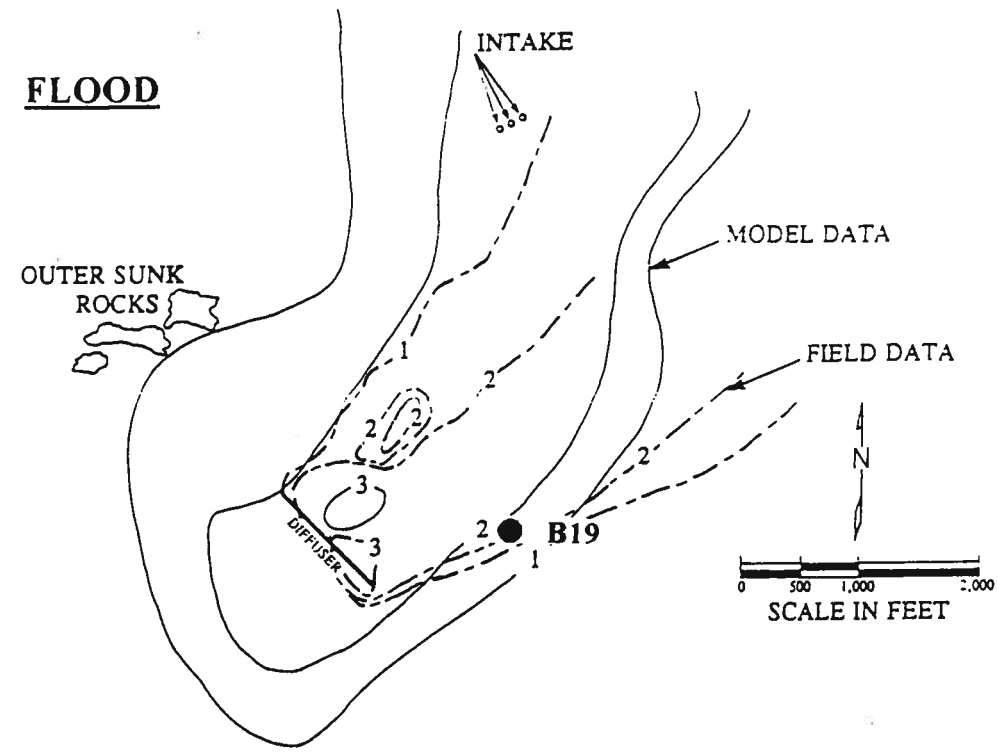


Fig. 2. Locations of selected Seabrook Station thermal plume isotherms (1°F, 2°F, and 3°F) under various tidal conditions in relation to the nearfield surface panel station (B19), based on hydrothermal modelling and field verification studies. From Padmanabhan and Hecker (1991).



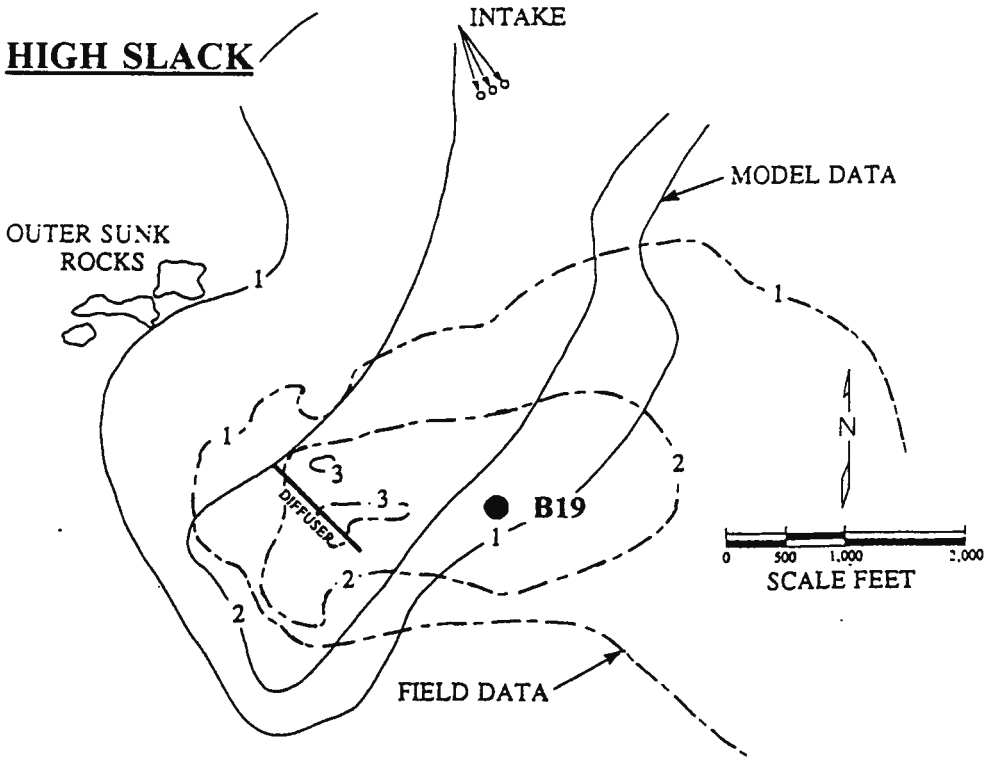
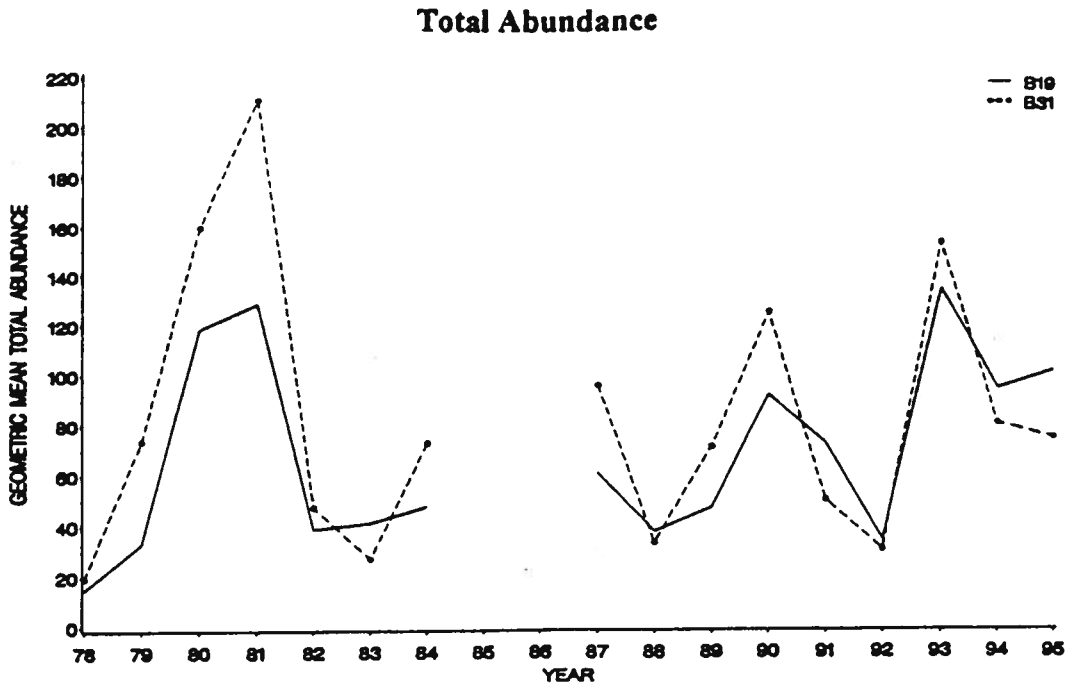


Fig. 2. (continued)



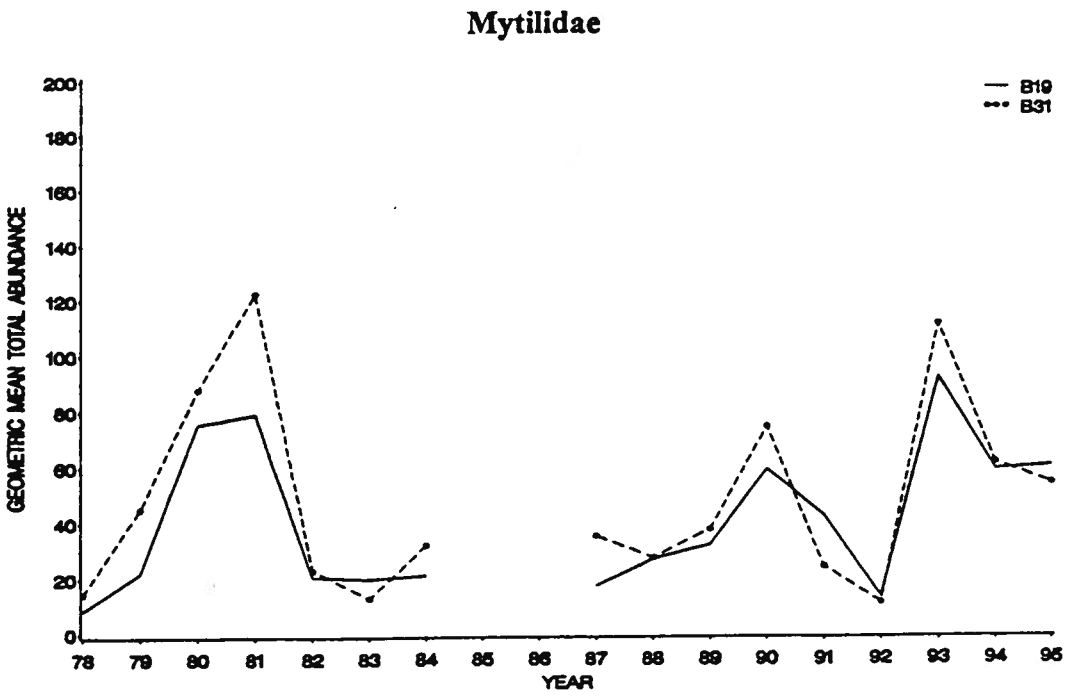


Fig. 3. Annual geometric means of total abundance and abundance of Mytilidae on short-term panels at Stations B19 and B31, 1978-1984 and 1987-1995.

Table 1. Summary of evaluation of discharge plume effects on the fouling community in the vicinity of Seabrook Station. From NAI (1996a).

COMMUNITY	PARAMETER[a]	OPERATIONAL PERIOD SIMILAR TO PREVIOUS YEARS	NEARFIELD-FARFIELD DIFFERENCES CONSISTENT WITH PREVIOUS YEARS?[b]
Fouling community: Settlement[c]	Abundance	no	NF:Op>Preop FF:Op=Preop
	No. of taxa	yes	yes
	Biomass	yes	yes
Fouling community: Development[c]	Biomass	yes	yes
Fouling community: Development-year end[c]	Abundance	yes	yes
	No. of taxa	no	NF:Op>Preop FF:Op=Preop
	Biomass	yes	yes
Fouling community: Settlement[c]	Mytilidae	yes	NF:Op>Preop FF:Op=Preop
	Jassa marmorata	yes	yes
	Tubularia sp.	yes	yes

[a] Abundance, number of taxa, biomass, total density, and frequency of occurrence evaluated using ANOVA or t-test.
[b] NF = nearfield, FF = farfield.
[c] Settlement = short-term panels; development = monthly sequential panels; year-end = one year exposure period.

Table 2. A summary of community parameters and selected taxa assessed in surface panel and marine macrobenthos studies as described in NAI (1996a, b).

	Surface Panels		**Marine Macrobenthos**		
	Short-term	Monthly/Quarterly Sequential	Bottom panels	Intertidal	Subtidal
Sampling stations	B19, B31	B19, B31	B04, B19, B31, B34	B1MLW, B5MLW	B04, B13, B17, B19, B31, B34, B35
Community parameters					
Species richness	monthly time-series and ANOVA	assessed monthly/ quarterly t-tests, for 1-yr panels		assessed with ANOVA for Aug.	assessed with ANOVA for Aug.
Total abundance (fauna only)	monthly time-series and ANOVA	assessed monthly/ quarterly, t-tests for 1-yr panels		assessed with ANOVA for Aug.	assessed with ANOVA for Aug.
Total biomass	monthly time-series and ANOVA	assessed monthly/ quarterly, ANOVA on monthly panels, t-tests for 1-yr panels		assessed for algae triannual samples, ANOVA for Aug.	assessed for algae triannual samples, ANOVA for Aug.
Selected taxa					
Mytilidae	monthly time-series and ANOVA	monthly/quarterly time-series (% freq.) and life-history studies	dominant taxon, counts on triannual and annual panels	dominant taxon, triannual abund. estimates and life stage studies	dominant taxon, triannual abund. estimates, ANOVA, and life stage studies
Jassa marmorata	monthly time-series and ANOVA	monthly/quarterly time-series (% freq.) and life-history studies			dominant taxon (shallow subtidal sites), triannual abund. estimates, ANOVA and life stage studies
Tubularia sp.	monthly time-series and ANOVA	monthly/quarterly time-series (% freq.)	counts on annual panels	presence/absence for August	presence/absence for August
Laminaria sp.		assessed on 1-yr panels with t-tests	counts on annual panels		triannual abund. estimates and ANOVA in transect study