Indian Point Generating Station

a 316(a) Demonstration

Consolidated Edison Company of New York, Inc.
Power Authority of the State of New York

prepared by Consolidated Edison Co., Inc.

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PREFACE

The Consolidated Edison Company of New York, Inc. (Con Edison) and the Power Authority of the State of New York (PASNY), owners of Indian Point Units Nos. 2 and 3, respectively, hereby submit this demonstration to the United States Environmental Protection Agency (USEPA) pursuant to Section 316(a) of the Federal Water Pollution Control Act (FWPCA), 33 U.S.C. Section 1326a, and the proposed National Pollutant Discharge Elimination System (NPDES) Permits Nos. NY0004472 for Unit No. 2 and NY0027065 for Unit No. 3.

The purpose of this demonstration is to show that the effluent limitations specified in these proposed NPDES permits are more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife in and on the Hudson River estuary and to request alternative thermal effluent limitations. This demonstration has been prepared in accordance with the USEPA (1976) regulations governing procedures for Section 316(a) demonstrations, 40 C.F.R. Part 122, and, wherever appropriate, the design and organization suggested by the USEPA in the May 1977 draft of the "316(a) Technical Guidance Manual" (TGM) were followed.

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SECTION 1 - INTRODUCTION

This demonstration is organized so that a single volume presents a summary of the information required to evaluate whether the Indian Point discharge allows for the protection and propagation of a balanced indigenous population (BIP) of fish, shellfish and wildlife in and on the Hudson River estuary. Although emphasis is placed on the predictive-type laboratory studies performed on the representative, important species (RIS), the results of baseline field surveys are also considered. Under contract to Con Edison and/or the other three Hudson River utilities (Central Hudson Gas & Electric Corporation, Orange & Rockland Utilities, Inc., and Power Authority of the State of New York) most of the studies described in this demonstration were performed by Ecological Analysts, Inc. (EA), New York University Medical Center (NYU) and Texas Instruments Incorporated (TI).

Within the summary, there are essentially three major elements. Section 3 presents an assessment of the impact of the Indian Point discharge on the RIS. Sections 4 through 9 indicate the observed effects of plant operation on the various biotic groups (phytoplankton, microzooplankton, etc.), focusing, wherever possible, on the thermal component of the discharge. Section 10 provides the basis for utilizing engineering and hydrological data in predicting the plume's ecological impact.* The conclusions reached throughout the demonstration are synthesized in the master rationale (Section 2), and are further supported by four appendices:

Appendix A. "Hudson River Thermal Effects Studies for Representative, Important Species", (EA 1978). This report presents the findings of recent laboratory investigations of the relationships between temperature and behavioral/physiological functioning in some Hudson River RIS.

Appendix B. "Thermal Effects Literature Review for Hudson River Representative, Important Species." A review of the pertinent literature based upon research conducted in the Hudson River and elsewhere.

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*Throughout the demonstration biological data are described using the Centigrade (°C) scale, while hydrothermal analyses are presented in terms of the Fahrenheit (°F) measure. In those cases where hydrothermal and biological considerations are discussed together, both units are provided.

Appendix C. "Indian Point Thermal Plume Surveys" (two volumes). Volume I contains data on plant operating characteristics and hydrological conditions that influence the extent and configuration of the thermal plume. Volume II presents the thermal mappings obtained in Con Edison's surveys from May 1974 through May 1977.

Appendix D. "Procedures and Analyses - Biological and Hydrothermal Studies." This report provides additional detail for the non-RIS biological and hydrothermal studies discussed in the summary.

This demonstration comprises a portion of the information submitted to the USEPA concerning the ecological impact of the present once-through cooling system at the Indian Point plants. On July 11, 1977, the four Hudson River utilities submitted evidence indicating that the location, design, construction and capacity of cooling water intake structures at Indian Point, Bowline Point and Roseton generating stations reflect the best technology available for minimizing adverse environmental impact, thereby complying with FWPCA Section 316(b). A number of reports addressing the effects of power plant operation on Hudson River biota were submitted as exhibits for the 316(b) proceeding. Among these were:

1. "Influence of Indian Point Unit 2 and Other Steam Electric Generating Plants on the Hudson River Estuary, with Emphasis on Striped Bass and Other Fish Populations," edited by J. McFadden (January 1977), and Supplement I edited by J. McFadden and J. Lawler (July 1977).

2. "Survival of Entrained Ichthyoplankton and Macroinvertebrates at Hudson River Power Plants," prepared by Ecological Analysts, Inc. (July 1977).

3. "The Effects of Intakes and Associated Cooling Water Systems on Phytoplankton and Aquatic Invertebrates of the Hudson River," prepared by Ecological Analysts, Inc. (July 1977).

In addition, Con Edison and PASNY jointly submitted a report describing the localized impact at Indian Point, entitled;

4. "Near-Field Effects of Once-Through Cooling System Operation on Hudson River Biota," (July 1977).

These five documents, as modified by the submitted addenda and errata, provide a comprehensive evaluation of the impact of the Indian Point station on the aquatic ecosystem of the Hudson

River. Although emphasis is clearly on intake effects (entrainment and impingement), thermal and chemical discharges were also recognized and evaluated. From the biological viewpoint, it is appropriate to assess the impacts determined in 316(a) and (b) demonstrations together. In a sense, this has already been done in that 316(a) issues were broadly considered prior to reaching the conclusions stated in the 316(b) reports

Analyses of impact found in the 316(b) reports were largely based on post-operational field data which incorporated the effects of all stresses on the ecosystem attributable to plant operations and other background sources. The long-river impact assessments involved, among other things, consideration of the mechanisms by which fish populations respond to fluctuations in their numbers. The scope of this 316(a) demonstration is more narrowly defined, primarily because the information presented in 316(b) allows subsequent evaluations (such as this one) greater flexibility in focusing on specific issues. The purpose of this demonstration is to address discharge effects and provide sufficient justification to permit the imposition of less stringent effluent limitations at the Indian Point generating station. No attempt was made to orient the 316(a) approach to include aspects of population dynamics previously detailed in the (b) presentation.

1.1 General Information

The Indian Point Generating Station is located on the east bank of the Hudson River in the Village of Buchanan in northern Westchester County. The plant is situated about 25 miles north of the New York City limits and some 43 river miles above the Battery at 41°16'20" north latitude and 73°57'10" west longitude (discharge coordinates). Significant points of reference include the City of Peekskill (2.5 miles to the northeast), the West Point Military Academy (8.3 miles to the north) and the Lovett and Bowline Point Generating Stations located across the river at mile points 41.0 and 37.5, respectively. Figure 1-1 shows the location of the station relative to other plants along the river. The Indian Point station consists of three nuclear generating units, which are situated on a site with an area of about 239 acres. Indian Point Units Nos. 2 and 3 have net rated capacities of 873 MWe and 965 MWe, respectively, and gross rated capacities of 906 MWe and 1000 MWe, respectively. Unit No. 1 has not operated since October 31, 1974.

1.2 Regulatory History

On June 24, 1971 Con Edison submitted an application to the United States Army Corps of Engineers for a discharge permit pursuant to Section 13 of the Rivers and Harbors Act of 1899 for

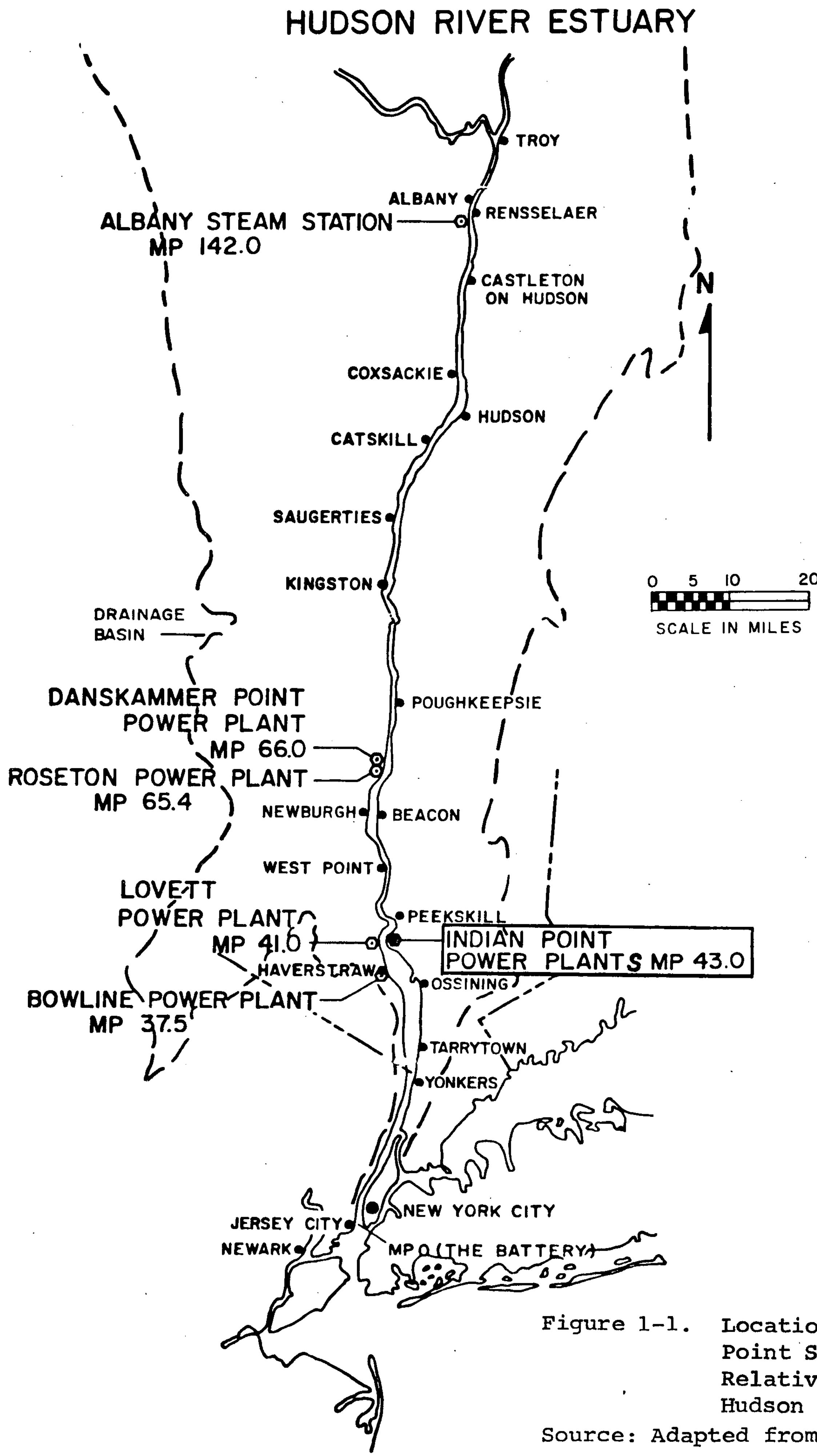

Figure 1-1. Location of Indian Point Station Relative to other Hudson River Stations.

Source: Adapted from QLM 1970

Indian Point Units Nos. 1 and 2. This application was revised on October 27, 1971 and December 2, 1971. This application became an application for an NPDES permit pursuant to Section 402 of the FWPCA by virtue of Section 402(a)(5) of the FWPCA. On January 25, 1973 this application was further amended by a submittal to the USEPA.

On June 24, 1974, USEPA sent Con Edison a draft NPDES permit for Indian Point Units Nos. 1 and 2. In order to comply with the effluent limits contained in the permit for the net amount of heat discharged to the river, operation of Indian Point Unit No. 2 after July, 1978 or of Indian Point Unit No. 1 after July 1, 1983 would have required the installation of a closed-cycle cooling system at each unit. Requests for alternative thermal limitations pursuant to Section 316(a) of the FWPCA and for an extension of time for filing evidence in support of these limitations were filed by Con Edison on July 26, 1974. Con Edison submitted comments on the draft permit and a request for a public hearing with respect to the tentative determinations contained in the draft permit on August 27, 1974. Con Edison subsequently filed an initial submittal of the 316(a) demonstration for these units on September 10, 1974.

The proposed NPDES permit for Indian Point Units Nos. 1 and 2 was sent to Con Edison on February 24, 1975. The proposed permit would have required the installation of closed-cycle cooling system for operation of Indian Point Unit No. 2 after May 1, 1979, but did not require such a system for Indian Point Unit No. 1. On April 7, 1975 Con Edison filed a request for an adjudicatory hearing with respect to certain conditions in the permit pursuant to Section 402(a)(1) of the FWPCA and 40 CFR 125.36(b). This request for an adjudicatory hearing was granted by USEPA on May 8, 1975. The conditions of the permit which were challenged include those conditions which, in effect, require the installation of a closed-cycle cooling system at Indian Point Unit No. 2. Pursuant to 40 CFR 125.36, these conditions have been stayed as a result of the request for a hearing pending final USEPA action.

With respect to Indian Point Unit No. 3, Con Edison filed with USEPA an application for an NPDES permit for the construction phase of the unit on January 9, 1974. The application for normal operation of the unit was filed on July 9, 1974 with additional information filed subsequent to that date. On February 13, 1975, Con Edison requested that alternative thermal effluent limitations be adopted for the unit. On April 22, 1975 USEPA sent a draft permit for this unit to Con Edison. The draft permit contained effluent limits on the discharge of heat from the main condensers which, in effect, prohibited operation of the unit without a closed-cycle cooling system after September 15,

1980. Comments on the draft NPDES permit were forwarded to USEPA by Con Edison on June 2, 1975.

The proposed NPDES permit for Indian Point Unit No. 3 was sent to Con Edison by USEPA on June 27, 1975. The proposed permit also contained effluent limits which prohibit the operation of the unit without a closed-cycle cooling system after September 15, 1980. On July 31, 1975 Con Edison filed a request for an adjudicatory hearing with respect to certain conditions contained in the proposed permit, including the condition which required installation of a closed-cycle cooling system. This request was granted by USEPA on August 28, 1975. Pursuant to 40 CFR § 125.36, the contested permit conditions have been stayed pending final USEPA action.

On December 30, 1975, PASNY acquired Indian Point Unit No. 3 from Con Edison. EPA was informed of this acquisition on April 6, 1976 at which time PASNY requested that the permittee's name in the NPDES permit be changed from Con Edison to PASNY.

Pursuant to Section 316(a) of the Act and 40 CFR Part 122, Con Edison, which had requested designation of the RIS for the Indian Point Unit Nos. 1 and 2 on July 26, 1974 and for the Indian Point Unit No. 3 on May 12, 1975, received from USEPA a list of the designated species of phytoplankton, macroinvertebrates and fish for Indian Point Units Nos. 1, 2 and 3. At that time, USEPA also required Con Edison to submit data in support of the Section 316(a) waiver request within 90 days or a written plan of study and demonstration within 60 days. On March 4, 1976 Con Edison submitted the plan of study and demonstration. USEPA issued a public notice dated April 2, 1976 of the submittal of the plan and approved the plan on June 15, 1976. Pursuant to the requirements of the approval of the plan, Con Edison has submitted progress reports on December 30, 1976 and June 28, 1977. This report is Con Edison's Section 316(a) demonstration filed in accordance with the schedule specified by USEPA.

The effluent limitations applied to the thermal component of the Indian Point discharge by the Tentative Determinations of USEPA Region II were based on Effluent Guidelines and Standards for the Steam Electric Power Generating Point Source Category issued on 8 October 1974 by USEPA, 40 CFR Part 423. On 16 July 1976, these effluent guidelines and standards were remanded to USEPA by the Court of Appeals, Fourth Circuit* for failure of USEPA to satisfy certain statutory standards relating to the promulgation

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*Appalachian Power Company versus Train, 545 F. 2d 1351 (4th Cir. 1976).

of such effluent guidelines and standards, including a failure to properly assess the costs and benefits of retrofitting closed-cycle cooling on existing plants. As a result of this decision, the basis for USEPA Region II's effluent limitations for such thermal component contained in the Tentative Determinations has been rendered inapplicable and the General Counsel of USEPA has ruled* that EPA Region II must develop effluent limitations for the Indian Point plants' thermal discharge based on its authority under FWPCA Section 402(a)(1).

On 11 July 1977, a motion was filed on behalf of Con Edison for a determination by the Regional Administrator, USEPA Region II, of the best available technology economically achievable (BATEA) under FWPCA Section 402(a) for certain electric generating stations on the Hudson River, including the Indian Point plants. More specifically, this motion requested the Regional Administrator to establish effluent limitations applicable to the thermal component of the discharge from the Indian Point plants. The Regional Administrator has not yet responded to this motion.

In keeping with the USEPA Administrator's decision in the Seabrook case,** the USEPA General Counsel in its determination that USEPA Region II develop effluent limitations for the Indian Point plants' thermal discharge*** held that the Regional Administrator must consider the factors set out in FWPCA Sections 304(b)(1)(B) and 304(b)(2)(B). These factors include whether the costs of the proposed technology to meet the effluent guidelines established under FWPCA Section 402(a)(1) are disproportionate to the expected benefits.

As a result of this holding, the relationship of the costs and benefits of the technology necessary to meet the effluent limitations ultimately established for the Indian Point plants by the Regional Administrator of USEPA Region II are relevant to this 316(a) demonstration. Since the practicable technology available to meet the present (but invalidated) effluent limitations contained in the Tentative Determinations of USEPA Region II is closed-cycle cooling towers, this demonstration incorporates by reference the cost-benefit analysis of cooling tower construction at the Indian Point plants submitted in Docket No. II-C/WP-77-1 of the consolidated adjudicatory hearing for the

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*Decision of the General Counsel on Matters of Law Pursuant to 50 CFR Section 125.36 (m), No. 63 (OGC #63).

**Matter of Public Service Company of New Hampshire, Case 76-7, 17 June 1977 modified 9 November 1977.

***Decision of the General Counsel on Matters of Law Pursuant to 40 CFR Section 125.36 (m), No. 63 (OGC #63).

major Hudson River electric generating stations. However, in the event that the Regional Administrator subsequently determines that a different technology represents BATEA for the Indian Point plants, Con Edison reserves its right to submit a demonstration regarding the costs versus the benefits of such technology.

SECTION 2 - MASTER RATIONALE

This section provides a synthesis of the key facts and evidence which demonstrate that the limitations applicable for once-through cooling system operation at the Indian Point generating station are sufficiently stringent to assure the protection and propagation of a balanced, indigenous population (BIP) of shellfish, fish and wildlife in and on the Hudson River estuary. This degree of compatibility between station operation and the maintenance of the BIP is examined in this demonstration through an approach based on field survey information for several major biological groups found within the estuary and using laboratory data on the thermal responses of several key species.

One of the principal ways to assess or characterize an ecosystem is to describe its primary components. This demonstration adopted the method for partitioning biota as provided in the USEPA May 1977 draft of the 316(a) Technical Guidance Manual. In essence, several divisions are formed comprising recognizable biotic categories; phytoplankton, microzooplankton, macroinvertebrates and fish. This type of segmentation is somewhat analogous to the trophic level organization commonly employed in energy flow and food web analyses. Each basic component is itself a community, a relatively distinct aggregation of organisms which has adapted and evolved through interactions with the environment. These evolutionary adjustments have reached a level such that the distinctiveness of the aggregation is maintained. It is not implied that this level is fixed or static, but rather that it is dynamic and capable of responding to further stimuli.

In this demonstration, all of the communities represented by the various biotic categories are viewed as parts of the overall estuarine community in the Hudson River. Collectively, these individual groups currently form a BIP in the Hudson River in that relationships and patterns in ecological structure have been established. Aspects of these relationships, specifically spatial and temporal factors linked to species composition, distribution and abundance were considered with other prominent features of community structure or function in examining the available field survey data. From these studies, it was concluded that the operation of the Indian Point station did not significantly alter the BIP. Furthermore, the results of thermal effects laboratory investigations predicted that the plume created by the Indian Point discharge lacks the potential to appreciably harm any of a select group of aquatic biota (the RIS), and therefore should not be considered a threat to the continued existence of the BIP.

The master rationale is comprised of four sections, each of which present specific information relevant to consideration of the discharge's effects upon the BIP. Section 2.1 outlines those aspects of the discharge plume's configuration that were found to be most relevant to the biological analyses. Sections 2.2 and 2.3 summarize the information found in the RIS and biotic categories presentations. Selected decision criteria suggested by USEPA to be of value in assessing the merit of the demonstration are addressed in Section 2.4.

2.1 Discharge Plume Areas and Determination of Impact

Of fundamental importance in evaluating the effects of a discharge upon aquatic biota is determination of the discharge plume's extent. Rather than specifically examining discrete isotherms or areas within the plume, the objective of this discussion is to broadly characterize the plume's general configuration and relate it to impact assessment. It should be noted that complete information on these aspects of plume geometry appear in Section 10, and in Appendices C and D.

Water that has passed through the condenser cooling systems at the Indian Point station is discharged to the river through submerged ports. The temperature to which the cooling water is elevated (ΔT) depends upon the number of circulating pumps in operation and the plant's generating load. Although the configuration of the thermal plume does not remain constant due to changing tidal, atmospheric and plant operating conditions, its overall shape in the immediate vicinity of the discharge is somewhat cone-like, bending upward from the discharge ports towards the surface. Within this "jet cone" are found the highest plume temperatures. Hydrothermal analyses and laboratory studies of thermal effects upon selected biota indicated that in every case where there was some recognizable possibility for the Indian Point discharge to adversely affect a RIS, the area of potential damage was restricted to the jet cone (Section 3).

Beyond the area where the plume approaches the surface, approximately 100 feet from the discharge ports, the plume's shape is primarily determined by river dynamics. At 100 feet, the plumes' excess temperatures are approximately one-half those found at the discharge ports. In terms of total water volume, nearly all of the excess (above ambient) temperatures associated with the discharge plume are found within a few meters of the surface. The plume has no significant benthic component. For this reason, it would be expected that certain bottom-oriented Indian Point RIS are highly invulnerable to discharge plume influence. In this group are shortnose sturgeon, Atlantic sturgeon, weakfish, Atlantic tomcod, and white catfish. Similarly, the three invertebrate RIS (*Neomysis americana*, Gammarus spp. and Crangon septemspinosa) are also less likely to encounter the plume than are pelagic species.

2.2 Representative, Important Species

Fourteen taxa were designated by USEPA as the RIS for the Indian Point area (Table 2-1). RIS designation permits research efforts to focus on several key species. If it is determined that these RIS are not appreciably harmed, there will be reasonable assurance that the BIP of fish, shellfish, and wildlife in and on the Hudson River estuary will be protected.

In Section 3, thermal effects data on the RIS are used to assess the capability of the Indian Point discharge to cause appreciable harm. In analyzing the laboratory data, it was necessary to determine which information was appropriate for evaluating appreciable harm potential and how to use that data in a meaningful manner. In brief, survival parameters were generally considered to be the most appropriate measures of adverse impact, although developmental and behavioral responses to temperature also formed parts of the assessment. Volumes of plume water in which potentially adverse effects may occur were calculated from the appropriate laboratory data and the hydrothermal analyses. These volumes constituted "zones of potential damage" (ZPD), and were compared to the total volume of water contained within a selected river segment, the "near-field region" (Section 10.2.2). This region was smaller than a tidal excursion and provided an extremely conservative estimate of the total range over which the RIS are found. The ratio of the water volumes within the ZPD to that contained within the near-field region was therefore a similarly conservative estimate of the potential for RIS to be appreciably harmed.* In those instances where adequate laboratory data on the RIS did not exist (e.g., the two sturgeon species and weakfish), the evaluation was based upon other information (Section 2.1).

The nature of plume entrainment at Indian Point is such that plankton are only briefly exposed to excessive temperatures. For instance, a planktonic organism entrained adjacent to the discharge port would reach the surface (where the excess

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*All the ZPD's were within the extent of the jet cone portion of the discharge, which approximately extends to the 7.7°F excess temperature isotherm during non-winter conditions. Since volumes associated with excess temperature isotherms greater than 6°F were not available from the thermal plume surveys, the ZPD's were based on the 6°F volumes.

Table 2-1. Representative, Important Species from the Indian Point Generating Station

1. Blue-green algae (Cyanophyta)
2. Opposum shrimp (*Neomysis americana*)
3. Scud (*Gammarus* spp.)
4. Sand shrimp (*Crangon septemspinosa*)
5. Striped bass (*Morone saxatilis*)
6. White perch (*Morone americana*)
7. Atlantic tomcod (*Microgadus tomcod*)
8. Atlantic sturgeon (*Acipenser oxyrhynchus*)
9. Shortnose sturgeon (*Acipenser brevirostrum*)
10. Spottail shiner (*Notropis hudsonius*)
11. Weakfish (*Cynoscion regalis*)
12. Alewife (*Alosa pseudoharengus*)
13. Bay anchovy (*Alosa mitchilli*)
14. White catfish (*Ictalurus catus*)

temperature is approximately one-half of that at the port) in less than 60 seconds for ebb and flood tides. The plume is also small enough in relation to the total river area available for juvenile and adult fish so that they need not be exposed to the plume's influence in the course of their normal biological activities, although, in many cases, plume temperatures present species with opportunities for optimal growth or development that would not have occurred if there were no discharge. There is a small zone, however, which represents an exclusion area for some fish species. The velocity of water exiting the discharge ports is maintained at 10 feet per second. This rapid stream of water precludes any inhabitation of juvenile or adult fish in that area, and, similarly, velocities associated with some of the higher plume temperatures within the jet cone exceed the swimming capabilities of various Hudson River fish species. Volumes of water corresponding to these high velocity sections of the plume are considered as exclusion zones if they represent regions in which the particular species might be found in the absence of the discharge. For instance, there would be an exclusion zone based upon these velocity considerations for striped bass or white perch, but not for Atlantic tomcod or shortnose sturgeon because these latter two are bottom dwellers.

In this demonstration, all factors that could contribute towards an accurate assessment of appreciable harm for each RIS were considered. Summarizations of these assessments are indicated below.

Blue-green algae (Cyanophyta)	These potentially nuisance organisms consistently comprised a small percentage of the total phytoplankton community in the Indian Point area. Their abundance relative to other phytoplankters followed a pattern of natural seasonal variation.
Opposum shrimp (*Neomysis americana*)	Although they are the most thermally sensitive of the major Hudson River macrozooplankters, *N. americana* may be adversely affected by plume entrainment only during the summer months. The estimated ZPD's during July and August correspond to less than 0.5% of the water volume contained within the near-field region. No appreciable harm to the *N. americana* population is predicted.

Scud (*Gammarus* spp.)

A major food item for a variety of Hudson River fish species, *Gammarus* spp. laboratory survival studies indicated that they experienced virtually no mortality upon exposure to harsher time - temperature conditions than would be encountered if they were plume entrained. Reproductive studies indicated that there were no significant differences in the number of live young produced between controls and test groups of ripe female *Gammarus daiberi* exposed to time-temperature combinations representative of plume entrainment.

Sand shrimp (*Crangon septemspinosa*)

Primarily found in the Indian Point area during the summer months when the salt front extends throughout the region, the estimated ZPD for *C. septemspinosa* in August is less than 0.5% of the water volume contained within the near-field region. Since the ZPD is restricted to a relatively small region in the vicinity of the discharge ports, no appreciable harm to this species is expected.

Striped bass (*Morone saxatilis*)

Of major importance as a commercial and recreationally valuable species, all life stages of this anadromous fish are found in the Indian Point area. Thermal effects studies on the egg and larval stages clearly indicated that plume entrainment does not present a threat to the striped bass ichthyoplankton population. Furthermore, the temperature range determined in the laboratory as the optimum for growth of larvae through the juvenile stage would generally exist only in plume areas. Behavioral and survival studies on juvenile fish implied that although prolonged (greater than 24 consecutive hours) contact with portions of the plume would probably be avoided during the summer months, striped bass could utilize most of the discharge area for briefer periods (several hours). A small exclusion zone based upon velocity considerations was predicted. No significant potential for cold shock is expected.

White perch (Morone americana)

An estuarine resident, white perch primarily spawn upstream of the Indian Point station. Survival of early life stages (eggs and larvae) would not be significantly affected by plume entrainment. As with the striped bass, behavioral and survival data imply that adult white perch can successfully utilize most portions of the discharge plume throughout the year, (they are excluded from a small area near the discharge ports because the velocity within that region exceeds their locomotor capabilities). For those white perch that might become acclimatized to the plume during the winter, no significant potential for cold shock is expected.

Atlantic tomcod (Microgadus tomcod)

The only winter spawner among the Hudson River RIS, the Atlantic tomcod primarily inhabits the estuary's bottom areas. Although their eggs are demersal and are therefore only marginally vulnerable to plume entrainment, both eggs and the larvae tolerated higher temperatures than those found at the discharge during the winter and spring periods. During the summer, juvenile and adult tomcod would likely not be found in those waters affected by the plume, even if there were no discharge.

Atlantic sturgeon (Acipenser oxyrhynchus)

Very little data on this slowly maturing, anadromous species is available. However, field collections have revealed that Atlantic sturgeon are found predominantly in the river's benthic areas. Since the Indian Point thermal plume primarily occurs in the uppermost water layers, it is expected that the discharge does not have the potential to exert appreciable harm on the Atlantic sturgeon population.

Shortnose sturgeon (*Acipenser brevirostrum*)

Not distinguishable in its larval stages from the Atlantic sturgeon, the shortnose sturgeon is classified as an endangered species. As with the Atlantic sturgeon, very little data on the biology of the species are found in the literature. The shortnose is a benthic inhabitant and would thus not be expected to contact any portion of the discharge plume that might have the potential to cause appreciable harm.

Spottail shiner (*Notropis hudsonius*)

A resident freshwater species, spottail shiner eggs and larvae are not generally found in the Indian Point area. Juveniles exhibited optimum growth at temperatures that would generally only be found in plume areas. Adult final preferenda indicated that these fish would probably avoid prolonged contact to most plume temperatures during the summer, but could tolerate short-term exposures. Spottail shiner would be excluded from a small area based upon velocity considerations. The cold shock potential for these fish is negligible since they are extremely tolerant to very low temperatures.

Weakfish (*Cynoscion regalis*)

Although weakfish eggs are pelagic, they were not found in the Indian Point area. Juvenile fish were primarily collected in bottom sampling. The scant data available describing thermal effects on weakfish indicated that the plume area would be generally avoided during the summer. Weakfish apparently do not remain in the river during the winter so that there is no potential for cold shock. The benthic habitat preference displayed by juvenile and adult fish signify that plume contact would not be sufficiently extensive to cause appreciable harm.

Alewife (*Alosa pseudoharengus*)

Alewife adults spawn in freshwater areas of the Hudson River and then return to the ocean. Laboratory studies demonstrated that alewife eggs and larvae would not be adversely affected by plume entrainment. Juveniles and adults would tend to avoid the warmest plume temperatures, but most of the discharge area would be accessible to them for at least brief periods of time (except for a small portion excluded on the basis of velocity considerations). Since most juvenile alewives migrate seaward in early fall, there is little potential for cold shock.

Bay anchovy (*Alosa mitchilli*)

Bay anchovy are abundant in the Indian Point area from June through November. An estimate of the thermal range for most rapid early development revealed that most of the plume during summer would include temperatures within the optimum range. Behavioral and survival studies on adult fish indicated that they could utilize virtually all of the discharge plume at least for brief periods of time. Bay anchovy do not remain within the river during winter, so there is no potential for cold shock.

White catfish (*Ictalurus catus*)

White catfish of all ages in the Hudson River were found in greatest abundances in bottom areas. The eggs are adhesive and are sometimes covered with substrate so they are not generally susceptible to plume entrainment. Laboratory studies indicated that the fish are extremely tolerant of warm temperatures such as those present in the Indian Point discharge, and no adverse effects due to plume entrainment of eggs or larvae are expected. White catfish are also capable of tolerating steep declines in temperature, so that the cold shock potential for any white catfish that may be entrained within the plume during winter is not significant.

2.3 Biotic Categories

Aside from the RIS, this demonstration also presents information on phytoplankton, microzooplankton, macrozooplankton and benthic invertebrate taxa found in the Indian Point area. Although not related exclusively to the ecological consequences associated with the plant's discharge, the information is important in that it documents certain changes, as well as lack of changes, that have occurred in these groups while the Indian Point units have been in operation. Predictions of zones of potential damage are not made. Emphasis is primarily placed on the results of field collections used to describe the distribution and abundance patterns of these organisms in the Indian Point area. Laboratory data on thermal effects not presented in the RIS section are also discussed. For each biotic category, decision criteria are established which provide a framework for evaluating whether expected or observed changes for that taxonomic group are biologically significant in relation to the maintenance of a BIP. In summary, the following conclusions were reached.

Phytoplankton — The Hudson River is a detrital-based system in which phytoplankton play a relatively minor role as a source of organic input. The magnitude of this role is not affected by the operation of the Indian Point station in the once-through cooling mode. Field studies have indicated that there have been no significant changes in the abundance, productivity and species composition of phytoplankton collected in the Indian Point area during a four year (1971-1975) period, nor has there been any discernible shift towards dominance by nuisance or undesirable species. There is no evidence that any response of the phytoplankton community to the effects of plant operation can produce changes that would result in appreciable harm to the BIP of fish, shellfish and wildlife in and on the Hudson River estuary.

Microzooplankton — Field studies have indicated that the occurrence and abundance of dominant microzooplankton species depend on environmental variables such as the duration of salt front intrusion in the area, and are not apparently related to any aspect of plant operation. Patterns of seasonal succession among microzooplankton species were consistent over the several years studied, and denoted a stable community. Laboratory investigations showed that major microzooplankters were extremely tolerant to temperatures equal to those found within the Indian Point discharge, so that the plume would not constitute a lethal barrier to the free movement of these organisms within the estuary. Under present once-through cooling conditions, the contact between the discharge plume and the microzooplankton community would not result in any appreciable harm to the BIP of fish, shellfish and wildlife.

Macrozooplankton

Although some individual taxa showed variations in abundance, total macrozooplankton abundance remained at a fairly stable level as indicated in data collected from 1972 through 1976. No trends in macrozooplankton standing crop estimates that could be associated with the effects of the discharge plume were evident. Similarly, species composition has remained essentially unchanged throughout the years of study. The community has been consistently dominated by three macrozooplankters; *Gammarus* spp., *Neomysis americana* and *Monoculodes edwardsi*. All macrozooplankton studied except *N. americana* survived thermal exposures more severe than that represented by entrainment within the Indian Point discharge plume. The potential for appreciable harm to the BIP as a result of any macrozooplankton community changes possibly caused by the Indian Point discharge is negligible.

Benthic Invertebrates

Since the plume reaches the bottom only in a limited area near the discharge ports, it is unlikely that any benthic organisms would be affected. Field studies (conducted from 1972 to 1974) revealed that although there was considerable variability in abundance in the entire benthic faunal assemblage, there were no trends towards any reduction in total standing crop nor any component of species diversity.

In addition to the four major groups mentioned above, habitat formers, other vertebrate wildlife and fish are also discussed in the biotic categories sections. Habitat formers are not considered in detail because the Indian Point area is generally devoid of rooted aquatic vegetation and is not close to any significant wetland areas. Similarly, the discharge has no effect on any terrestrial wildlife or Hudson River waterfowl populations. The information presented on fish involves observations made on fish distributional patterns as a result of field collections, and basically serves to reinforce concepts introduced in the fish RIS sections.

2.4 Supplemental Decision Criteria

In the May 1, 1977 draft of the Technical Guidance Manual, USEPA suggests that a 316(a) demonstration will be successful if it meets each of eight criteria, seven of which pertain to the responsibilities of the demonstration to include essential technical information. Some of these seven criteria have already been discussed in Sections 2.1 through 2.3. The remainder are considered in detail elsewhere in this demonstration. Listed below are the seven criteria and references to the sections in which they are evaluated. Brief summarizations of the demonstration's approach towards each criteria are also provided.

1. "There is no convincing evidence that there will be damage to the balanced, indigenous community, or community components, resulting in such phenomena as those identified in the definition of appreciable harm."

   As presented in Section 3, and summarized in Section 2.2, the RIS are not appreciably harmed by the Indian Point discharge. In the absence of any contrary evidence, it is inferred from this conclusion that the balanced, indigenous community is similarly not damaged. Furthermore, evidence is presented in Sections 4 through 8 to show that spatial and temporal trends in the distribution, abundance and species composition of phytoplankton and the major invertebrate groups in the Indian Point area are associated with environmental factors such as salinity intrusion, rather than factors related to the plants' discharge.

2. "Receiving water temperatures outside any (State established) mixing zone will not be in excess of the upper temperature limits for survival, growth, and reproduction, as applicable, of any RIS occurring in the receiving water."

   The RIS analyses presented in Section 3 indicated that zones of potential damage within the discharge plume are confined to extremely small regions near the discharge ports. The analysis is conservative in that it is based on critical time-temperature combinations exceeding those which may be experienced by entrained organisms.

3. "The receiving waters are not of such quality that in the absence of the proposed thermal discharge excessive growths of nuisance organisms would take place."

   Potentially noxious species of blue-green algae have not historically achieved nuisance proportions in the Indian Point area prior to plant operation, nor have they significantly increased in abundance since phytoplankton studies were initiated in 1971 (Section 4).

4. "A zone of passage will not be impaired to the extent that it will not provide for the normal movement of populations of RIS, dominant species of fish, and economically (commercial or recreational) species of fish, shellfish and wildlife."

   Information presented in Section 10 and Appendices C and D clearly show that the maximum percentages of river cross-section area and surface width at Indian Point associated with the 4°F excess temperature isotherm are within the limits established by New York State for protection of the aquatic community. The continued spawning success of Hudson River fish populations as evidenced by no abnormally low year classes since Indian Point came on-line in 1973 (Con Edison 1977a) further attests to the discharge's compatibility with migratory pathways and normal population movements of the balanced, indigenous population.

5. "There will be no adverse impact on threatened or endangered species."

   Shortnose sturgeon is the only endangered species in the Hudson River estuary. Atlantic sturgeon are considered rare. The life history information for these species is discussed in Sections 3.11 and 3.12. Since sturgeon are predominantly bottom dwellers during all life stages, and since the Indian Point discharge plume extends into these depths only in the immediate vicinity of the discharge, it is expected that no adverse effects occur.

6. "There will be no destruction of unique or rare habitat without a detailed and convincing justification of why the destruction should not constitute a basis for denial."

   There are no rare or unique habitats within the influence of the Indian Point discharge plume. The river depths in the within 200 feet of the plant range from 10-40 feet below mean sea level. Water turbidity and lack of suitably shallow areas preclude formation of submerged or emergent vegetation in the region. Bottom sediments are composed of extremely fine particles of sand, silt and clay.

7. "The applicant's rationales present convincing summaries explaining why the planned use of biocides such as chlorine will not result in appreciable harm to the balanced indigenous population."

Data on the chemical aspects of the Indian Point discharge appear in Section 10 and in Appendix D. The discharge of chemical wastes, including chlorine, into the Hudson River from the Indian Point generating station is regulated by the Environmental Technical Specification Requirements (ETSR) set forth by the USNRC, the NPDES permit issued by the USEPA, and the certificate issued by New York State pursuant to FWPCA Section 401(a). The three documents not only specify the limits of various chemical discharges, but mandate a continuous monitoring program to assure that chemical discharges do not exceed the established limits. In reports submitted to the various regulatory agencies to date, these limits have not been exceeded.

Due to rapid, vertical mixing in the Indian Point discharge plume, chlorine values fall below detectable limits of amperometric titration (0.03mg/1). The low chlorine residual values are also attributable to chlorination procedures adopted since 1975 to minimize chlorination frequency. The new procedure calls for physical examination of the condensers in order to determine whether chlorination is necessary. The actual chlorination frequency at Indian Point is far less than the maximum possible yearly frequency of chlorination specified in the ETSR. There were no chlorinations at Indian Point during 1976 and 1977. Studies on Hudson River phytoplankton, microzooplankton, macrozooplankton and fish indicated that the chlorine concentrations present in the Indian Point discharge plume following condenser chlorination did not pose any threat to these groups (NYU 1976b).

SECTION 3 - REPRESENTATIVE, IMPORTANT SPECIES

The RIS concept assumes that since it is not economically nor technically feasible to study every species at a site in great detail, examination of the effects upon a select group will allow for a determination of the impact on the BIP. If it is shown that the RIS will not suffer appreciable harm as a result of the heated discharge, then there will be reasonable assurance that other species will also be protected. In this section, information from a variety of sources is integrated to provide predictions of the impact of the Indian Point discharge plume upon the RIS. The RIS list designated by the USEPA for the Indian Point area appears as Table 2-1. Of the 14 taxa, one (shortnose sturgeon) was included because of its status as an endangered species.

3.1 RIS Rationale

It was determined that the discharge plume created by the once-through cooling operation of the Indian Point generating station does not appreciably harm any of the designated RIS, thus assuring the protection and propagation of a BIP of fish, shellfish and wildlife in and on the Hudson River estuary. The lack of significantly adverse effects is due to the rapid dilution of discharge waters at potentially harmful temperature levels, resulting in a thermal plume that generally does not present stressful conditions for any organism that may become entrained within it. In fact, the excess temperatures found in plume areas frequently provide more favorable thermal conditions for growth and development of many fish species than the cooler ambient temperatures in the river. This does not necessarily imply that these species actually take advantage or prefer the warmer plume waters. The information supporting these conclusions is contained in the following sections.

3.2 Approach to Impact Prediction

Three basic factors provide the input necessary for impact prediction on the RIS. These are 1) the hydrothermal analyses of the Indian Point discharge plume, 2) laboratory investigations into the effects of thermal stress, and 3) life history information acquired from field observations and literature search. The impact predictions are essentially based upon the application of data from the two biotic elements (factors #2 and 3) to a projection of the configuration of isotherms within the discharge plume (factor #1). Applying the biological information to the projections provided by the hydrothermal analyses results in an estimate of the plume's potential to adversely affect a particular RIS. To determine the overall impact on the species, the plume area(s) in which potentially adverse effects are predicted is (are) compared to an appropriate nearfield region. This comparison represents a measure of the plume's potential to exert appreciable harm on that species.

3.3 Hydrothermal Analyses

In accordance with the New York State certification pursuant to FWPCA Section 401 for Indian Point Units Nos. 1, 2 and 3, Con Edison has conducted a number of surveys to determine the thermal characteristics of the Indian Point discharge plume. The procedures and results of these studies are fully discussed in Section 10 and in Appendices C and D. Of the 15 surveys for which data are available, various surveys were selected to represent typical fall, spring and summer conditions. The rationale for selecting each of the particular surveys is explained in Section 10.4.2. No surveys were conducted during the winter months.

An agreement with New York State provides that when ambient water temperatures fall below 40°F, the volume of cooling water intake flow be reduced by 40% to help reduce impingement. During this reduced flow "winter" condition, the ΔT of the cooling water is approximately 27.0°F, or about 11°F higher than during non-winter periods. The heated water passes through the rectangular (slot) discharge ports, which are located approximately 12 feet beneath the surface, at a velocity of 10 feet per second. This velocity is maintained regardless of intake flow volume variation. Upon contact with the river (receiving water), the discharge is rapidly diluted and surfaces some distance away from the outfall structure. In USNRC (1975a), a slot jet application to the Koh-Fan hydraulic model indicates the horizontal distance of plume travel (from the discharge ports to the point where the plume emerges at the surface). The basic principles of the Koh-Fan model and its application in this demonstration are discussed in Section 1.3, Appendix D. The USNRC analysis indicates that for the non-winter case, the plume will approach surface approximately 106 feet from the discharge; for winter, at approximately 92 feet. Using this basic information, it was possible to obtain estimates of the time, temperature and velocity at various distances within the plume. This information is presented in Table 3-1 for the jet cone portion of the plume.

To estimate the volume and surface area of water encompassed by a specific isotherm, data collected from the thermal plume surveys were utilized. Three isotherms were of particular interest; those corresponding to the 3, 4 and 6°F excess temperatures. The 3°F isotherm generally conforms to the "primary study area" as defined in the TGM. The 4°F value has significance as a

Table 3-1. Temperature and Velocity Profiles of the Indian Point Generating Station Discharge Plume

X, ft	0	20	40	60	80	100	106/92*
ΔT_N, ^oF	16.1	14.6	13.2	11.8	10.4	9.0	7.7
ΔT_W, ^oF	27.0	24.5	22.0	19.5	18.1	15.4	12.3
V_F, ft/sec	10.0	6.6	4.4	2.9	1.9	1.3	0.9
V_E, ft/sec	10.0	7.1	5.0	3.6	2.5	1.8	1.3
V_S, ft/sec	10.0	5.2	2.7	1.4	0.7	0.4	0.2
t_F, sec.	0.0	2.5	6.2	11.8	20.5	33.4	53.4
t_E, sec.	0.0	2.6	6.0	10.6	17.4	26.8	40.2
t_S, sec.	0.0	2.8	8.1	18.1	36.3	76.3	156.3

X = distance measured along the centerline of thermal plume

ΔT_N = water excess temperature for non-winter conditions

ΔT_W = water excess temperature for winter conditions

V_F = plume velocity at flood

V_E = plume velocity at ebb

V_S = plume velocity at slack

t_F = time required for water particle to travel distance x at flood tide

t_E = time required for water particle to travel distance x at ebb tide

t_S = time required for water particle to travel distance x at slack tide

* 106 ft. during non-winter conditions
92 ft. during winter conditions

criterion for state water quality standards (FWPCA, Section 401). Volumes contained within isotherms greater than that defined by the 6°F excess temperature are very difficult to measure because of their extreme proximity to the discharge.

Since most of the thermal plume surveys were performed when the station was operating at less than the combined maximum rated capacity of Units Nos. 2 and 3 (Table 10-8), a projection of the extent of certain excess temperature isctherms was developed for the situation in which both units Nos. 2 and 3 would be operating at 100% capacity. The techniques involved in this scale-up procedure are discussed in Section 10.4.1. The approximate volumes and surface areas enclosed within the scaled-up 3, 4 and 6°F excess temperatures isotherms under various tidal conditions for spring, summer and fall, are presented in Table 10-14.

3.3.1 Exclusion Areas

Planktonic organisms are not physically excluded from any portion of the discharge plume.

The size of the exclusion areas for more motile life stages (juvenile and adult fish) are dependent on the relationship of the locomotor ability of the particular species to plume hydrodynamics. Among the Hudson River fish RIS for which sustained swimming speed data were available (Meldrim et al 1974; Wyllie et al 1976), striped bass exhibited the greatest capacity for rapid movement - approximately 4 feet per second. At this velocity the fish would be able to maintain their positions near the 11.8°F (6.6°C) excess temperature isotherm in non-winter conditions and near the 19.5°F (10.8°C) isotherm during winter (Table 3-1). Similarly, other species would also be able to penetrate the jet cone region to some lesser extent. However, since estimates of the plume volumes associated with isotherms greater than 6°F were not available, it is conservatively stated that the exclusion zones for juvenile and adult fish are less than the volumes encompassed by the 6°F isotherm.

3.4 Analysis of Biological Data

Many of the Indian Point RIS have been studied as part of, or as the focus of, numerous ecological investigations on the effects of power plant operation on the aquatic biota of the Hudson River. It was not possible to examine every RIS in the laboratory environment. In some instances, difficulties encountered with the collection or maintenance of test stock precluded experimentation. In these cases, predictions of impact relied upon information from field work in the Hudson River, or upon laboratory thermal effects data and field research acquired in other estuarine systems (Section 2.1).

The purpose of performing the laboratory studies was to obtain temperature values for certain biological functions which would indicate the point beyond which adverse effects might occur. In the framework provided by the hydrothermal analyses, these threshold values corresponded to distinct excess temperature isotherms. The volume of those waters warmer than these threshold values, and encompassed by the corresponding excess temperature isotherm, is referred to as the zone of potential damage (ZPD). The excess temperature isotherm that is used to define the ZPD is referred to in this demonstration as the critical isotherm.

For each of the RIS for which sufficient information was available, a "thermal effects diagram" is presented to illustrate the relationship between maximum discharge temperature (MDT) and a variety of biological functions, the measurements of which are termed thermal response parameters. Some of these laboratory-derived thermal response parameters (on survival, growth, reproductive success, final preferenda, avoidance, etc.), are used directly as input to impact prediction, while others serve primarily to describe responses to thermal stresses in a less restrictive sense.

Each thermal response parameter has a specific temperature, or temperature range associated with it. Since the thermal effects diagrams serve to illustrate certain important relationships which form the basis for predicting the impact, it would be useful to explain the manner in which the data are presented. In the thermal effects diagrams, the value(s) associated with a specific thermal response parameter may be represented in one of two ways. For those cases when the thermal response parameters were independent of acclimation temperature, a horizontal line indicating the parameter's temperature value was drawn to correspond to that particular life stage's occurrence in the Indian Point area. In all other cases, the thermal response parameter's value was indicated as a point, corresponding to a specific acclimation temperature on the mean "ambient" temperature (MAT) line.

The monthly MAT's plotted in the thermal effects diagrams were taken from data accumulated over a ten year period by the United States Geologic Survey (USGS). These data, reported in Con Edison (1972b), were the most appropriate source available for this demonstration because they were gathered daily over a reasonably long period of time. However, the methodology used to record these measurements, and the locations at which they were taken, caused these values to be somewhat higher than those reported in more recent surveys (Con Edison 1977b). The MAT, the highest recorded ambient temperature (HRAT), and the lowest recorded ambient temperature (LRAT) for the ten year period are presented in Table 3-2.

Table 3-2. Hudson River Water Temperatures in the Vicinity of Indian Point

(USGS:1959-1969)

Month	Highest Recorded Ambient Temperature (HRAT) (^{o}C)	(^{o}F)	Lowest Recorded Ambient Temperature (LRAT) (^{o}C)	(^{o}F)	Mean Ambient Temperature (MAT) (^{o}C)	(^{o}F)
January	5.6	43.0	0.0	32.0	1.1	34.0
February	3.3	38.0	0.0	32.0	0.7	33.2
March	6.1	43.0	0.0	32.0	1.7	35.0
April	13.9	57.0	2.8	37.0	7.0	44.6
May	19.4	67.0	8.9	48.0	14.1	57.3
June	25.6	78.0	15.6	60.0	20.1	68.2
July	27.2	81.0	21.7	71.0	24.4	75.9
August	27.2	81.0	22.8	73.0	24.9	76.9
September	26.7	80.0	17.8	64.0	22.8	73.0
October	22.7	73.0	13.9	57.0	17.9	64.2
November	16.1	61.0	6.1	43.0	11.6	52.9
December	10.6	51.0	0.0	32.0	4.9	40.8

Source: Con Edison 1972b

The MDT was plotted in the thermal effects diagrams by adding the calculated maximum ΔT (Section 3.2) to the specific MAT. These calculations did not include additional dilution of the effluent due to plant service water. Also included in the thermal effects diagrams is abundance information plotted in histogram form. These data were obtained from field efforts in the vicinity of Indian Point (TI 1975a, 1976d, 1976e, 1976g, 1976h, 1977b), and impingement collections at the plant (Con Edison 1977b). By allowing visual comparison between the MDT and each of the thermal response parameters, the thermal effects diagrams graphically delineate instances in which potentially adverse effects may occur. When the temperature value of a thermal response parameter used to determine a ZPD exceeds that associated with the relevant MDT, no adverse impact would be predicted. In those cases where the appropriate thermal response parameter value is less than the MDT, the extent of potentially adverse impact would be proportional to the difference between the two levels. It should be noted that not every thermal response parameter investigated in the laboratory studies is plotted in the thermal effects diagrams, although all those used to estimate zones of potential damage are included.

The ability of each thermal response parameter to function in determining appreciable harm varies from species to species. However, for the purposes of this demonstration, the most appropriate class of parameters that may be used are those which express thermal stress in terms of survival. Parameters such as thermal preferenda, avoidance behavicr and growth are important in describing the species' overall response to thermal stimuli, but they are not as useful as survival measures in assessing the potentially adverse effects associated with the discharge plume. Although there is a range of optimum temperatures for many physiological processes such as growth, the level acceptable for sustaining normal functioning cannot be as precisely defined. Temperatures outside the optimum range are often exceeded in nature at places and times where populations can be sampled and found to be in good condition and growing. Specifically, with respect to water temperature standards at power plants, it was noted that optimum temperatures are not necessary for maintaining a population (Coutant 1972). Survival bioassays have the advantage of being fairly routine and can be very precisely interpreted. There is also substantially more information on lethal stress than on organism response to sublethal concentrations.

Since plankton are exposed to the warmest plume temperatures for only very brief (Table 3-1) periods of time, a parameter like the 30 minute TL95 (the temperature to which exposure for 30 minutes results in survival of 95% of the test organisms) is a very conservative indicator (i.e. a likely overestimate) of the plume's potential to adversely affect this group. Unlike plankton, juvenile and older fish are capable of remaining within the plume for extended durations. In these cases, survival parameters based upon laboratory exposures of up to 96 hours are considered, although it would be expected that fish would avoid thermally lethal plume regions. These survival parameters are most useful in evaluating the cold shock potential of plume-entrained fish during winter.

Even though adverse effects other than mortality may possibly occur for plume-entrained planktonic RIS, it is highly unlikely that any of these effects would be meaningful because plume exposures are so brief. To account for any sublethal effects that might be disregarded by concentrating on survival parameters, the approach to impact analysis is decidedly conservative. For example, the laboratory conditions to which the test organisms were exposed were more severe than those which plume-entrained organisms would encounter. The laboratory specimens were exposed to the test temperatures instantaneously, held at that temperature for a specified duration, and then instantaneously returned to their acclimation level. Organisms entrained within the plume would be returned to ambient temperature at a much less rapid rate. Another major factor contributing to the conservativeness of this demonstration's assessment is that most of the survival parameters used are based upon laboratory exposures many times greater than those estimated in Table 3-1. Other elements which bias the analysis on the conservative side are discussed as they appear in the presentations for the individual RIS.

3.5 *Neomysis americana*

3.5.1 Life History Information

N. americana is a common inhabitant of estuaries and nearshore waters of the eastern United States, ranging from the St. Lawrence River to St. Augustine, Florida (Gosner 1971; Williams et al 1974). *N. americana* is a euryhaline organism (Gosner 1971), whose appearance in the vicinity of Indian Point is usually associated with the intrusion of the salt front (Lauer et al 1974; Ginn 1977; Section 7.2.3). *N. americana* is primarily epibenthic, but does show some diel migration, moving up into the water column at night (NYU 1973, 1974, 1976a, 1977a, 1977b).

Reproduction may occur throughout the year in some coastal areas but generally reaches a peak during the warmer months (Wigley and Burns 1971). As many as two to three generations per year may be produced (Hopkins 1965; Williams 1972). *N. americana* is omnivorous, consuming detritus, diatoms and smaller crustaceans (Williams et al 1974). In the Hudson River estuary, they were found to form small portions of the total diet of striped bass, white perch and Atlantic tomcod. (TI 1972, 1974, 1975b, 1976b).

3.5.2 Thermal Tolerance Studies

To determine its lethal tolerance, N. americana were exposed for varying durations to elevated temperatures. Information on collection procedures, holding and test conditions, and criteria used to establish viability appear in Appendix A and in Section 4.1, Appendix D.

During the cooler months from March to mid-June and from October through December, the thermal discharge is not expected to cause any significant mortality. Survival data for N. americana tested in laboratory conditions representative of these cool temperatures were reported as 24 hour TL50's,* and are illustrated in Figure 3-1. It can be seen from this figure that the 24 hour TL50 values plotted during January and February are slightly lower than the MDT. Exposure time to temperatures above the TL50 value would be so short that mortality would be negligible. Furthermore, although there were only limited abundance data available during January and February, the N. americana population is probably very low, since salinity intrusions are an infrequent occurrence at this time of year (Con Edison 1977b). It was reported that N. americana abundances during the winter intrusion were approximately 0.1% of the peak summer abundances (Ginn 1977).

During the summer months, the situation is noticeably different in that there is a distinct plume area in which temperatures exceed the lethal tolerance levels of these organisms. Figure 4 - 1, Appendix D presents N. americana survival at temperatures above ambient summer levels. For five minute exposures, test organisms began to show mortality (TL95) at approximately 32.5°C. The 5 minute TL50 was 34°C (NYU 1973). This threshold-like response was also found for longer exposure times in that the TL50 values were generally less than 2°C higher than the TL95 values.

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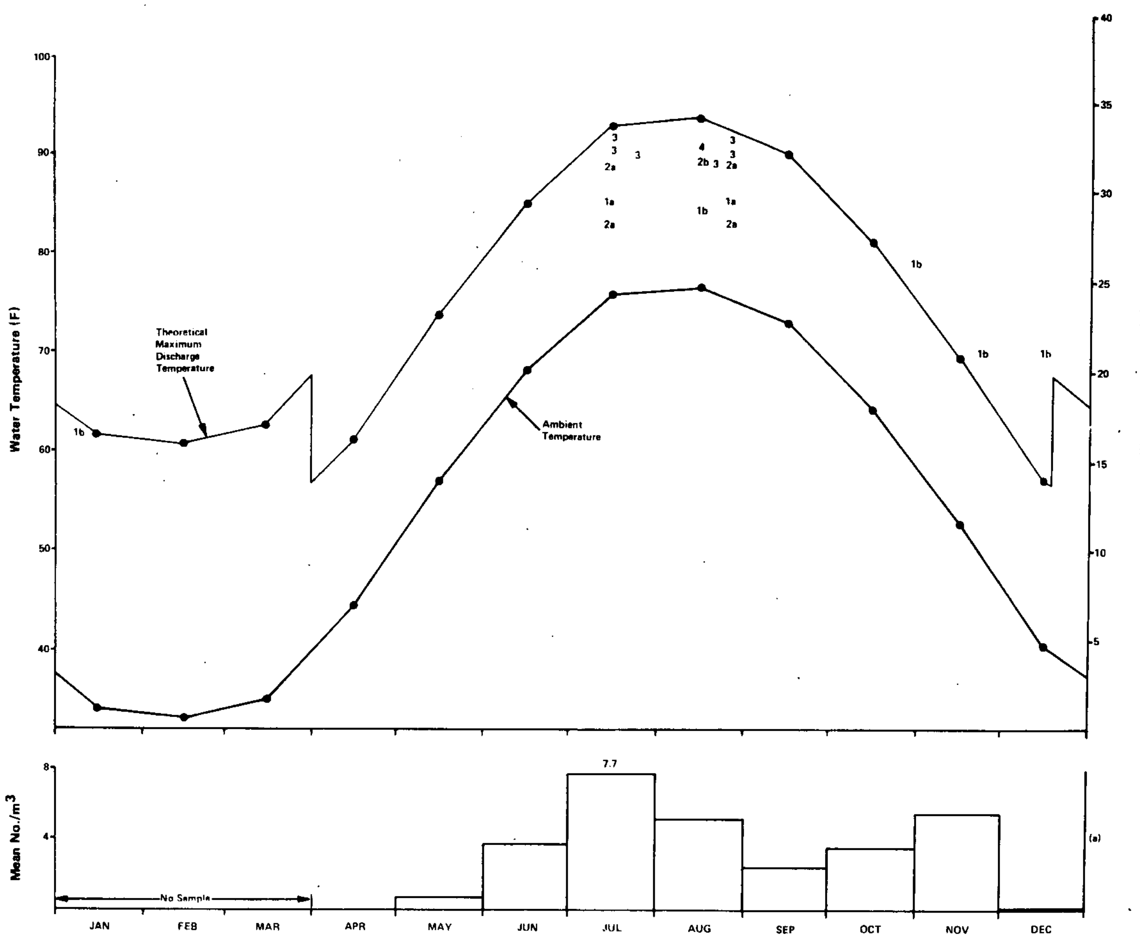
*Although it was previously mentioned that the 30 minute TL95 was a conservative estimate of impact for plume-entrained plankton (Section 3.4.1), the 24 hour TL50 is a far more common measurement of lethal stress. Since 24 hours TL50 values are usually quite close or lower than the corresponding 30 minute TL95's they also provide a conservative estimate of impact on planktonic organisms.



Key to Thermal Effects Data Points

1. 17.0-29.4 C, 24-hr TL50s; (a) EA 1978, (b) Mihursky and Kennedy 1967.
2. 28.8-31.7 C, 30-min TL95s; (a) EA 1978, (b) NYU 1973.
3. 31.7-33.0 C, 10-min TL95s; EA 1978.
4. 32.5 C, 5-min TL95; NYU 1973.

Key to Seasonal Distribution Histograms

(a) Mean no. per m^3 collected in 10-min plankton tows at night, RM 40-44; 1971, 1972, 1974, 1975; NYU 1973, NYU 1974, NYU 1976a, NYU 1977a.

Figure 3-1. Thermal effects diagram for *Neomysis americana* at the Indian Point Generating Station on the Hudson River.

In July and August, the MAT was 24.4°C and 24.9°C respectively (Table 3-2). The lowest 30 minute TL95 calculated above mean summer temperatures of 24-25°C was 28.6°C. For July and August, this value represents critical isotherms of 4.2°C (7.6°F) and 3.7°C (6.7°F), corresponding to zones of potential damage (ZPD) considerably less than 606 acre-feet, (Table 10-14). It should be noted that the 30 minute TL95's ranged from 28.8°C to 31.7°C, but the lowest reported value was used to obtain the most conservative estimate of impact. To evaluate whether the ZPD's listed above are large enough to appreciably harm the N. americana population, they are compared to the nearfield region described in Section 10.2.3. The July or August ZPD is less than 0.5% of the water volume contained in this river region (Table 10-15). In addition, since the plume does not generally extend to the bottom (Table 10-9), the epibenthic characteristics of N. americana mean that it will be subjected to plume entrainment only during those times that it is present in the middle and upper portions of the water column. On the basis of the available information, it is concluded that N. americana will not suffer appreciable harm as a result of the discharge from the Indian Point plants.

3.6 Gammarus spp.

3.6.1 Life History Information

Three gammarid species are found in the Hudson River estuary, G. fasciatus, G. daiberi and G. tigrinus. G. fasciatus is primarily a freshwater species, found in coastal drainages from southern New England to the Chesapeake Bay (Bousfield 1973). G. daiberi is an oligohaline-mesohaline species, ranging from the Hudson River to South Carolina, while G. tigrinus, which is also oligohaline-mesohaline ranges from southern Labrador to the Chesapeake Bay (Bousfield 1973).

G. daiberi is the dominant species collected in the brackish portion of the Hudson River estuary. G. tigrinus also occurs in these waters, but is less planktonic than G. daiberi and is more abundant in the shallow water sediments and among macrophytes (Ginn 1977). G. fasciatus is primarily found in the estuary's freshwater reaches, and is seldom collected in that portion of the estuary within the range of salinity intrusions (Ginn 1977). Each of the three species' life cycles are completed within one year. The rapid growth and reproductive capabilities of Gammarus spp. enable them to maintain high population levels despite heavy predation by Hudson River fishes. The first young are produced by overwintering adults in the early spring (Bousfield 1973; Ginn 1977). These young have sufficient time to mature and produce several more generations before cessation of reproduction in the winter. Each female has the potential for several broods per summer.

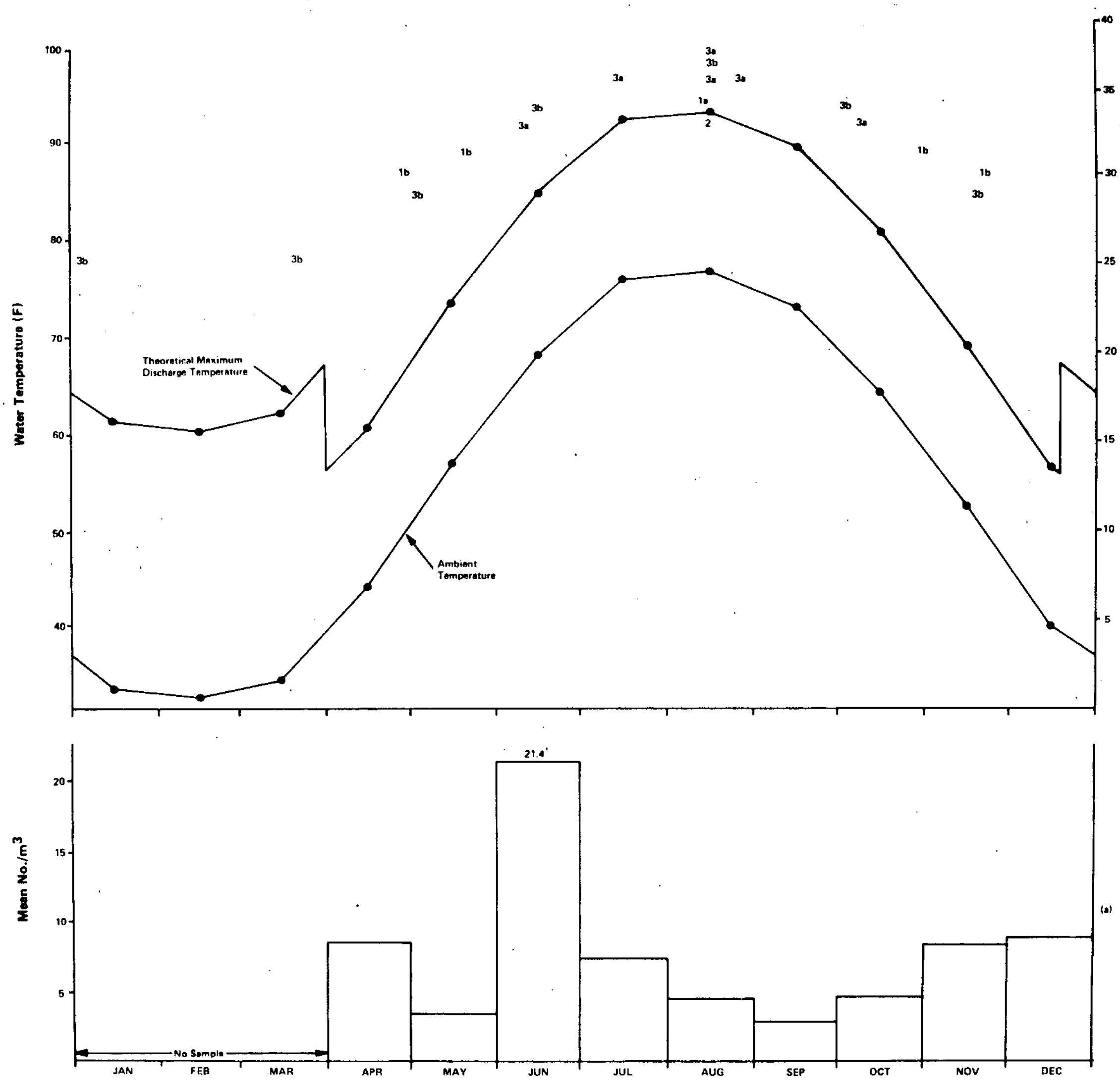
Abundance data, collected at different depths in the vicinity of Indian Point, have indicated that Gammarus spp. are primarily epibenthic, with some organisms moving up into the water column at night (Section 7.2.3). Gammarus spp. are omnivorous scavengers. They feed on plant, animal and detrital matter, and browse through aquatic vegetation (Bousfield 1973). Gammarus spp. are a major food item for a variety of juvenile and adult Hudson River fishes such as white perch, striped bass, Atlantic tomcod, johnny darter, eel, white sucker, spottail shiner, brown bullhead, killifish, shad and alewife (Hirshfield et al 1966; TI 1972, 1974, 1975b, 1976a, 1976b).

3.6.2 Thermal Tolerance Studies

The upper lethal temperatures for Gammarus spp. were investigated in several sets of laboratory experiments. To determine their lethal tolerance, the tests organisms were exposed for varying durations to a number of different elevated temperatures. Information on collection procedures, holding and test conditions, and criteria used to establish viability appear in Appendix A and in Section 4.1, 4.2 and 4.3, Appendix D.

The results of these laboratory studies and others reported in the literature indicated that for the entire year, 24 hour TL50 and 30 minute TL95 temperatures exceeded the MDT (Figure 3-2). The time of year during which the MDT most closely approached these survival parameter values was in August. As with N. americana (Section 3.5), Gammarus spp. displayed a threshold-like response to temperature increases above summer ambient levels. However, the values at which mortality was observed were much higher than those found for N. americana. The 5 minute TL95 was 38.0°C and the TL50 for the same exposure time was 38.7°C (Table 4 - 1, Appendix D). Other laboratory studies performed on Gammarus spp. acclimated at 25.5°C indicated excellent immediate and latent survival after 60 minute exposure to a ΔT similar to that found at Indian Point (Table 3-3). Tolerance generally decreased with increasing exposure time, yet the difference between the 5 and 60 minute TL50 was quite small (Figure 4 - 2, Appendix D).

For those organisms capable of acclimating to conditions within the thermal plume, a potential source of adverse impact is the rapid exposure to lower temperatures, as might occur during a winter plant shutdown. Although it is highly unlikely that macrozooplankton could maintain their position within the plume for a sufficient period of time to fully acclimatize to the higher temperatures, Gammarus spp. could potentially suffer some form of cold shock. In studies examining the consequences of



Key to Thermal Effects Data Points

1. 30.5-33.8 C, 24-hr TL50s; (a) EA 1978, (b) Mihursky and Kennedy 1967.
2. 33.0 C, 48-hr TL50; NYU 1973.
3. 25.5-37.1 C, 30-min TL95s; (a) EA 1978, (b) NYU 1973.

Key to Seasonal Distribution Histograms

(a) Mean no. per m3 collected in 10-min plankton tows at night for 1971, 1972, 1974, and 1975, RM 40-44; NYU 1973, NYU 1974, NYU 1976a, NYU 1977a.

Figure 3-2. Thermal effects diagram for *Gammarus* spp. at the Indian Point Generating Station on the Hudson River.

Table 3-3. Percent survival of *Gammarus* spp. exposed to an 8.3°C ΔT at an ambient temperature of 25.5°C (100 organisms per test group).

Exposure Time	Survival		
	Immediate	5 day	10 day
0 (control)	100	97	90
5 minutes	100	97	90
30 minutes	100	95	88
60 minutes	100	96	92

Source: Ginn 1977.

such a possibility, it was found that Gammarus spp. acclimated to 15.6°C and subjected to an instantaneous decrease to 9.1°C experienced no significant mortality (Ginn 1977). It is clear from these studies that the Indian Point discharge plume cannot appreciably harm the Gammarus spp. population.

3.6.3 Reproductive Studies

Although the thermal tolerances studies clearly indicated that the potential for adverse effects was negligible, the possibility of certain sublethal effects resulting from plume entrainment was also investigated. In this regard, the effects of short-term exposure to elevated temperatures on Gammarus spp. fecundity and viability of young were examined. Details of laboratory procedures and analyses are found in Section 4.4, Appendix D.

The results of these studies indicated that there were no significant differences in the number of live young produced by control and test groups of ovigerous female G. daiberi acclimated at 26°C and exposed for 5 and 60 minutes to an 8.3°C ΔT. However, thirty minute exposures at a higher ΔT, 11°C, did result in a significant reduction in the number of young produced (Table 4-2, Appendix D). Other experiments on Gammarus spp. reproduction found that there was no reduction in the production of young from pairs (male and female) of G. daiberi that had been subjected to an 8.3°C ΔT for 60 minutes (Table 4-3, Appendix D). It was also found in these experiments that the reproductive capacity of Gammarus spp. was stimulated by long-term exposure to a ΔT of 15.6°C above an ambient temperature of approximately 10°C (Ginn 1977).

3.6.4 Plume-Transit Studies

To further evaluate the effects of the Indian Point discharge plume on Gammarus spp., experiments were conducted which exposed test organisms to actual plume conditions.

Gammarus spp. test organisms were confined to cages which were attached beneath the water surface to a floating rack (Figure 4-3, Appendix D). The rack was then placed in the area of the plume where the highest ΔT was located. At the same time, a control rack was placed in a non-plume area of the river. The racks were permitted to drift in the river for one hour under the influence of local tidal and current conditions. More detailed discussion of field methods is found in Section 4.5, Appendix D. Following simulated plume transit, the organisms were returned to the laboratory for immediate viability assessment; others were retained for observations of latent effects.

At the time the tests were performed, the ambient temperature was approximately 25°C and the highest surface temperature reached in the plume was 30°C. The survival of Gammarus spp. exposed to the control and plume transits were both greater than 90%. No statistical differences were determined between the 120 hour survivals of control and plume transit groups (NYU 1976b).

3.7 Crangon septemspinosa

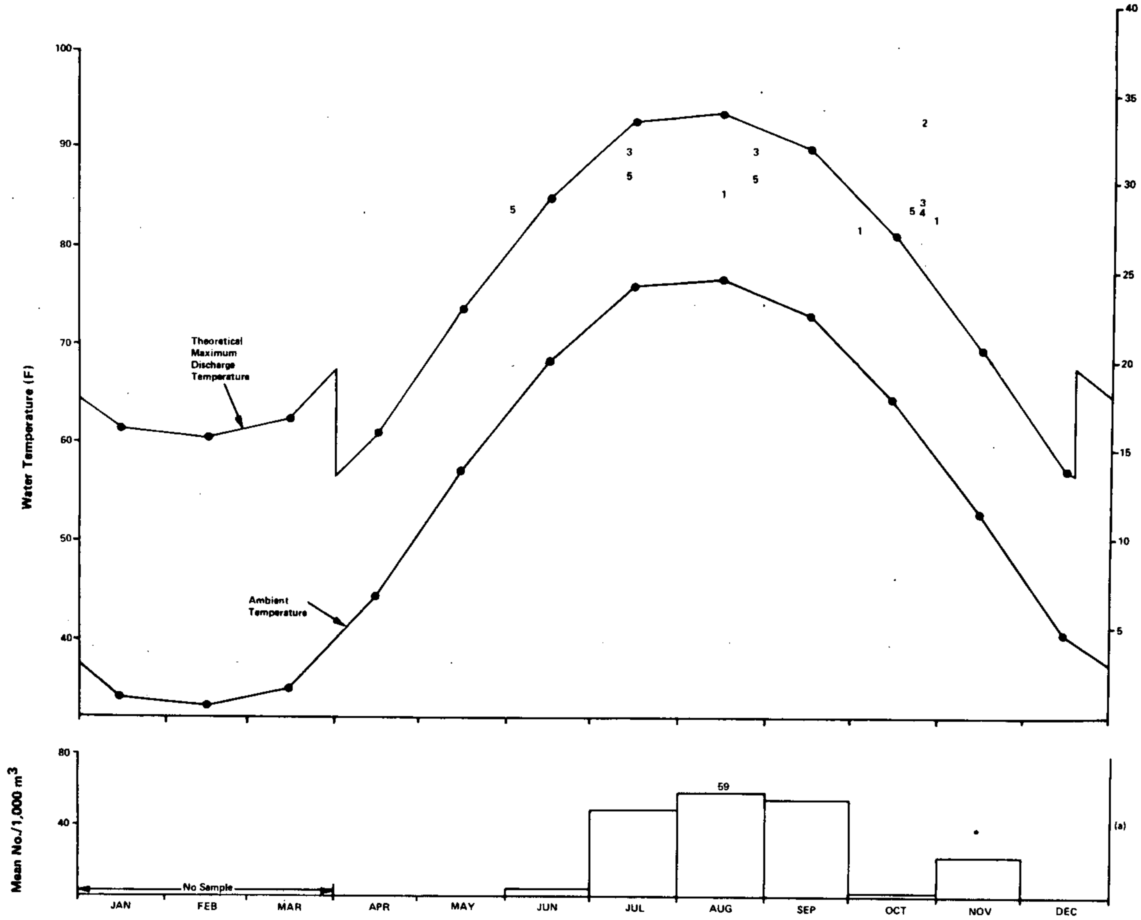
3.7.1 Life History Information

Crangon septemspinosa is an estuarine shrimp found along the eastern coast of North America from Baffin Bay (between Canada and Greenland) to Florida. It appears to be limited to waters with salinities greater than 4 ppt (Price 1962; Haefner 1976). C. septemspinosa has been collected from May through December in the Indian Point vicinity, with peak densities usually occurring from July through September, coinciding with the presence of the salt front in the area (NYU 1974, 1976a, 1977a, 1977b, Raytheon 1971).

C. septemspinosus is an epibenthic species (Price 1962) whose larvae are planktonic for part of their existence (Sage and Herman 1972). It has an extended breeding season, with ovigerous females found throughout the year in the Chesapeake Bay region (Haefner 1976). Price (1962) found that C. septemspinosa had a life span of from 2 to 3 years. C. septemspinosa feed on a variety of invertebrates and in turn they form a small portion of the total diet of a number of fish species in the Hudson River estuary including stiped bass, white perch and Atlantic tomcod (Price 1962; Raytheon 1970; TI 1974, 1975b, 1976b; Con Edison 1977a).

3.7.2 Thermal Tolerance Studies

C. septemspinosa is most abundant in the Indian Point area from July through September. It is only during this time that any of the 30 minute TL95 values derived from the laboratory studies failed to exceed the MDT (Figure 3-3). The 30 minute TL95 associated with the summmer period is 31.8°C (EA 1978). During August, the month with the highest MAT, this TL95 value would correspond to a 6.9°C (12.4°F) critical isotherm. This represents a ZPD of considerably less than 606 acre-feet (Table 10-14), or less than 0.5% (Table 10-15) of the volume contained within the nearfield region described in Section 10.2.3. The epibenthic habitat preference of C. septemspinosa would tend to limit its susceptibility to plume entrainment and thus minimize the expected impact. Since the ZPD is restricted to a very small region near the discharge ports (Table 10-14), the plume would not be capable of exertng appreciable harm on the C. septemspinosa population in the Hudson River.



Key to Thermal Effects Data Points

1. 27.5-29.5 C, 24-hr TL50s; Mihursky and Kennedy 1967.
2. 33.9 C, 10-sec TL95; EA 1978b.
3. 29.0-31.8 C, 30-min TL95s; EA 1978.
4. 28.6 C, 60-min TL95; EA 1978.
5. 28.7-30.3 C, 10-min TL95s; EA 1978b.

Key to Seasonal Distribution Histograms

(a) Mean no. per 1,000 m^3 collected in 10-min plankton tows at night for 1974-1975, RM 40-44; NYU 1976a, NYU 1977a.

Figure 3-3. Thermal effects diagram for *Crangon septemspinosa* at the Indian Point Generating Station on the Hudson River.

3.8 Striped Bass

3.8.1 Life History Information

The anadromous striped bass uses the Indian Point vicinity, as well as many other areas in the river, as a spawning and nursery site. Spawning adults migrate from overwintering locations in the deeper water of bays, estuaries, or coastal rivers to spawn between early May and early June in freshwater or areas with salinities not greater than 0.1 ppt and water temperatures in the range of 11-21°C (TI 1976a). Spawning occurs in areas of sufficient current to keep the semi-buoyant eggs from settling to the bottom where siltation would prevent hatching (Con Edison 1977a).

The yolk-sac stage extends until the digestive tract is fully developed and generally lasts four to six days at 19-21°C. The larvae at this stage are only capable of limited movement and are usually oriented vertically in the water column due to the density characteristics of the yolk-sac. Post yolk-sac larvae are capable of active swimming movements in order to feed, avoid predators, and oppose currents. Post yolk-sac larvae have been found distributed similarly to the yolk-sac on a diel basis. However, they have been found to be more strongly oriented towards the bottom at night than the yolk-sac larvae (Con Edison 1977a).

When striped bass reach the juvenile stage, they show a general migration towards shoal areas and the shore zone. In the Hudson River, this migration usually lasts until the end of July. The fish remain in these areas until October-November, at which time there is generally a downstream movement of juveniles to the lower estuary. At this point, they either leave the estuary or remain in deeper water during the overwintering period (Con Edison 1977a). Studies on the food habits of the striped bass indicate that the post yolk-sac diet consists primarily of many small invertebrates (Kretser 1973). As individuals increase to juvenile size, their feeding changes to larger invertebrates such as Gammarus spp. This macroinvertebrate remains a preferred food source until the fish exceed approximately 150 mm in length. These larger fish may be classified as opportunistic piscivores (TI 1976a).

3.8.2 Thermal Tolerance Studies

Laboratory tolerance studies were performed on striped bass from the egg through the juvenile stage. For those studies performed by Ecological Analysts, Inc., complete information on laboratory procedures and data analyses appears in Appendix A of this demonstration.

3.8.2.1 Eggs

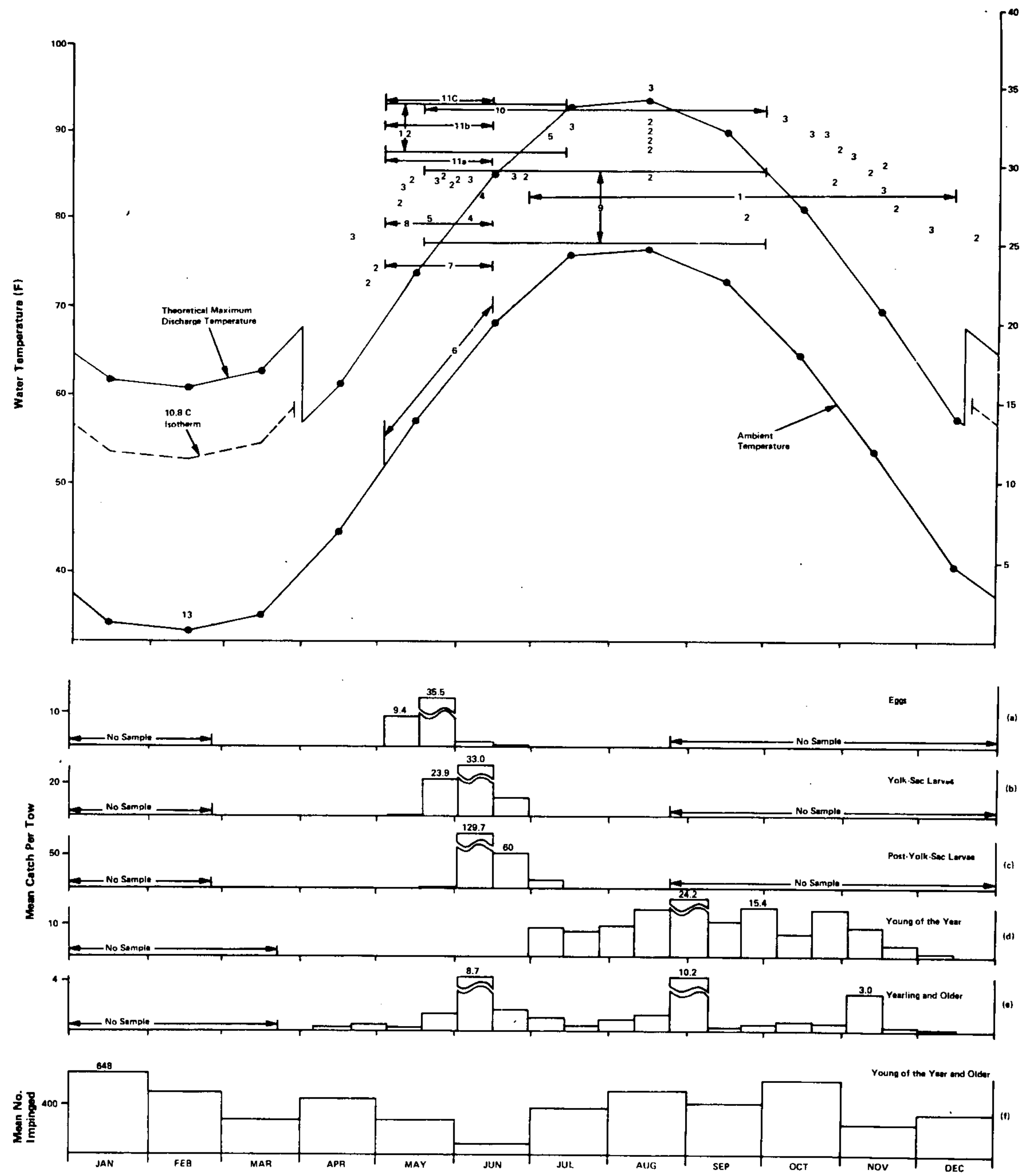
Striped bass eggs are present in the Indian Point area during May and to a minor extent in early June. The 30 minute TL95's for three egg stages (gastrula, tail bud stage and tail-free stage) were determined to be from 30.2 - 34.1°C (EA 1978). As can be seen in Figure 3-4, these values exceed the MDT. Even if the highest recorded ambient temperature (HRAT) for May is considered (Table 3-2), the TL95 values would still be higher than the MDT. It would not be expected, therefore, that striped bass eggs would suffer any adverse effects as a result of plume entrainment.

Other thermal response parameters of striped bass eggs were also investigated. The upper limit of the optimum range for normal hatch was found to be 23.7°C (EA 1978). Since the May MAT was 14.1°C, this would indicate that the entire discharge plume would generally be at a temperature level below the optimum upper limit for normal hatch. Since it would take at most only a few minutes for eggs entrained adjacent to the discharge ports to reach the surface (Table 3-1), the plume's overall temperature variation is within the optimum range for normal hatch of striped bass eggs.

3.8.2.2 Larvae

Yolk-sac and post yolk-sac striped bass larvae are found in the Indian Point area from the middle of May through early July, with the peak collections occurring in early June (Figure 3-4). The 30 minute TL95 values for these larvae ranged from 30.8°C to 34°C (EA 1978). As is illustrated in Figure 3-4, these values exceed the MDT during most of the May-July period when the larvae are present in the vicinity of the plant. For those relatively few larvae found in the area in early July, a critical isotherm of 6.4°C (11.5°F) would exist if the lowest 30 minute TL95 valve (30.8°C) were used. This would be associated with a ZPD of considerably less than 0.5% of the near-field region (Table 10-15). These thermal tolerance studies clearly indicate that larval striped bass are insignificantly affected by the Indian Point discharge plume.

As with the eggs, studies on parameters other than survival were also performed. The optimum range for growth of post yolk-sac larvae through the juvenile stage was 25.1 to 29.6°C (EA 1978), in excess of the MAT for both June and July (Table 3-2). The growth studies lasted for 16 days and a TL50 value was calculated for this period. This 16 day TL50 is an excellent estimate of the temperature below which survival is sufficient to assure that no significant harm results, regardless of exposure time or acclimation level. Frequently termed the "ultimate upper incipient lethal temperature" this value was 33.5°C, placing it close to the maximum larval 30 minute TL95, and further



Key to Thermal Effects Data Points

1. 27.8 C, final preferendum for juveniles (<170 mm); EA 1978.
2. 22.5-33.0 C, upper avoidance temps. for juveniles; TI 1976c.
3. 25.5-34.8 C, upper incipient lethal temps. for juveniles (96-hr TL50); TI 1976c.
4. 26.4-27.9 C, 24-hr TL50 for yolk-sac larvae; EA 1978.
5. 26.3-32.4 C, 24-hr TL50 for post-yolk-sac larvae; EA 1978.
6. 11.0-20.0 C, normal spawning temp. range; TI 1976h, McFadden 1977.
7. 23.7 C, upper limit of optimum range for normal hatch; EA 1978.
8. 26.3 C, TL50 for normal hatch; EA 1978.
9. 25.1-29.6 C, optimum range for growth of post-yolk-sac larvae and early juveniles; EA 1978.
10. 33.5 C, ultimate upper incipient lethal temp. for post-yolk-sac larvae and early juveniles (16-day TL50); EA 1978.
11. 30.2-34.1 C, 30-min TL95s for eggs: (a) gastrula stage, (b) tail-bud embryo stage, (c) tail-free embryo stage; EA 1978.
12. 30.8-34.0 C, range of 30-min TL95s for yolk-sac and post-yolk-sac larvae; EA 1978.
13. 2.0 C, temp. resulting in no mortality after 96 hr; TL 1976c.

Key to Seasonal Distribution Histograms

(a) Mean no. of eggs collected in 5-min plankton tows for 1974-1975, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(b) Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1975, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(c) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(d) Mean no. young of the year collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(e) Mean no. yearling and older collected in beach seines for 1974-1975, RM 39-43; TI 1976d; TI 1976g.
(f) Mean no. young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-4. Thermal effects diagram for striped bass at the Indian Point Generating Station on the Hudson River.

supporting the conclusion of the plume's insignificant adverse effect on this life stage.

3.8.2.3 Juveniles and Adults

Unlike the earlier life stages,* juveniles are not likely to be passively drawn into the discharge plume and swept along with it, subject to hydrodynamic influences exclusively. Instead, they are capable of reacting to the temperatures within the plume by, among other things, avoiding or entering certain areas. The time-temperature survival parameters used to estimate ZPD's for planktonic organisms are therefore not particularly relevant when examing the plume's effects upon juvenile and adult fish. Furthermore, it might be expected that fish would tend to avoid relatively confined areas of water in which the temperatures were high enough to produce potentially lethal stress. Nevertheless, there are several thermal response parameters, including some survival measures, that are useful in evaluating the effects of the discharge plume upon fish.

Based upon several studies of temperature preferenda, EA (1978) determined a juvenile striped bass final preferendum of 27.8°C. In theory, the final preferendum should lie somewhere within a range of temperatures which are optimal for many physiological processes. The relationship between optimal function and the criterion of appreciable harm was earlier discussed (Section 3.4.1). It need only be noted that fish can function normally above the final preferendum value.

The 96 hour TL50 of juvenile striped bass was found to range from 25.5 to 34.0°C (TI 1976c). As can be seen in Figure 3-4, these values exceed the MDT except during the summer months. The range of upper avoidance temperatures for these fish, 22.5 to 33.0°C (TI 1976c), is very similar to that determined for their 96 hour TL50. During the summer months, it is concluded that juvenile and adult striped bass could withstand brief exposure to plume areas without experiencing any adverse effect. The unsuitability of prolonged contact with plume waters during the summer months is not expected to result in any adverse effect on the striped bass population.

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*Although it was indicated in Section 3.8.1 that post yolk-sac larvae were capable of some active swimming movement, they are not considered in this demonstration to be sufficiently developed to resist the entrainment forces associated with the thermal plume; hence their classification as planktonic organisms.

Some potential for adverse effects does exist during winter. At this time, striped bass may acclimatize to the warmer plume waters. If the discharge were suddenly terminated, these fish would be subjected to much colder ambient water temperatures and might experience cold shock. To investigate this possibility, it is first necessary to estimate the maximum plume temperature to which entrained fish could acclimatize. The maximum swimming speed of striped bass is approximately 4 feet per second at temperatures around 25°C (Meldrim et al 1974). Based upon the values presented in Table 3-1, it might be possible for fish to reside within plume waters as warm as the 19.5°F (10.8°C as indicated by the dotted line in Figure 3-4) excess temperature isotherm, or about 53-55°F for January-March MAT (see also Section 3.2.1). In all likelihood, the entrained striped bass would be found at some lower temperature level since there are probably no environmental stimuli causing these fish to sustain maximum swimming speed. Studies (TI 1976c) conducted on juvenile fish held at 10°C (50°F) indicated that no mortality occurred when they experienced a rapid temperature decline to 2°C (35.6°F).

Projections of plant shutdown for maintenance, refueling, etc. are influenced by many variables including power demand and fuel supply. Of the many schedules that have been proposed (one of which is provided in Con Edison 1977b), there are no planned concurrent shutdowns of Units Nos. 2 and 3 during the December through March winter period. Since the units share a common discharge canal, operation of one unit would be sufficient to maintain the configuration of the plume and ensure the well-being of the fish contained therein. It is expected, therefore, that the potential for cold shock for any striped bass entrained within the plume during winter is not appreciable.

3.8.3 Plume-Transit Studies

Field studies simulating the plume entrainment of juvenile striped bass involved the transit of caged fish through the Indian Point discharge plume in an exposure rack similar to that previously discussed for Gammarus spp. (Section 3.6.3). The studies were performed on two separate occasions in July 1975. The highest plume temperature to which they were exposed was 28.3°C. Results of these experiments indicated that there were no statistically significant differences in mortality between tests groups exposed to plume ΔT's and controls. Test controls were observed for survival up to 96 hours after test exposure (NYU 1976b).

3.9 White Perch

3.9.1 Life History Information

White perch generally remain within the estuary throughout the year. In May, when water temperatures approach 18°C, they migrate into primarily freshwater areas of the upper Hudson River to spawn. More than 99% of white perch eggs are found above the salt front (TI 1976a).

White perch prefer spawning in shallow streams and their eggs are demersal and adhesive. The eggs become pelagic in moving water after the adhesive nature of the eggs is reduced by adhering silt and detritus particles (Lippson and Moran 1974). Highest egg densities have been found in the Saugerties-Kingston (MP 90-102) areas where major tributaries are located - indicating that white perch may be using these streams as spawning areas (TI 1976a). The yolk-sac stage is partially demersal. Highest concentrations were found in the Indian Point region in late May and in the Saugerties and Catskill (MP 113) regions in mid-June. Distributions at the post yolk-sac stage were characterized by peaks in densities during late June from the Croton-Haverstraw (MP 34-36) to Saugerties region (TI 1976a).

Juvenile white perch display an inshore and downstream movement to shoal areas beginning in the summer. Peak densities were recorded in the Croton-Haverstraw and Tappan Zee Bay (MP 26-28) areas in September and early October (TI 1976a).

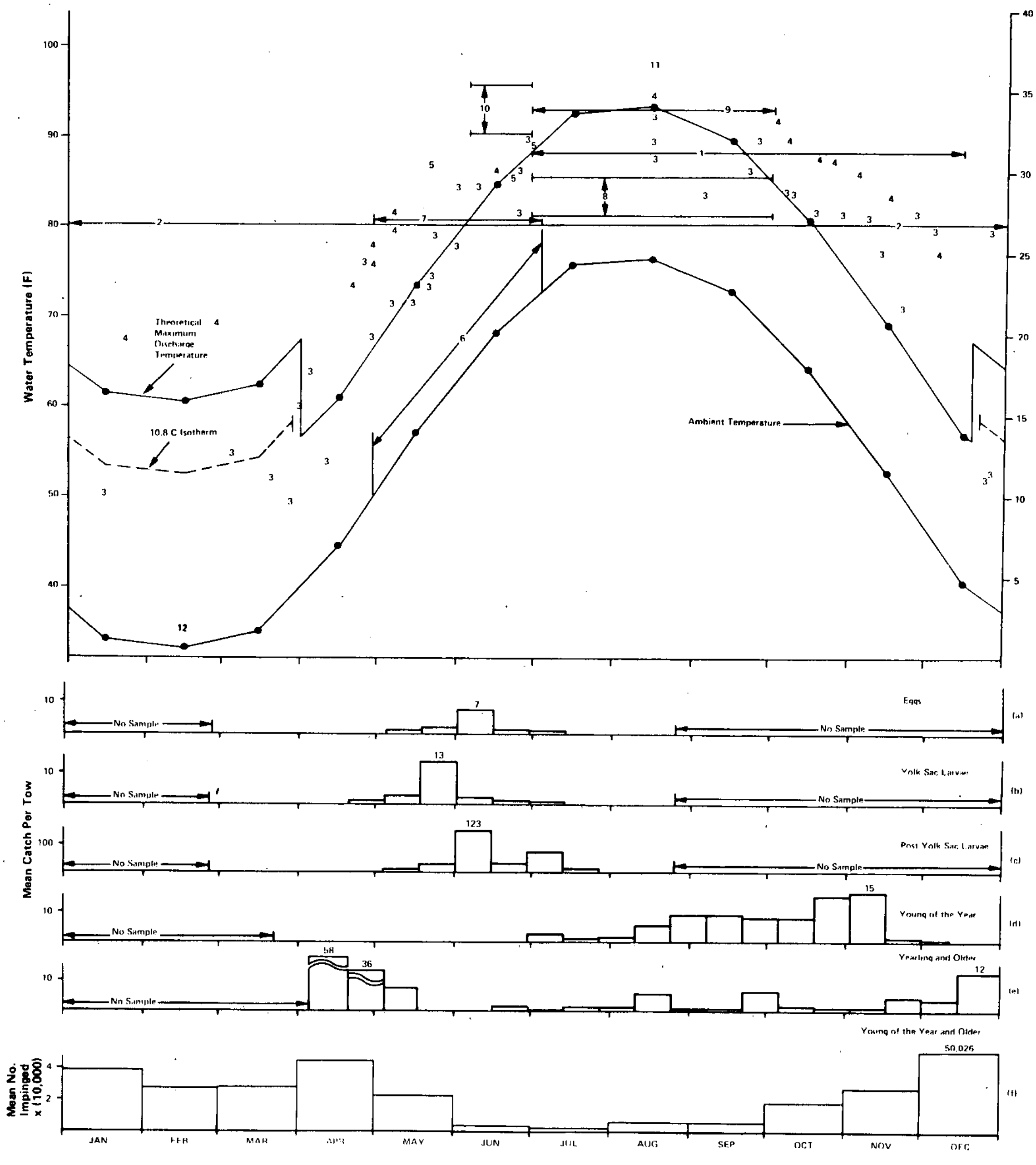
The feeding habits of the white perch indicate a wide variety in diet, with a preference for copepods at the yearling stage and large invertebrates such as amphipods and polychaetes as the fish grows. Clupeid eggs have been found to be an important food item during May-July and small fish an occasionally important food item for adults (Con Edison 1977a).

3.9.2 Thermal Tolerance Studies

Laboratory tolerance studies were performed on white perch from the egg through the juvenile stage. For those studies performed by Ecological Analysts, Inc., complete information on laboratory procedures and data analyses appears in Appendix A of this demonstration.

3.9.2.1 Eggs

White perch eggs are not very abundant in the Indian Point area; most of those that are found are present during May and June (Figure 3-5). A minimum estimate of the upper level of the optimum range for normal hatch was 27.0°C (EA 1978). No survival data were available for white perch eggs. However, if any



Key to Thermal Effects Data Points

1. 31.2 C, final preferendum for young of the year (<60 mm): EA 1978.
2. 26.8 C, final preferendum for adults (>150 mm); EA 1978.
3. 9.5-34.5 C, upper avoidance temp. for adults and juveniles; TI 1976c.
4. 19.5-35.0 C, upper incipient lethal temp. for adults and juveniles (96-hr TL50); TI 1976c.
5. 30.2-31.8 C, 24 hr TL50 for yolk-sac larvae; EA 1978.
6. 10-22.6 C, spawning temp.; TI 1976h.
7. 27 C, minimum estimate of upper limit of optimum range for normal hatch; EA 1978.
8. 27.3-29.7 C, optimum range for growth of early juveniles; EA 1978.
9. 33.8 C, ultimate upper incipient lethal temp. for early juveniles (14-day TL50); EA 1978.
10. 32.4-35.4 C, range of 30-min TL95s for yolk-sac larvae (1-day-old) at acclimation temps. from 18 to 22 C; EA 1978.
11. 36.7 C, 30-min TL95 for early juveniles; EA 1978.
12. 2.0 C, temp. resulting in no mortality after 96 hr; TI 1976c.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(b) Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(c) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(d) Mean no. young of the year collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(e) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(f) Mean no young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-5. Thermal effects diagram for white perch at the Indian Point Generating Station on the Hudson River.

parallel between the early life stages of white perch (Morone americana) and striped bass (Morone saxatilis) could be made, it would seem reasonable to assume that the 30 minute TL95 for white perch eggs would be considerably higher that 27.0°C. This is based upon the relationship between the upper limit of the optimum range for normal hatch of striped bass eggs (23.7°C) to the range (30.2 - 34.1°C) of 30 minute TL95's (Section 3.8.2.1). In addition, it should be noted that the 27°C value is indicative of the optimum range for normal hatch measured over the entire incubation period. At 15°C, Scott and Crossman (1973) reported that it would take at least 96 hours for white perch eggs to hatch. Since any entrained eggs would probably spend less than three minutes at temperatures greater than 27°C during June, it is evident that this value is indeed a very conservative estimate of adverse effects. Using this conservative measure, a critical isotherm of 6.9°C (12.4°F) was obtained. The scarcity of the eggs in the Indian Point area and the extremely small ZPD associated with a 12.4°F excess temperature isotherm indicate that no adverse effects on white perch eggs as a result of the discharge plume would occur.

3.9.2.2 Larvae

As with the eggs, white perch yolk-sac larvae are found at Indian Point primarily during May and June. Post yolk-sac larvae are relatively abundant through early July (Figure 3-11). One day old yolk-sac larvae acclimated at temperatures from 18-22°C exhibited 30 minute TL95 values of 32.4 - 35.4°C (EA 1978). Figure 3-5 clearly illustrates that these values exceed the MDT. No laboratory studies were performed on post yolk-sac larvae.

3.9.2.3 Juveniles and Adults

The final perferendum (see Section 3.8.2.3) for young of the year (<60 mm) and adult (>150 mm) white perch were 31.2°C and 26.8°C, respectively. The HRAT in the Indian Point area was 27.2°C, and occurred in July and August (Table 3-2). For most of the year, therefore, final preferendum temperatures would only be found in the discharge plume. Similarly, the optimum growth range for early juveniles (27.3 - 29.7°C) was also higher than the July/August HRAT (EA 1978).

The ultimate upper incipient lethal temperature, (see Section 3.8.2.2), based upon the 14 day growth study was 33.8°C (EA 1978). This indicates that sizable portions of the discharge plume can probably be tolerated by juvenile and adult white perch for relatively long-term exposures. It also appears that these fish can successfully withstand relatively brief exposures to any portion of the discharge plume. The 30 minute TL95 for early juvenile white perch acclimatized to summer ambient levels was 36.7°C (EA 1978). This value would be higher than the plume temperature at the discharge ports for the August HRAT (Table 3-2). It seems reasonable to assume, therefore, that juvenile and adult white perch would not be precluded from utilizing plume waters for any biological activity that the fish might ordinarily be involved with in the plume's absence. The fish would, however, be excluded from the plume's warmest regions on the basis of velocity considerations (Section 3.3.1).

Laboratory studies were also performed to investigate the cold-shock potential for white perch entrained within the plume during winter. It would not be expected that plume-entrained white perch could acclimatize themselves to plume temperatures higher than those estimated for a stronger swimmer such as the striped bass (Section 3.8.2.3). This means that the very highest temperature at which white perch would be found in the discharge plume during the December-March period is approximately 53-55°F, corresponding to the 19.5°F (10.8°C) excess temperature isotherm. White perch acclimatized in the laboratory to 10°C (50°F) and 15°C (59°F) suffered no mortality after 96 hours when exposed to 2°C (TI 1976c). In addition, the operating schedules for Units Nos. 2 and 3 indicate that concurrent shutdowns of these units is an unlikely event. It is concluded that the potential for cold shock for those white perch entrained within the plume during winter is not appreciable.

3.10 Atlantic Tomcod

3.10.1 Life History Information

The Atlantic tomcod is an inshore marine species which spawns predominantly in brackish or fresh water. The Hudson River spawning migration takes place during late fall and winter, and consists almost entirely of 11 to 13 month old fish. Spawning generally occurs under an ice cover at temperatures from 0 to 4°C. The adhesive eggs which are produced develop slowly, with hatching occurring in approximately 30 days. The absorption of yolk during the yolk-sac stages also takes about one month. The fish reach the juvenile stage by early spring, but grow very little during the summer (Con Edison 1977a). Studies on the feeding habits of the tomcod in the Hudson River indicated a preference for copepods and *Gammarus* spp. at the juvenile stage, and a diet of larger invertebrates, tomcod eggs and small fish as adults (Con Edison 1977a). Yearling and older Atlantic tomcod were generally uncommon in shore zone areas, except during late May and June when relatively large beach seine catches were taken in the Yonkers (MP 17) region (TI 1976a). Raytheon (1971) also collected only small numbers of Atlantic tomcod by beach seine in the Indian Point area during 1969 and 1970; however, this species was very abundant in bottom trawl catches and showed a definite preference for deeper channel water (TI 1976a).

3.10.2 Thermal Tolerance Studies

3.10.2.1 Eggs

The adhesive and demersal nature of tomcod eggs would make them generally less susceptible to plume entrainment than ichthyoplankton with semi-buoyant (e.g., striped bass) or pelagic (e.g., bay anchovy) eggs. The 30 minute TL95 values are still considered, however. As illustrated in Figure 3-6, these values for the tailbud and eyed-up stage (EA 1978) exceed the MDT.

Hatching studies indicated that the optimum range for normal hatch was from 0°C through 4.9°C (EA 1978). Although most discharge plume temperatures are above this range, most tomcod eggs would remain within water strata below the plume's influence. For those few that might be entrained, exposure to excess temperatures would be relatively brief (Table 3-1). From these studies, it can be concluded that the Indian Point discharge plume does not represent a potentially harmful area for Atlantic tomcod eggs.

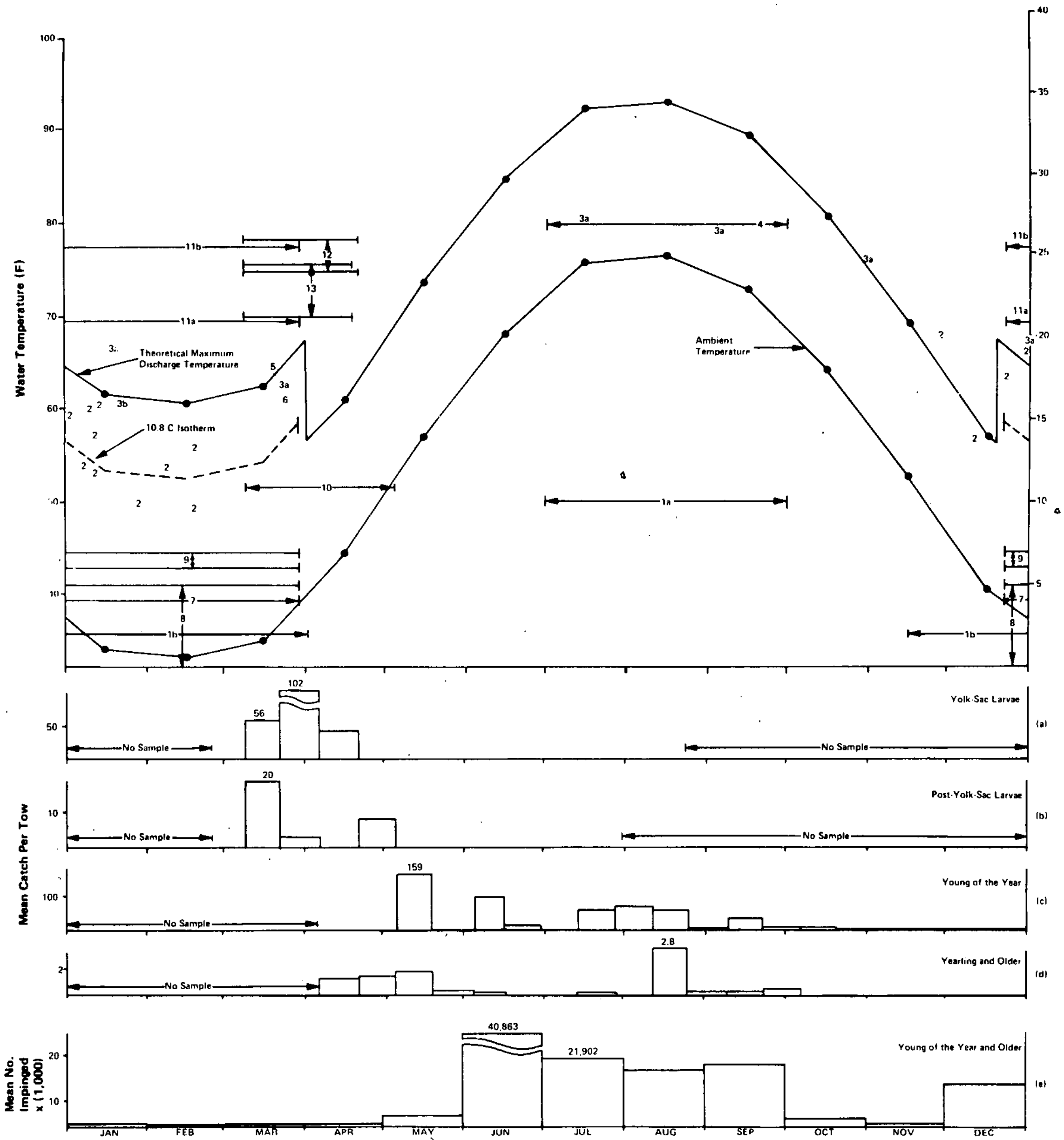
3.10.2.2 Larvae

Atlantic tomcod larvae are found in the Indian Point area from March till early May (Figure 3-6). At acclimation temperatures of 3.0 to 7.5°C, the 30 minute TL95 values for one day old yolk-sac larvae and post yolk-sac larvae ranged from 23.8 - 25.7°C, respectively (EA 1978). In examining Figure 3-6, it can be seen that for both the yolk-sac and post yolk-sac stages, the 30 minute TL95 ranges indicated exceed the MDT plotted for the March to May period.

The minimum estimate of the optimum temperature for growth and development of Atlantic tomcod from hatch to advanced post yolk-sac larvae was 10.9°C (EA 1978). This value is greater than the HFAT for December, January, February, and March, and is also higher than the April MAT (Table 3-2). Therefore, only in the discharge plume would temperatures of 10.9°C and above be found. Nevertheless, the early life stages of Atlantic tomcod would only be exposed to plume temperatures for extremely brief periods of time, if at all. It is clear that the Indian Point discharge plume has no adverse effects upon the tomcod larvae.

3.10.2.3 Juveniles and Adults

Laboratory studies indicated that the final preferendum (see Section 3.8.2.3) for adult tomcod during the winter was approximately 2°C, while that of juveniles during the summer was 10°C (EA 1978). Although limited ecological significance can be attached to the final preferendum value, it seems obvious that this value is of greater importance for the non-winter case. The



Key to Thermal Effects Data Points

1. <2-10 C, final preferendum: (a) juveniles during the summer, (b) adults during the winter; EA 1978.
2. 9.6-20.0 C, upper avoidance temp. for adults; TI 1976c.
3. 16.3-26.8 C, 96-hr TL50, upper incipient lethal temps. for adults and juveniles; (a) EA 1978, (b) TI 1976c.
4. 26.6 C, ultimate upper incipient lethal temp. for juveniles during the summer; EA 1978.
5. 17.8 C, 24-hr TL50 for yolk-sac larvae (1 day old); EA 1978.
6. 16.1 C, 24-hr TL50 for post-yolk-sac larvae; EA 1978.
7. 0.0-4.0 C, normal spawning temp.; Scott and Crossman 1973.
8. 0.0-4.9 C, optimum range for normal hatch; EA 1978.
9. 6.0-6.9 C, range of TL50s for normal hatch; EA 1978.
10. 10.9 C, minimum estimate of optimum temp. for growth and development from hatch to advanced post-yolk-sac larvae; EA 1978.
11. 20.8-25.3 C, 30-min TL95s for eggs: (a) tailbud embryo stage, (b) eyed-up embryo stage; EA 1978.
12. 23.8-25.7 C, range of 30-min TL95s for yolk-sac larvae (1-day-old); EA 1978.
13. 21.1-24.2 C, range of 30-min TL95s at acclimation temps. of 3.0 to 7.5 C for post-yolk-sac larvae; EA 1978.

Key to Seasonal Distribution Histograms

(a) Mean no. yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(c) Mean no. young of the year collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(d) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(e) Mean no. young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-6. Thermal effects diagram for Atlantic tomcod at the Indian Point Generating Station on the Hudson River.

MAT's for May through November are greater than 10°C (Table 3-2). If one assumes that final preferenda are representative of optimum physiological functioning, Hudson River tomcod are apparently operating at somewhat less than maximum biological efficiency for most of the year. The ultimate upper incipient lethal temperature (see Section 3.8.2.2) for juveniles during the summer was 26.6°C (EA 1978). Figure 3-6 illustrates the proximity of this value to the plotted summer MAT's.

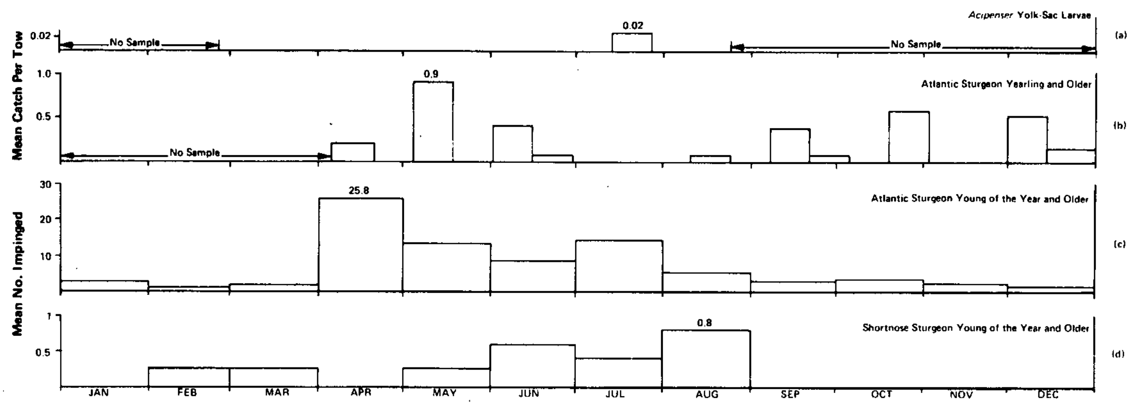
For most of the year, and especially during the summer period, the juvenile and adult tomcod probably seek out the deepest (and coolest) portions of the river. This behavior would occur whether the Indian Point discharge plume was present or not. Since the plume does not have a significant benthic component, it would be expected that no appreciable harm to the Atlantic tomcod population would result from the Indian Point discharge.

3.11 Atlantic Sturgeon

An anadromous species, the Atlantic sturgeon spawns between May and July in areas above the salt front. A spawn of demersal eggs hatches in approximately a week after fertilization and the development and growth of larvae to a 4-5 inch size occurs within about two months (Bigelow and Schroeder 1953). Juvenile and sexually immature fish have been found to remain in primarily freshwater areas from the Tappan Zee to Cornwall at depths of 15-85 feet. Of 160 Atlantic sturgeon collected in field surveys during 1973, 158 were captured by bottom trawl. None of these were taken below the Indian Point area after July (TI 1976a).

Atlantic sturgeon mature slowly until they migrate to the ocean, where more rapid growth and sexual maturation are attained. Greeley (1937) reported collections of immature specimens up to eight years of age in freshwater portions of the Hudson River estuary near Kingston (MP 93), and indicated that the older individuals would soon migrate to the sea. During their fresh or brackish water residency, smaller sturgeon feed primary on amphipods and isopods. No feeding takes place as mature adults migrate upstream to spawn (Bigelow and Schroeder 1953). The seasonal distribution of Atlantic and shortnose sturgeon (*Acipenser* spp.) in the vicinity of Indian Point is presented in Figure 3-7.

No thermal tolerance testing was performed on Atlantic sturgeon because adequate stocks of test fish were not available. However, the pronounced tendency of these fish and their eggs to remain in bottom waters signifies that their contact with the thermal plume is extremely limited. It is expected, therefore, that the Indian Point discharge plume does not exert appreciable harm on the Atlantic sturgeon population in the Hudson River.



Key to Seasonal Distribution Histograms

(a) Mean no. *Acipenser* yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.

(b) Mean no. yearling and older Atlantic sturgeon collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.

(c) Mean no. young-of-the-year and older Atlantic sturgeon from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

(d) Mean no. young-of-the-year and older shortnose sturgeon from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-7. Seasonal distribution histograms for Atlantic sturgeon and shortnose sturgeon in the vicinity of the Indian Point Generating Station on the Hudson River.

3.12 Shortnose Sturgeon

This fish inhabits fresh, brackish and salt water but is more commonly found in the lower reaches of large tidal rivers (Vladykov and Greeley 1963: Scott and Crossman 1973). However, Greeley (1937) has also stated that the shortnose sturgeon was probably a permanent freshwater resident of the Hudson River. Spawning occurs in the spring in freshwater or estuarine portions of the river (Con Edison 1977a). The eggs are demersal and adhesive and develop into larvae which are difficult to distinguish from Atlantic sturgeon and are grouped as Acipenser spp.

Males grow more slowly than females, but reach sexual maturity earlier. Males mature at ages 3-5 at a total length of 50 cm and females at ages 5-8 at a total length of 60 cm (Vladykov and Greeley 1963: Scott and Crossman 1973).

Dadswell (1975) has conducted an extensive study of shortnose sturgeon in the St. John River estuary in Canada and has found that females mature at approximately 15 years. It was found that after their first spawning these females required a minimum of three years before spawning again. Spawning in the St. John River took place adjacent to deep, turbulent channels in freshwater; the fish were also observed to spawn over mud in flooded areas. The St. John River shortnose sturgeon showed downstream movement to the deeper, more saline regions of the estuary beginning in September and October. The fish apparently overwintered in these areas and started their upstream migration in early April. Adult shortnose sturgeon have been collected in the Hudson River estuary, yet their distribution and migration patterns have not been clearly established.

The fish are well adapted for bottom feeding through the use of a tube-like mouth. The young (<50 cm) feed mainly on insects in freshwater areas and crustaceans in brackish/saltwater areas, ingesting considerable quantities of mud and detritus with their food. The adults selectively feed on gastropods in freshwater and clams in saltwater (Dadswell 1975).

As with the Atlantic sturgeon, the eggs, larvae and adult stages of shortnose sturgeon all inhabit the estuary's deeper waters. Since this signifies minimal contact with the Indian Point discharge plume, no appreciable harm to the existing shortnose sturgeon population is expected.

3.13 Spottail Shiner

3.13.1 Life History Information

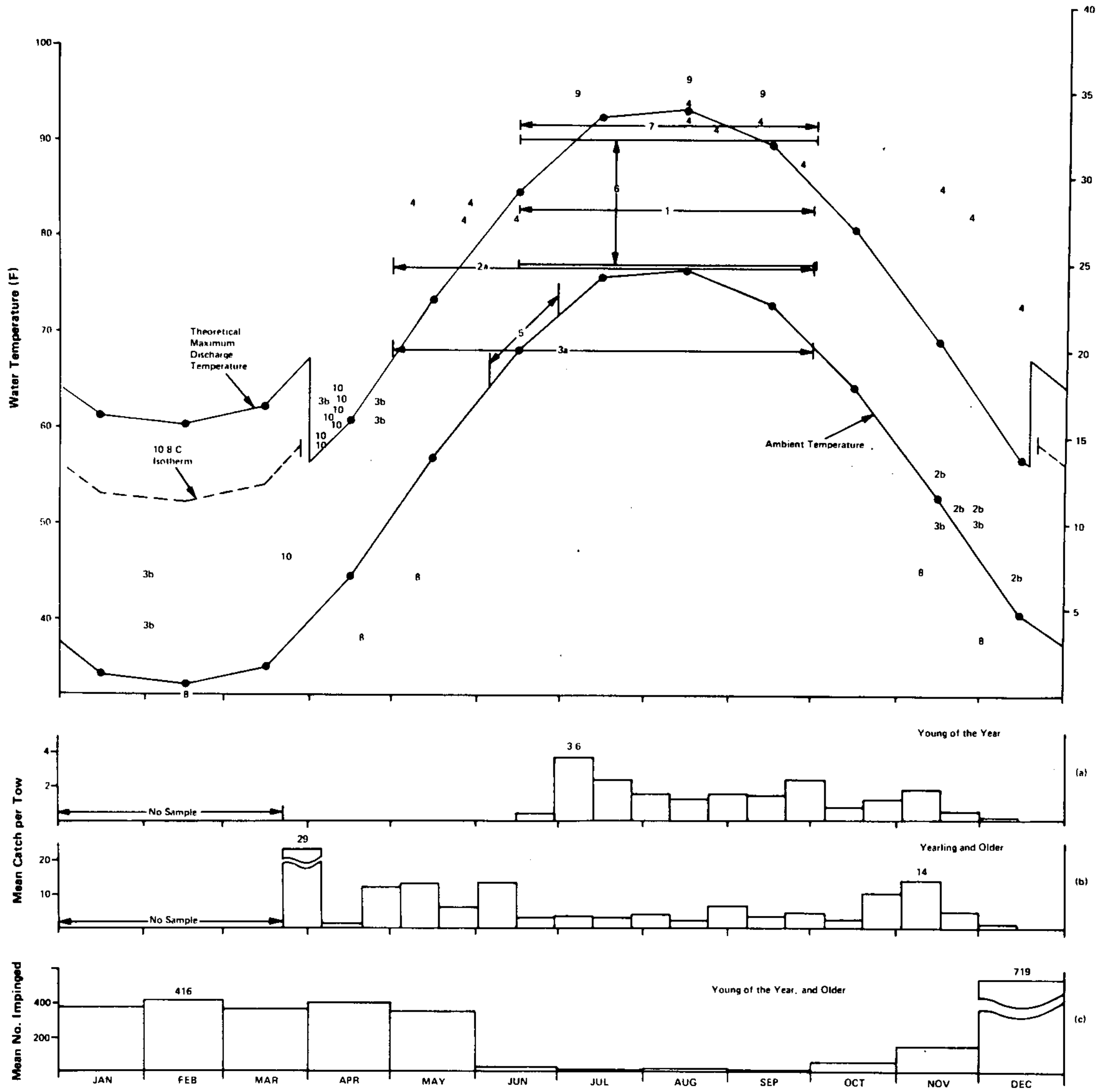
A resident freshwater species of the Hudson River, the spottail shiner spawns in April to mid-June in shallow water over sandy shoals, and has been found to be abundant during the spawning period above the Croton-Haverstraw Bay regions (TI 1976a). Spawning generally occurs in freshwater, but may also be possible in slightly brackish waters (Lippson and Moran 1974). Spottail shiner eggs are demersal, grouped together in clusters and commonly found in masses of algae (Lippson and Moran 1974). Development through the larval to juvenile stages takes place in shallow shoal areas, with highest concentrations of juveniles collected in late summer and fall in upstream areas above Poughkeepsie. With the onset of colder water temperatures in late fall, juveniles and adults move offshore to deeper water (TI 1976a).

Food preference studies for the spottail shiner have indicated a variety in diet, from planktonic crustaceans such as Daphnia spp. to benthic insect larvae and algae. Larger fish also feed on their own larvae and eggs. The spottail shiner itself constitutes an important food source for many other fishes (Scott and Crossman 1973).

3.13.2 Thermal Tolerance Studies

Since spottail shiner eggs and larvae are not generally found in the Indian Point area, emphasis was placed on juveniles and adults. Final preferenda (EA 1978) for young-of-the-year (<50 mm), immature (50-90 mm) and adult (> 90 mm) fish are shown in Figure 3-8. Although all the final preferendum values are less than the plotted MDT's, the summertime adult preference temperature (20.1°C) is also below the MAT's for the June through September period.

A 21 day growth study indicated that the optimum range for growth of early juveniles was 25.0 - 32.3°C (EA 1978). Since the highest MAT in the Indian Point area is 24.9°C (found in August; Table 3-2), temperatures within this optimum range are present only in the discharge plume. The ultimate upper incipient lethal temperature (see Section 3.8.2.2) based upon the growth study was 33.1°C (EA 1978). As can be seen in Figure 3-8, 33.1°C exceeds the MDT except for a portion of the summer period. During that portion, it falls only slightly below the MDT. For briefer exposures, the early juvenile 30 minute TL95 values ranged from 35.0 - 35.8°C (EA 1978). In view of the fact that the adult final preferendum are below MAT for the summer months, it is reasonable to assume that spottail shiner generally avoid prolonged exposure to the plume, although the data indicate that



Key to Thermal Effects Data Points

1. 28.2 C, final preferendum for <50 mm, May-September; EA 1978.
2. 7.0-24.8 C, final preferendum for 50-90 mm, (a) May-September, (b) October-April; EA 1978.
3. 4.0-20.1 C, final preferendum for >90 mm, (a) May-September, (b) October-April; EA 1978.
4. 22.6-34.4 C, upper incipient lethal temp. for juveniles and adults (96-hr TL50); EA 1978.
5. 18.0-22.0 C, normal spawning temp.; EA 1978.
6. 25.0-32.2 C, optimum range for growth of early juveniles; EA 1978.
7. 33.1 C, ultimate upper incipient lethal temp. for early juveniles (21-day TL50); EA 1978.
8. 0.0-6.7 C, lower incipient lethal temp. for juveniles and adults (96-hr TL50); EA 1978.
9. 35.0-35.8 C, 30-min TL95s for early juveniles; EA 1978.
10. 8.0-17.8 C, upper avoidance temps. for adults; T' 1973.

Key to Seasonal Distribution Histograms

(a) Mean no. young of the year collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(b) Mean no. yearling and older collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(c) Mean no. young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-8. Thermal effects diagram for spottail shiner at the Indian Point Generating Station on the Hudson River.

brief contact would not be lethal. Spottail shiner would be excluded from a small plume area based upon velocity considerations (Section 3.3.1).

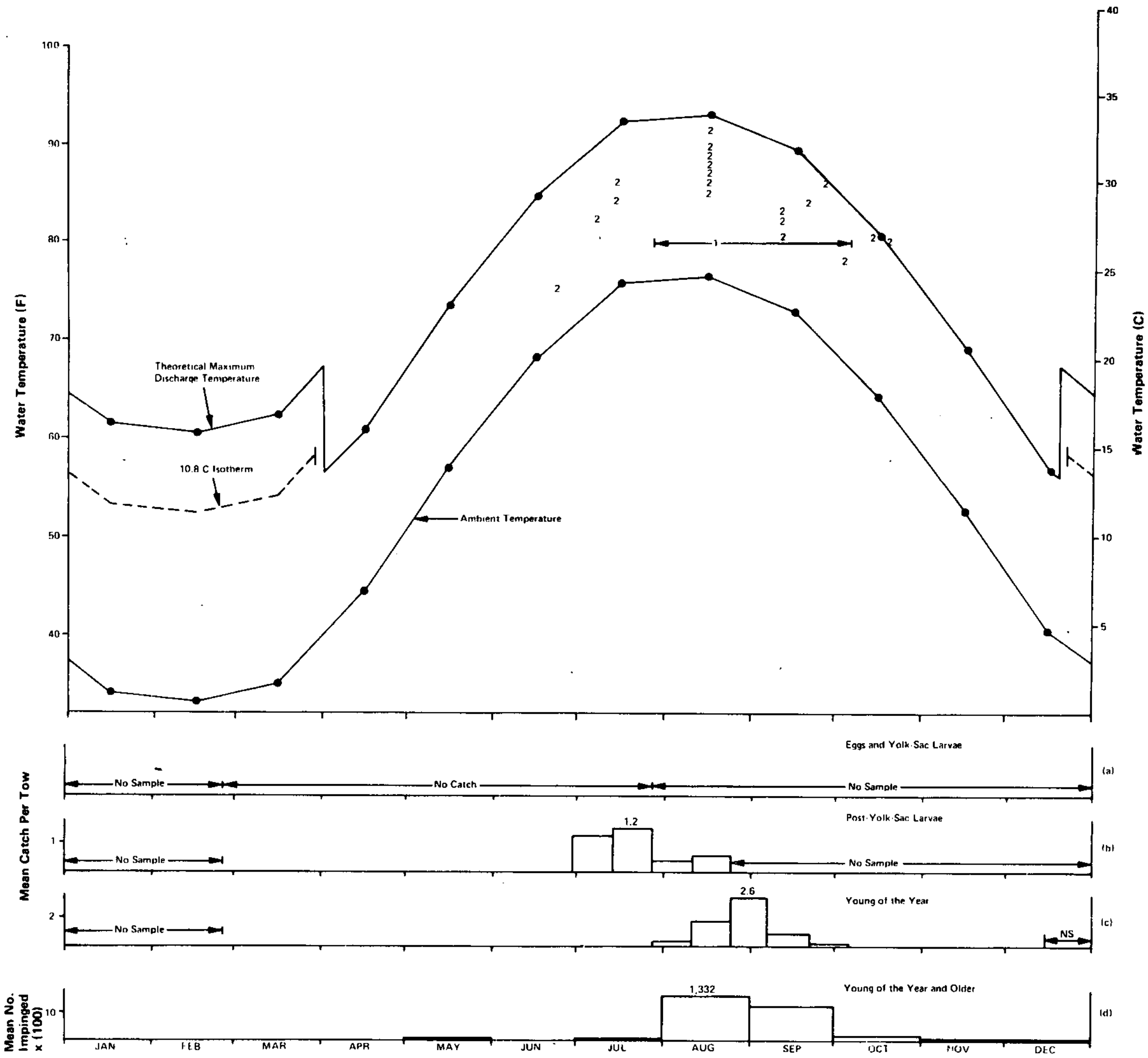
Since spottail shiner is a resident river species, it is expected that they can tolerate cold very well. Although swimming speed data are not available, it is safe to predict that these fish cannot swim faster than 4 feet per second. During the winter, this corresponds to the 19.5°F (10.8°C) excess temperature isotherm, or about 53-55°F (see Section 3.8.2.3). Juvenile and adult fish acclimatized to 10°C (50°F) and 17°C (62.6°F) had 96 hour TL50 values of 0°C and 2.2°C, respectively. The cold shock potential for these fish is therefore negligible.

3.14 Weakfish

The weakfish is an anadromous fish which generally spawns in late May through June when salinities range from approximately 28-31 ppt and temperatures are from 15.5 to 21°C. Spawning usually occurs in the mouth of estuaries (Welsh and Breeder 1923; Lippson and Moran 1974), resulting in the projection of pelagic, buoyant eggs. Soon after hatching the larvae begin to migrate upstream into areas of low salinities. In the Hudson River, post yolk-sac larvae appeared in predominantly brackish water areas below West Point (MP 53) between early July and early August, with highest densities recorded in mid-July in the Tappan Zee region. Juveniles were taken predominantly in bottom collections in channel and shoal areas (TI 1976a).

The general pattern of upstream migration appears to follow deeper channel areas and spreads out into shallower shore zone and shoal areas. Juveniles remain in these areas throughout the summer and into early fall at which time they begin a downstream movement (TI 1976a), apparently to avoid increasingly colder temperatures in upstream areas. The feeding habits of the larvae and juvenile weakfish in the Hudson River are not available; however, adult feeding preference has been described by Bigelow and Schroeder (1953), and constituted an essentially piscivorous diet.

The only thermal response data available in the literature for weakfish were on final preferenda and avoidance. Wyllie et al (1976) indicated a final preferendum of 26.7°C for juvenile weakfish. Avoidance temperatures were also reported for a variety of ambient levels, and they are presented in Figure 3-9. Weakfish will apparently avoid certain of the warmer sections of the discharge plume. The preference of these fish for deeper waters indicates that they are relatively invulnerable to any significantly adverse impact due to the discharge plume.



Key to Thermal Effects Data Points

1. 26.7 C, final preferendum for juveniles; Wyllie et al. 1976.
2. 24.0-33.0 C, upper avoidance temp. for juveniles; Public Service Electric and Gas Company 1977.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs and yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.

(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.

(c) Mean no. young of the year collected in 5-min plankton tows for 1974-1976, RM 39-43; TI 1975a, TI 1976e, TI 1977b.

(d) Mean no. young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-9. Thermal effects diagram for weakfish at the Indian Point Generating Station on the Hudson River.

3.15 Alewife

3.15.1 Life History Information

This anadromous fish spawns in freshwater areas of the Hudson River in late April through May. Preferred spawning areas are small feeder streams and occasionally shallow rocky shorelines in water temperatures that average between 10 and 17.5°C (TI 1976a). Semi-demersal eggs are deposited in quiet pool areas and spawning adults return immediately to the ocean (Bigelow and Schroeder 1973).

Development of larvae to the juvenile stage occurs in the shallow shore zone, and the juveniles demonstrate considerable upstream movement during late June through July. Higher densities of juveniles in the shore zone at night has been noted in beach seine collections. Although some fish remain in estuarine nursery areas throughout the winter, the major part of the population migrates seaward (Hildebrand 1963). In the Hudson River, downstream movement of juveniles begins in the fall (TI 1976a).

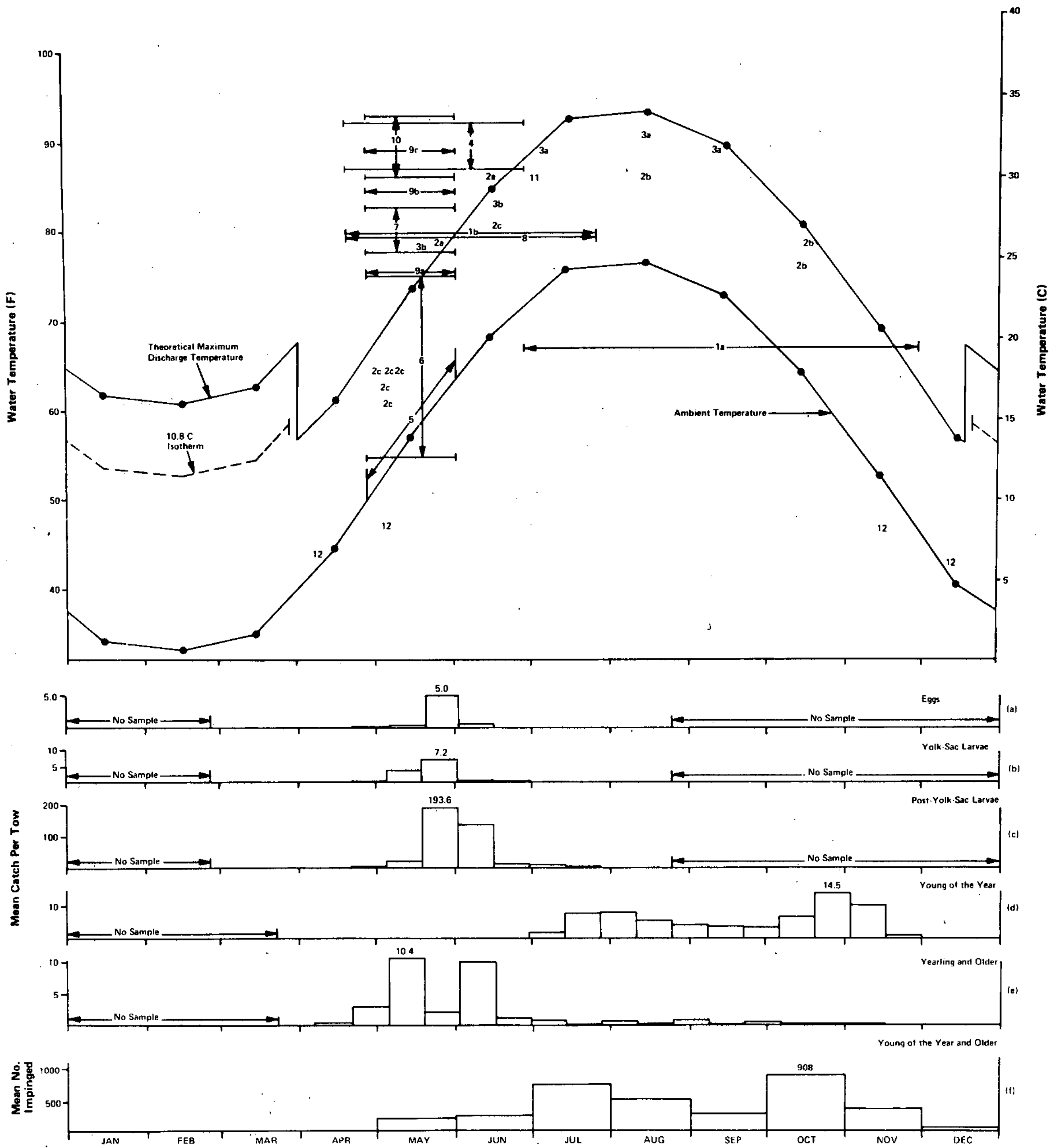
The alewife is primarily a plankton feeder and feeds on copepods, amphipods and shrimp, both as a juvenile and adult. Adult feeding ceases during the upstream spawning run but resumes as the spent fish migrate back to the ocean (Bigelow and Schroeder 1953).

3.15.2 Thermal Tolerance Studies

3.15.2.1 Eggs

Alewife eggs are present in the Indian Point area during May and June. Survival tests performed on the blastula, tail-bud, and tail-free embryo stages indicated a 30 minute TL95 range of 24.2 - 31.7°C (EA 1978). These values exceed the plotted MDT during May; in June only the blastula stage did not exceed the MDT (Figure 3-10). The critical isotherm for the blastula stage in June is 4.6°C (8.3°F). However, most alewife spawning areas would be upstream of Indian Point in the river's freshwater reaches. Since the blastula stage of egg development occurs within the first 24 hours after spawning, the probability of the blastula stage being found at Indian Point is slight.

The optimum range for normal hatch of alewife eggs is 12.7 - 23.9°C (EA 1978). Eggs entrained at the discharge ports would reach the 7.7°F excess temperature isotherm in less than three minutes (Table 3-1). The 7.7°F (4.2°C) excess temperature isotherm would correspond to a river temperature of 24.3°C (extremely close to the observed upper limit of the optimum range for normal hatch) when compared to June MAT. Since the



Key to Thermal Effects Data Points

1. 19.5-26.5 C, final preferendum; (a) young-of-the-year, EA 1978, (b) advanced post-yolk-sac larvae, EA 1978.
2. 16.0-30.0 C, upper avoidance temps.; (a) adults, EA 1978; (b) young-of-the-year, Meldrim and Gift 1971; (c) adults, TI 1973.
3. 25.5-32.6 C, upper incipient lethal temps. (96-hr TL50), (a) young-of-the-year, (b) adults; EA 1978.
4. 30.7-33.5 C, range of 24-hr TL50s for yolk-sac larvae; EA 1978.
5. 10.0-17.5 C, normal spawning range; TI 1976h.
6. 12.7-23.9 C, optimum range for normal hatch; EA 1978.
7. 25.4-28.2 C, range of TL50s for normal hatch; EA 1978.
8. 26.4 C, optimum temp. for net biomass gain for development from hatch through post-yolk-sac stage; EA 1978.
9. 24.2-31.7 C, 30-min TL95s for eggs: (a) blastula stage, (b) tail-bud embryo stage, (c) tail-free embryo stage; EA 1978.
10. 30.1-33.8 C, range of 30-min TL95s for yolk-sac larvae (1-day-old); EA 1978.
11. 30.1 C, 30-min TL95 for advanced post-yolk-sac larvae; EA 1978.
12. 6.0-8.0 C, lower incipient lethal temps. (TL60) for adults; Otto et al. 1976.

Key to Seasonal Distribution Histograms

(a) Mean no. Clupeidae eggs collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(b) Mean no. Clupeidae yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(c) Mean no. Clupeidae post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.
(d) Mean no. young-of-the-year alewife collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(e) Mean no. yearling and older alewife collected in beach seines for 1974-1975, RM 39-43; TI 1976d, TI 1976g.
(f) Mean no. young-of-the-year and older alewife from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-10. Thermal effects diagram for alewife at the Indian Point Generating Station on the Hudson River.

incubation period of alewife eggs (at 15.6°C) is approximately six days (Scott and Crossman 1973), plume-entrained eggs may experience temperatures greater than the upper limit of their optimum normal hatch range for only a very small proportion of the total time spent in that stage.

3.15.2.2 Larvae

Alewife larvae are primarily found during May and June in the Indian Point area, although some post yolk-sac were also collected in July (Figure 3-10). The 30 minutes TL95 range for one day old yolk-sac larvae was 30.1 - 33.8°C (EA 1978). The lower limit of this range exceeds the plotted MDT's for May and June (Figure 3-10). The 30 minute TL95 for advanced post yolk-sac was also 30.1°C (EA 1978) and would similarly exceed the plotted MDT during those two months. For those relatively few post yolk-sac larvae present in the Indian Point area during July, the critical isotherm is 5.7°C (10.3°C). The retention time within the plume to the 10.3°F excess temperature isotherm for alewife post yolk-sac larvae entrained at the discharge ports would be less than three minutes (Table 3-1). It is concluded that the Indian Point discharge does not exert appreciable harm on alewife larvae.

The optimum temperature for net biomass gain, which is directly related to growth, for development from hatch through post yolk-sac larvae was 26.4°C (EA 1978). Temperatures this high would only be consistently found in waters directly affected by the discharge plume. The final preferendum of post yolk-sac larvae, 26.5°C (EA 1978), would also generally exist only in plume waters.

3.15.2.3 Juveniles and Adults

Young-of-the-year alewives remain in the Hudson River until October-November when most of them migrate seaward. The final preferendum of these fish is 19.5°C (EA 1978), and is exceeded by the MAT for July, August and September (Table 3-2). For young-of-the-year fish acclimatized to 25°C (representative of July and August ambient levels) an avoidance reaction was elicited at 30°C (EA 1978). However, the 96 hour TL50 for these fish during this summer period was 32.6°C (EA 1978), so that the entire plume (except for that small portion which would be excluded on the basis of velocity considerations) would be accessible for at least brief periods of time.

As stated in Section 3.5.1, adult alewives spawn in freshwater areas and then return to the ocean. They may be found in the Indian Point area during April and May. Tests performed to determine the avoidance temperatures of these adult fish presented widely differing results (EA 1978; TI 1973). However, the 96 hour TL50 was 25.5°C, indicating that the plume does not have any adverse effect on the spawning adults (Figure 3-10).

Since most juvenile alewives migrate seaward in early fall, there is little potential for cold shock. For those that remain within the river, plume entrainment at Indian Point does not seem to be a very distinct possibility since impingement collections did not reveal any alewife during the January-March period (Figure 3-10). The only lower lethal temperatures reported (Otto et al 1976) indicated that alewives were not very tolerant to extreme cold.

3.16 Bay Anchovy

3.16.1 Life History Information

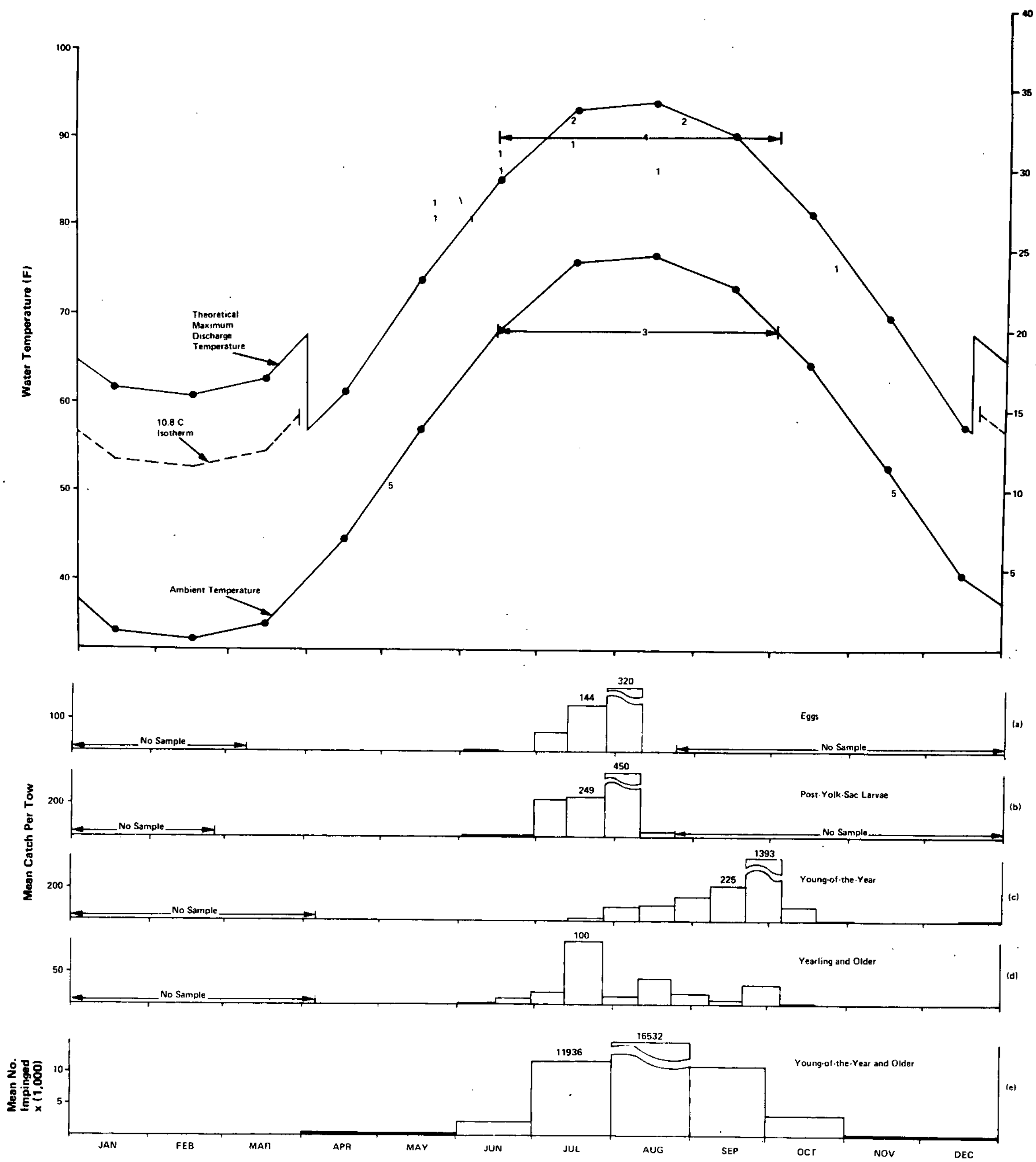
The bay anchovy has a two year life span and spawns as early as age 2.5 months within a wide range of salinities in estuarine areas (Hildebrand and Schroeder 1928). Largest concentrations of eggs are usually found in the salinity range of 13-15 ppt (Dovel 1971). Spawning in the Hudson River occurs between June and September at temperatures from 25-27°C (Con Edison 1977b).

Bay anchovy eggs are pelagic and were collected throughout the water column. Peak concentrations were found in the Tappan Zee region during early August (TI 1976a). Duration of the yolk-sac stage is approximately 24 hours (Hildebrand and Schroeder 1928). Collections of post yolk-sac larvae indicated that these larvae were generally distributed upstream of areas where major egg concentrations were found. Patterns of upstream movement were also noted at the juvenile stage when major concentrations were encountered in late July in the Tappan Zee and Croton-Haverstraw Bay regions. Juvenile bay anchovy were relatively more abundant in the shore zone than the offshore zone. Catches of juveniles during late fall declined, indicating that a downstream migration may occur in response to colder water temperatures (TI 1976a). The bay anchovy has been found to be a major food item of the striped bass in the Chesapeake Bay (Dovel 1968).

3.16.2 Thermal Tolerance Studies

3.16.2.1 Eggs and Larvae

Bay anchovy eggs and larvae are essentially present in the Indian Point area only during July and August (Figure 3-11). The optimum temperature for early development, 32°C (Houde 1974) is a minimum estimate because test temperatures did not exceed that level. Nevertheless, it is apparent that most of the plume presents an optimum level for development of these early stages, although as noted for other ichthyoplankton, the retention time is relatively brief. No thermal effects studies were performed



Key to Thermal Effects Data Points

1. 24.0-32.0 C, upper avoidance temp., Meldrim, Gift, and Petrosky 1974.
2. 33.0 C, upper incipient lethal temp. (93-hr TL50) for sub-adults; EA 1978.
3. From 20.0 C to maximum summer ambient, normal spawning temps.; Dovel 1971, TI 1976h.
4. 32.0 C, minimum estimate of optimum temp. for early development, from hatch through feeding stage (7 days); Houde 1974.
5. 10.0 C, lower incipient lethal (168-hr LD60); Wyllie et al. 1976.

Key to Seasonal Distribution Histograms

(a) Mean no. eggs collected in 5-min plankton tows for 1974-1976, RM 42-43; TI 1975a, TI 1976e, TI 1977b.

(b) Mean no. post-yolk-sac larvae collected in 5-min plankton tows for 1974-1976, RM 39-43; TI 1975a, TI 1976e, TI 1977b.

(c) Mean no. young of the year collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.

(d) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.

(e) Mean no. young of the year and older from impingement collections June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1977b.

Figure 3-11. Thermal effects diagram for bay anchovy at the Indian Point Generating Station on the Hudson River.

on these early stages of bay anchovy because they could not be collected and maintained in a laboratory environment.

3.16.2.2 Juveniles and Adults

The minimum avoidance temperature for bay anchovy adults was 30°C during the June-September spawning season (Meldrin et al 1974) and is illustrated in Figure 3-11. A 93 hour TL50 for sub-adults of 33.0°C was also determined (EA 1978). Since the June-September MAT's are from 8.1 - 12.9°C lower than this value, adult bay anchovy can probably utilize virtually all of the discharge plume for at least brief periods. However, they would be excluded from a small volume based upon swimming speed and velocity considerations (Section 3.3.1). Although they show poor survival once temperatures drop to winter ambient levels, bay anchovy were not found in impingement collections from January through April. It is likely, therefore that they do not remain within the river during the winter and consequently there is little potential for cold shock effects.

3.17 White Catfish

3.17.1 Life History Information

The white catfish inhabits fresh or moderately brackish water, showing a preference for warm waters, usually where there is a current, and the bottom type is sand, gravel, or bedrock (Miller 1966). In California waters, spawning occurred when water temperatures reached approximately 21.1°C. Adhesive eggs were deposited in the nest and were occasionally covered by 5-6 inches of gravel. The nest was guarded by one or both parents. After the eggs hatched, the male guarded the young (Miller 1966).

The distribution of the white catfish in the Hudson River may be defined by using beach seine and bottom trawl collections made from 1973 and 1975. Catch results indicated that all ages of white catfish were found in higher densities in water generally deeper than ten feet. Young-of-the-year began appearing in July-August whereas yearling and older fish were found throughout the sampling season. Distribution patterns indicated generally similar densities throughout the year, with abundances of white catfish greater in Croton and Haverstraw Bays than upstream at Cornwall and Poughkeepsie (TI 1977c).

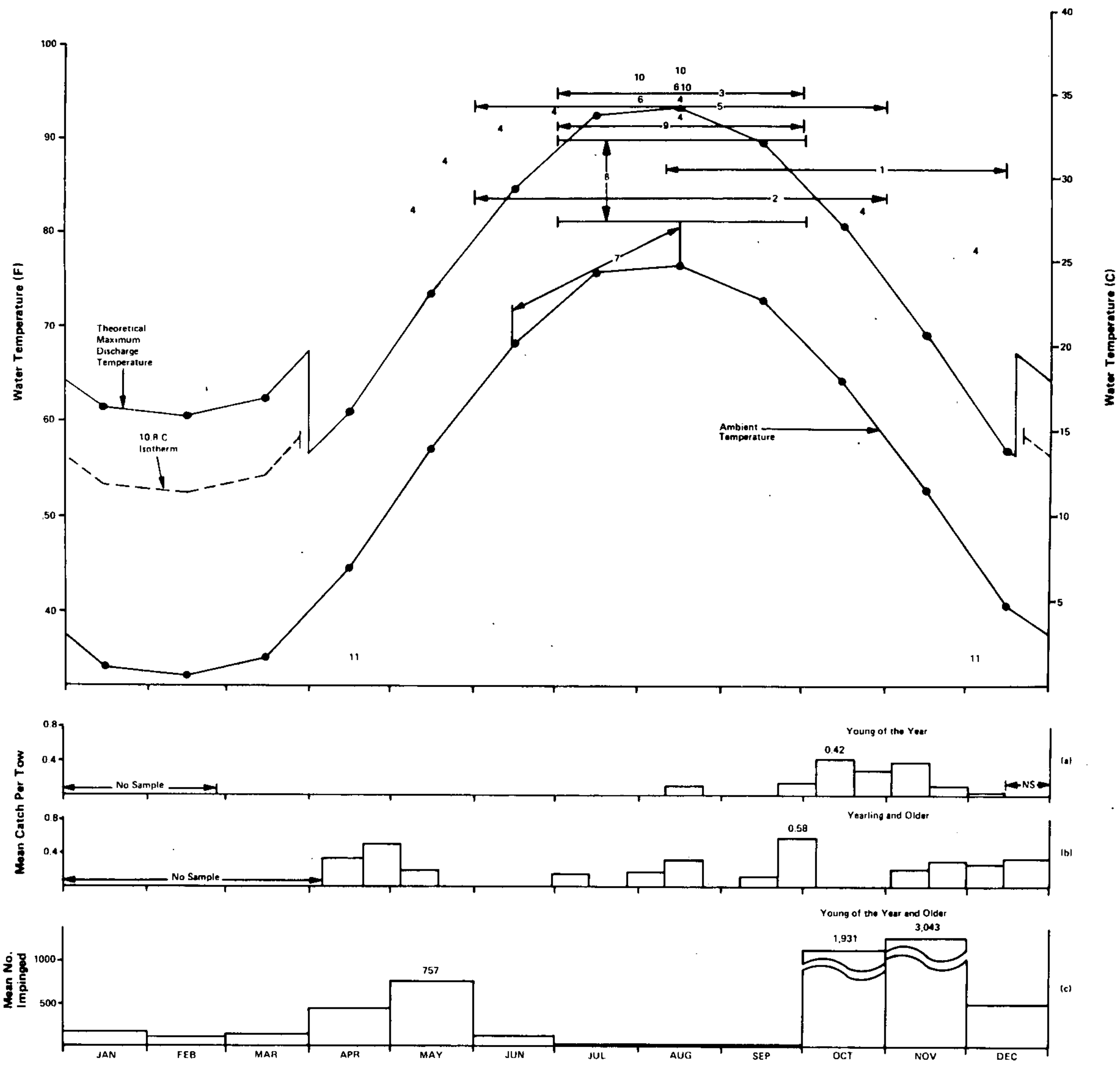
The feeding habits of the white catfish in the central Atlantic states have been documented by Menzel (1945) and Stevens (1959). Omnivorous feeding was observed; the major food items were herring, menhaden, gizzard and threadfin shad, and bluegills. Aquatic insects, small crustaceans, fish eggs and vegetative matter were also found in the white catfish diet.

3.17.2 Thermal Tolerance Studies

Since white catfish eggs are adhesive and may be covered with substrate, they are not susceptible to plume entrainment. White catfish young-of-the-year and older are found throughout the year in the Indian Point area. The 30 minute TL95 values obtained for post yolk-sac larvae and early juveniles, 35.0 - 36.3°C (EA 1978), exceed the plotted MDT, as does the 96 hour TL50 (EA 1978) value (Figure 3-12).

The results of a 21 day study on the post yolk-sac juvenile stage indicated that the optimum growth range for these fish was 27.3 - 32.2°C (EA 1978). These temperatures would be found only within the discharge plume. The ultimate incipient lethal temperature (see Section 3.8.2.3), the TL50 value based upon the growth study, was 33.0°C (EA 1978). Further confirming the lack of potentially adverse effects is a field observation of white catfish avoidance at 35°C (Marcy 1976), which exceeds the plotted MDT (Figure 3-12).

Although plume entrainment during winter is not very probable because it would require the catfish to maintain their position in the water column for prolonged periods, lower lethal temperature data do exist. When acclimatized at 16.5°C, the 96 hour TL50 for white catfish was 1.6°C (EA 1978). Since they would be entrained in plume waters no warmer than approximately 10°C (see Section 3.8.2.3), it would be expected that the catfish could withstand drops in temperature to less than 1.6°C.



Key to Thermal Effects Data Points

1. 30.5 C, final preferendum for young of the year; EA 1978.
2. 28.7 C, final preferendum for adults; EA 1978.
3. 35.0 C, field avoidance temp. for adults; Marcy 1976.
4. 25.6-34.7 C, upper incipient lethal temp. for juveniles and adults (96-hr TL50); EA 1978.
5. 34.2 C, ultimate upper incipient lethal temp. for adults; EA 1978.
6. 34.6-35.4 C, 24-hr TL50 for post-yolk-sac larvae and early juveniles; EA 1978.
7. 20-26.0 C, normal spawning temp.; Turner and Kelly 1966, EA 1978.
8. 27.3-32.2 C, optimum range for growth from post-yolk-sac larvae to juveniles; EA 1978.
9. 33.0 C, ultimate upper incipient lethal temp. for post-yolk-sac larvae and early juveniles (21-day TL50); EA 1978.
10. 35-36.3 C, 30-min TL95 for post-yolk-sac larvae and early juveniles; EA 1978.
11. 1.6 C, lower incipient lethal temp. for juveniles (96-hr TL50); EA 1978.

Key to Seasonal Distribution Histograms

(a) Mean no. young of the year collected in 5-min plankton tows for 1974-1976, RM 39-43; TI 1975a, TI 1976e, TI 1977b.

(b) Mean no. yearling and older collected in 5-min bottom trawls for 1974-1975, RM 39-43; TI 1976d, TI 1976g.

(c) Mean no. young of the year and older from impingement collections for June-December 1972 and January-December 1973-1976; Con Edison and PASNY 1978.

Figure 3-12. Thermal effects diagram for white catfish at the Indian Point Generating Station on the Hudson River.

SECTION 4 - PHYTOPLANKTON

As primary producers, phytoplankton convert carbon dioxide, minerals and water into organic matter. In some aquatic ecosystems they function as the food web base. However, it has been found that in the Hudson River estuary, as with many rivers and streams, that detrital material is a significantly larger source of organic input. Phytoplankton contribute approximately 200 x 10^9 kcal yr^{-1} or 0.24% of the total energy input, whereas detritus and dissolved organic materials contribute approximately 99% (Con Edison 1977a). The Hudson River is turbid, and the lack of light penetration is a major limiting factor of plant growth; photosynthesis is generally restricted to a shallow surface zone (the upper 1 meter) (Con Edison 1977a).

The algal community in the area of Indian Point is primarily composed of three major taxonomic groups: Bacillariophyta (diatoms), Chlorophyta (green algae) and Cyanophyta (blue-green algae). In each of these major groups there are many species. Each species has its range of temperature tolerance, optimum growth, photosynthesis and reproduction. In general, the blue-green and green algae are found in greatest abundances in waters warmer than 30°C, whereas most of the diatom species prefer lower temperatures (Patrick 1968; Hynes 1970).

4.1 Decision Criteria

As stated in Section 3.3.1.1 of the TGM, there are three criteria that may establish whether a demonstration can be judged successful for phytoplankton. These are to show that;

1. A shift towards nuisance species of phytoplankton is not likely to occur;

2. There is little likelihood that the discharge will alter the indigenous community from a detrital to a phytoplankton based system; and

3. Appreciable harm to the balanced indigenous population is not likely to occur as a result of phytoplankton community changes caused by the heated discharge.

Meeting these three criteria is sufficient to ensure that the heated discharge will not cause appreciable harm to the phytoplankton BIP.

4.2 Introduction

Comprehensive studies of the phytoplankton community were conducted from 1971 through 1975. The goal of this five year program was to determine the impact of the Indian Point plant on Hudson River phytoplankton. From 1971 through 1973, emphasis was placed on the potentially adverse effects of entrainment on organisms passing through the plant's condenser cooling system (pumped entrainment). Plume entrainment studies began in 1974 and were completed in 1975. This section presents analyses from the five year period which are relevant to determining the effect of the thermal discharge on phytoplankton.

4.3 Community Structure

The composition of the phytoplankton community in the area of Indian Point was determined by routine sampling at river stations A through G (Figure 4-1). Table 4-1 presents a summary of sampling procedures. Detailed information on laboratory methodology appears in Section 2-1, Appendix D.

The large diversity of phytoplankton found in the vicinity of Indian Point is illustrated by the fact that no one species was present in more than 5% of the total number of collections in which species were found from 1972 through 1975 (Table 2-1, Appendix D). Year-to-year comparisons of phytoplankton populations were limited to 1972, 1974 and 1975 because Units Nos. 1 and 2 were off-line during most of the 1973 sampling season. In 1972, nannoplankton net sampling was performed simultaneously with whole water sampling. A comparison of abundances between the two methods indicated that 90% or more of the microflora passed through the nannoplankton net (NYU 1974). Dominant species collected by nannoplankton net in 1971 are shown in Table 2-2, Appendix D. A total of 67 genera were identified from 1972 through 1975, of which 31 genera appeared in every year. This high percentage (46%) of genera recurring annually is an indication of the stable phytoplankton population in the Indian Point area.

Each year from 1971 through 1975 presented similar patterns of seasonal succession. In general, diatom pulses were found during late April and May and again in October and November. Green algae forms predominated during the remainder of the March-December sampling seasons, although blue-greens occasionally comprised significant portions of the community in late summer (Figures 4-2 through 4-5). It is evident that there has not been any major shift in algal community composition over the five year period. Analyses were undertaken to compare the composition of phytoplankton groups among stations from 1972 to 1975. These data are presented in Table 4-2. Table 4-2 clearly indicates that within each year the species percent compositions were very

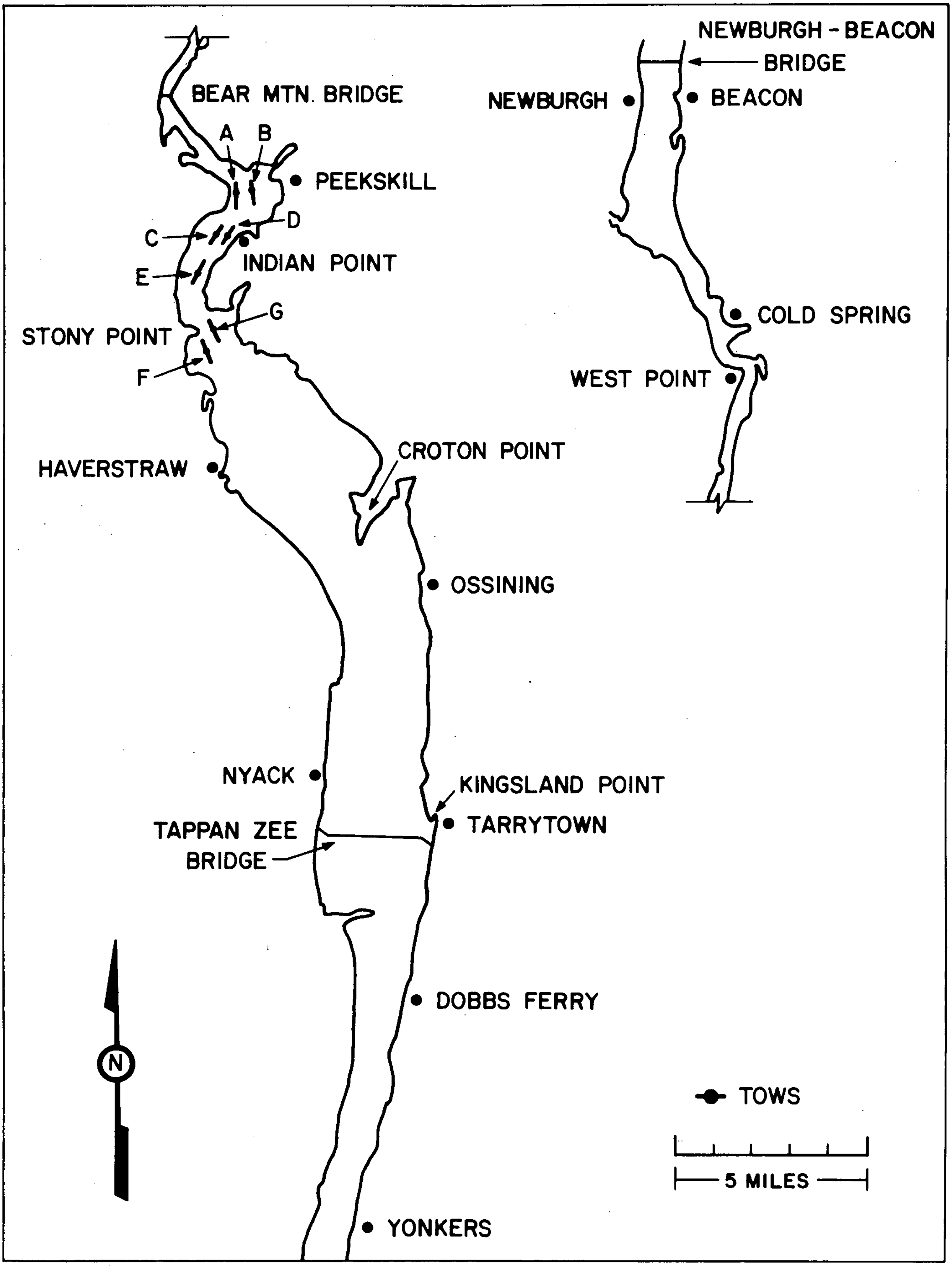


Figure 4-1. Phytoplankton Sampling Stations
Source: Derived from NYU 1977a.

Table 4-1. Summary of Field Materials and Methods for Phytoplankton Collection 1971-1975

Year	Sampling Frequency	Collection Gear	Collection Depths	Sampling Time
1971-72	April - Nov. 1 per week	nannoplankton net	pumped sample 0-20 ft.; 2 ft. intervals for 15 sec. each	day & night
1972	May - Nov. 1 per week	whole-water	pumped sample 0-20 ft.; 2 ft. intervals for 15 sec. each	day
1974	April - Dec. 1 per week during spring & summer; 1 per month in fall	whole-water	pumped sample 0-20 ft.; 2 ft. intervals for 1.5 min each	day
1975	April - Dec. biweekly during spring & summer monthly during fall	whole-water	pumped sample 0-20 ft.; 2 ft. intervals for 1.5 min. each	day

Source: Derived from NYU 1973, 1974, 1976a, 1977a

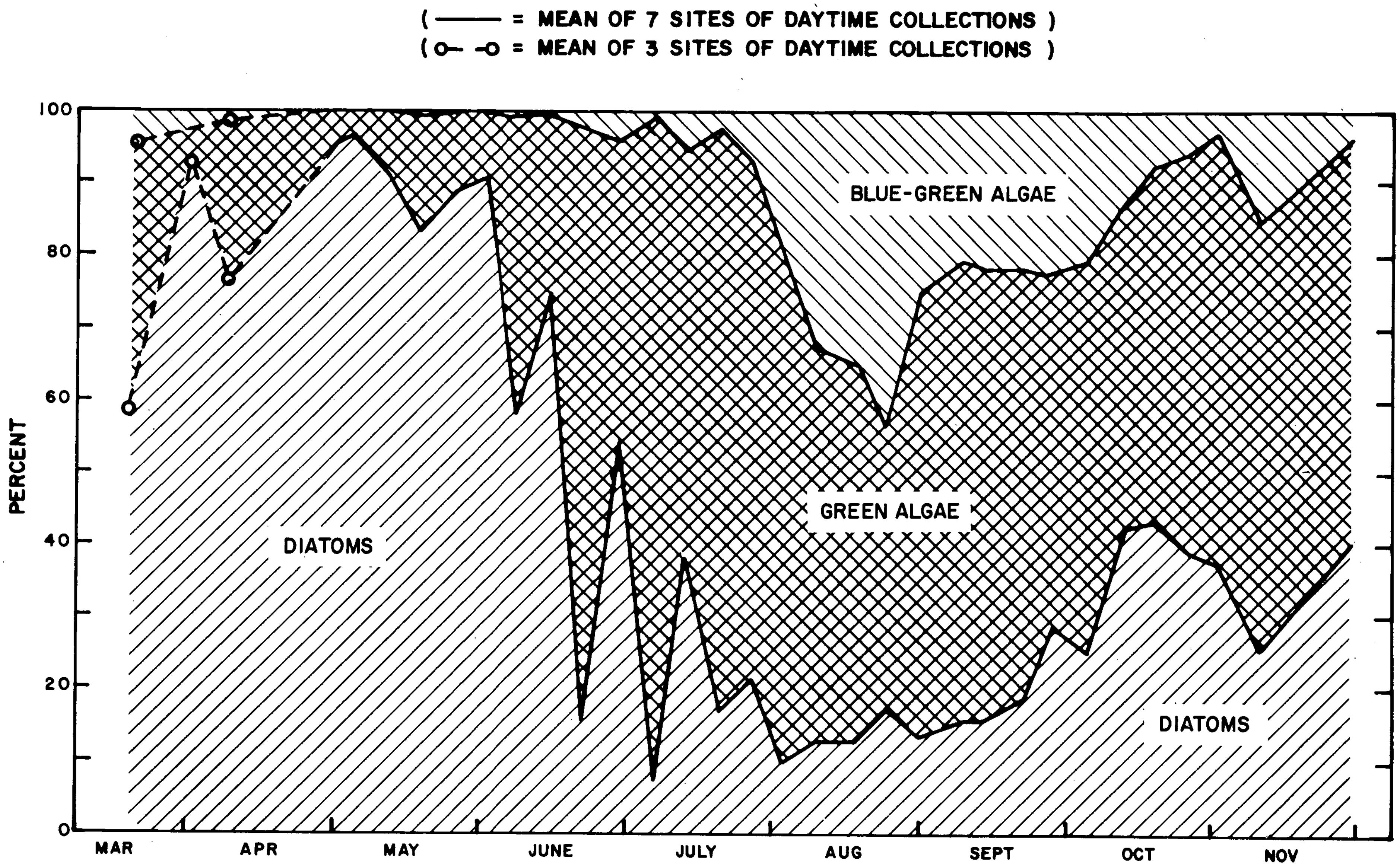


Figure 4-2. Percent composition of phytoplankton in the Hudson River, 1971.
Source: NYU 1973

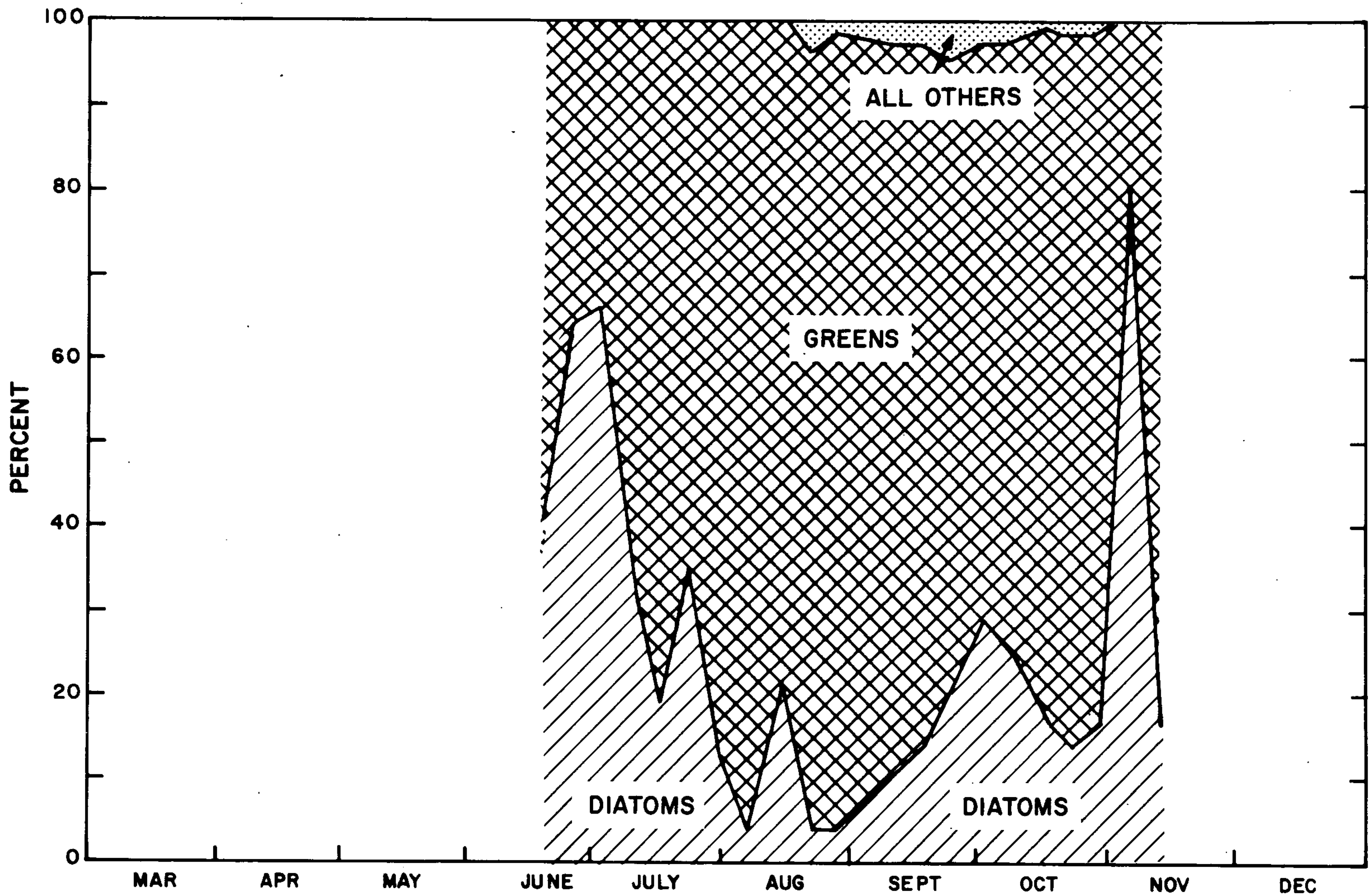


Figure 4-3. Percent composition of phytoplankton in whole-water samples by algal groups, 1972.

Source: NYU 1974.

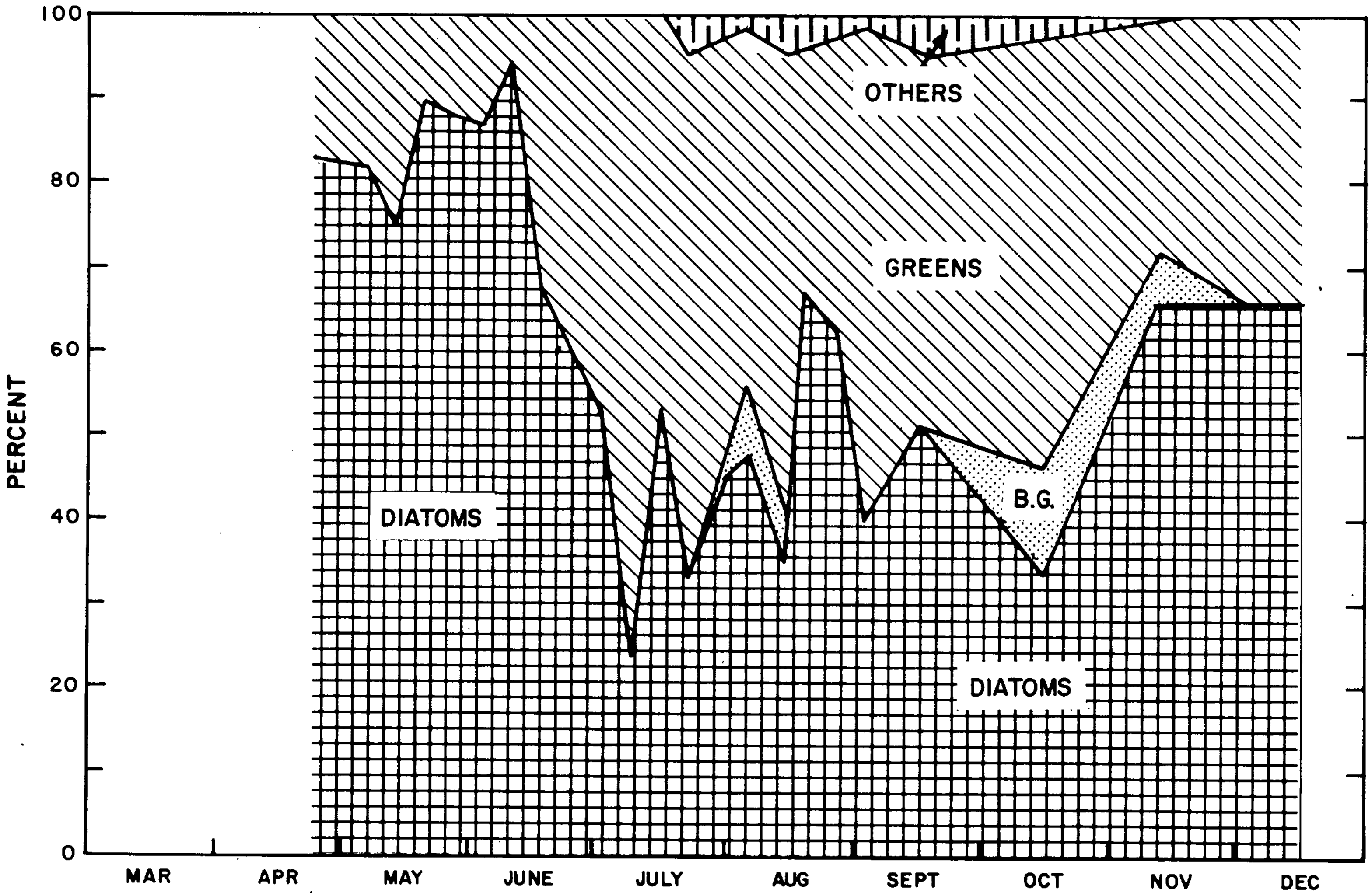


Figure 4-4. Percent composition of phytoplankton in whole-river water collection by algal groups, 1974.

Source: NYU 1976a.

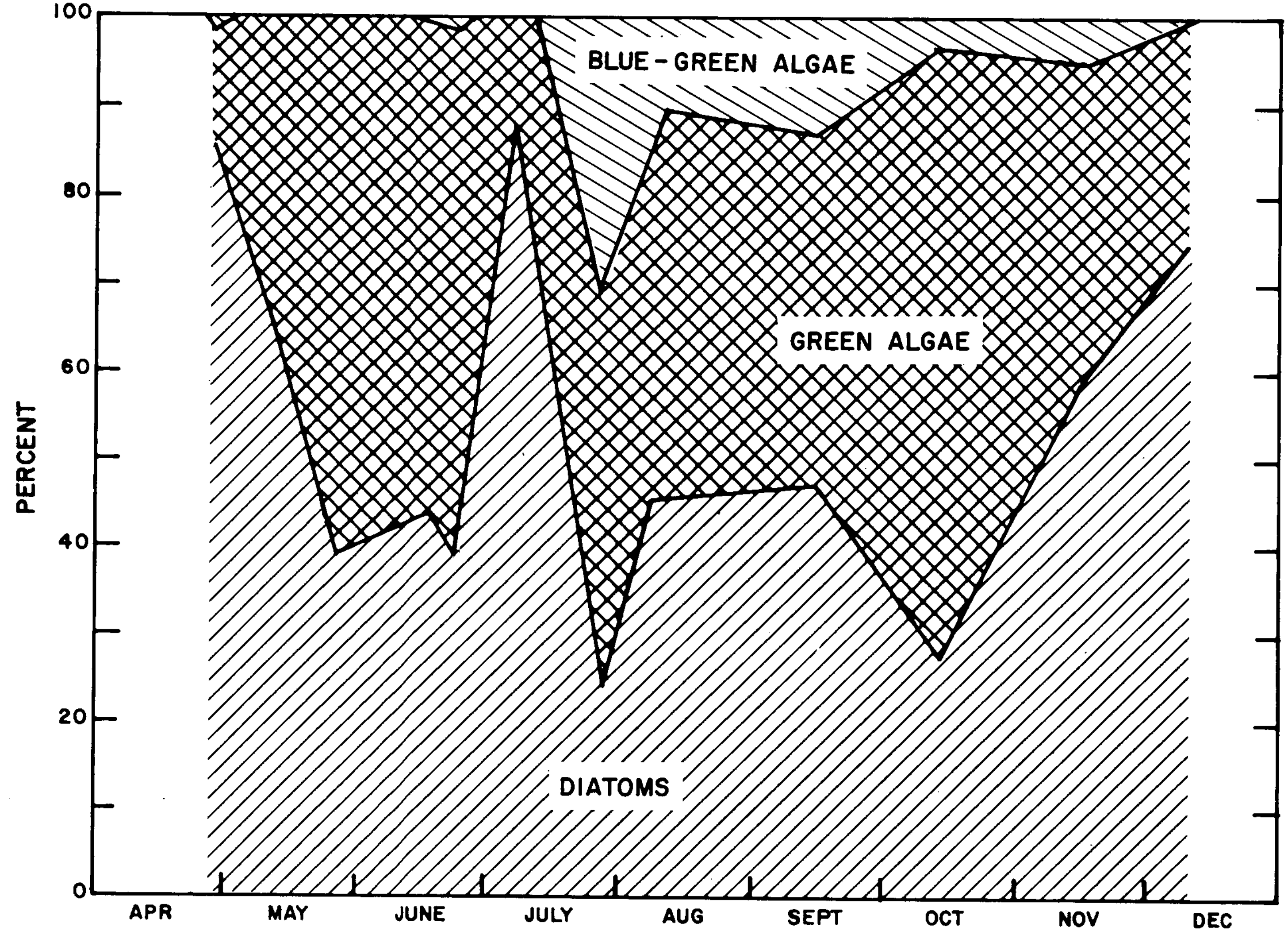


Figure 4-5. Percent composition of phytoplankton community in whole-river-water collections by algae groups, 1975.

Source: NYU 1976b.

Table 4-2. Percent Composition of Phytoplankton in Collections at Stations A - G from 1972 through 1975*

1972 Nannoplankton net collection	Station Means						
	A	B	C	D	E	F	G
Blue-greens	1	1	1	1	1	1	1
Greens	14	19	18	19	16	17	20
Chrysophytes	1	1	3	3	3	2	1
Diatoms	84	79	78	77	80	81	777
Euglenophytes	0	0	0	0	0	0	0

1972 Whole-water collection	Station Means						
	A	B	C	D	E	F	G
Blue-greens	0	0	(no samples collected)			0	0
Greens	68	71				74	72
Chrysophytes	1	1				0	1
Diatoms	29	25				24	26
Euglenophytes	0	0				0	0

1974 Whole-water collection	Station Means						
	A	B	C	D	E	F	G
Blue-greens	0	1	0	1	1	0	0
Greens	28	26	28	29	29	34	31
Chrysophytes	1	0	1	1	1	1	0
Diatoms	68	70	68	65	68	63	66
Euglenophytes	0	0	0	0	0	0	0

1975 Whole-water collection	Station Means						
	A	B	C	D	E	F	G
Blue-greens	5	5	4	5	5	33	2
Greens	44	37	42	38	45	32	36
Chrysophytes	0	0	0	0	0	0	0
Diatoms	51	58	54	57	49	65	62
Euglenophytes	0	0	0	0	0	0	0

Source: Derived from NYU 1974, 1976a, 1977a

* Complete percent composition data for 1971 were not available.

similar among stations. In the same manner, differences in the number of species found at each station within the same year were also analyzed. The results showed that the total number of species was similar in all areas (Table 4-3). The 1971 and 1972 data were analyzed using diversity indices. These analyses were consistent with the findings discussed above (NYU 1974).

4.4 Laboratory Studies

Investigations designed to characterize the effects of the thermal discharge on the phytoplankton community were performed during June, July and September of 1975. Phytoplankton samples collected from the river near Indian Point were exposed for two hours to ΔT's of +2-5°C and +9-13°C. The lower range was selected because it was representative of the overall temperature elevation of the plume area (NYU 1976b). The higher range was included to determine the effect of temperatures exceeding those which would normally be encountered in the plume.

To determine the effects of these laboratory thermal exposures, measurements were made of the photosynthetic rate (using carbon-14 uptake) and cell chlorophyll a (procedures are outlined in Section 2.2, Appendix D). The metabolic activity of the phytoplankton was examined by calculating the ratio of the photosynthetic rate to chlorophyll a, which is termed the assimilation number.

The results indicated that the effect of temperature increases in the range of 2-5°C produced no change in the metabolic activity of the phytoplankton samples (NYU 1976b; Section 2.3, Appendix D). The 9-13°C increases did produce corresponding increases in primary productivity and metabolic rate (Table 2-3, Appendix D).

4.5 Rationale - Thermal Plume Effects on the Phytoplankton Community of the Hudson River in the Vicinity of Indian Point

The results presented in this section and in Section 2, Appendix D, are oriented towards responding to the phytoplankton decision criteria originally suggested by the USEPA in the TGM and restated in Section 4.1 of this report. This rationale focuses on those aspects of the phytoplankton study program at Indian Point which provide information directly related to meeting these established decision criteria.

Criterion 1 - Shift Towards Nuisance Species

A list of those species which when present in high concentrations are considered of "nuisance" importance, appears in Table 2-4, Appendix D. None of these species comprised a major portion of the Indian Point phytoplankton community, nor were there any

Table 4-3. Number of Phytoplankton Species at Stations A - G during 1971, 1972, 1974, 1975

Year	Stations						
	A	B	C	D	E	F	G
1971	88	92	85	90	95	79	83
1972	114	114	104	108	119	98	99
1974	122	102	103	109	108	97	96
1975	86	82	90	89	75	83	84

Source: Derived from NYU 1973, 1974, 1976a, 1977a trends toward an increase in their abundances (Table 2-1, Appendix D).

<u>Criterion 2</u> - Alteration from a Detrital to a Phytoplankton-Based System

The organic input to the Hudson River estuary is primarily through freshwater runoff from upstream watershed areas and from discharges of municipal and industrial wastes. Phytoplankton play a relatively small role in the Hudson River food web, as in most riverine systems (TGM, Section 3.3.1.2; Table 2-5, Appendix D). Since there have been no significant changes in the abundance, productivity and species composition of the phytoplankton populations exposed to the discharge, there is little likelihood that the discharge can alter the reliance of the Hudson River ecosystem upon detrital input.

<u>Criterion 3</u> - Appreciable Harm to the Balanced Indigenous Population of Fish, Shellfish and Wildlife

The interaction of the phytoplankton community in the vicinity of Indian Point with the plant's thermal discharge could theoretically affect the BIP by stimulating the growth of noxious species (causing fouling of shellfish and/or respiratory distress in finfish) and/or by inducing changes in the food web upon which these higher trophic levels depend. As addressed in criteria 1 and 2, respectively, neither of these possibilities are likely occurrences. Furthermore, studies have indicated that phytoplankton community composition has remained stable over several years during which the plant was in operation. On the basis of these findings, it is evident that the Indian Point discharge does not produce any changes in the phytoplankton of the Indian Point area that would result in appreciable harm to the BIP of fish, shellfish and wildlife.

SECTION 5 - MICROZOOPLANKTON

Microzooplankton maintain a vital place in the estuarine food chain, forming a link between primary and higher trophic levels. As primary and secondary consumers, their diet ranges from detritus and bacteria to phytoplankton and other zooplankters. They in turn serve as food for other zooplankters and many larval and adult fishes.

The microzooplankton may be categorized into two basic groups, the holoplankton and the meroplankton. The holoplankton are planktonic throughout their life cycle, whereas meroplankton spend only a portion of their early developmental stages as plankton. This section discusses four groups of holoplanktonic organisms; the copepods, protozoans, cladocerans and rotifers. Meroplankton are treated in Sections 3 (life history information for fish RIS), 7 (macrozooplankton), and 8 (ichthyoplankton field collections at Indian Point).

5.1 Decision Criteria

This section examines the effects of thermal discharge upon the microzooplankton community to determine if;

1. Changes in the microzooplankton community that may be caused by the heated discharge result in appreciable harm to the balanced indigenous fish and shellfish populations, and if

2. The thermal plume constitutes a lethal barrier to the free movement (drift) of these organisms.

These two concepts are presented as criteria 1 and 3 in Section 3.3.2.1 of the Technical Guidance Manual (TGM). TGM criterion #2, which states that the heated discharge should not alter the standing crop and relative abundance from "...those values typical of the receiving water body segment prior to plant operation," cannot be fully addressed because appropriate pre-operational data are not available. The standing crop and relative abundance parameters are discussed in Section 5.4 and are used to evaluate microzooplankton criterion #1 listed above.

5.2 Introduction

Microzooplankton studies on the lower Hudson River estuary in the Indian Point vicinity were initiated in 1969. The sampling techniques varied in the early stages of the study, and it was not until 1971 that they became sufficiently standardized to permit comparison among years. Only data from 1971, 1974, 1975, and 1976 are included in this demonstration.*

Samples were collected from seven standard stations (Figure 5-1) with a #20-mesh (76um) net drawn vertically through the uppermost 10 meters of the water column. The samples were preserved, identified and enumerated using standard techniques. Further details on field and laboratory procedures appear in Section 3.1, Appendix D.

5.3 Community Structure

The most abundant forms of microzooplankton in the Hudson River estuary in the vicinity of Indian Point during the study period have been the copepods, cladocerans, rotifers and protozoans (NYU 1973, 1974, 1976a, 1977a, 1977b).

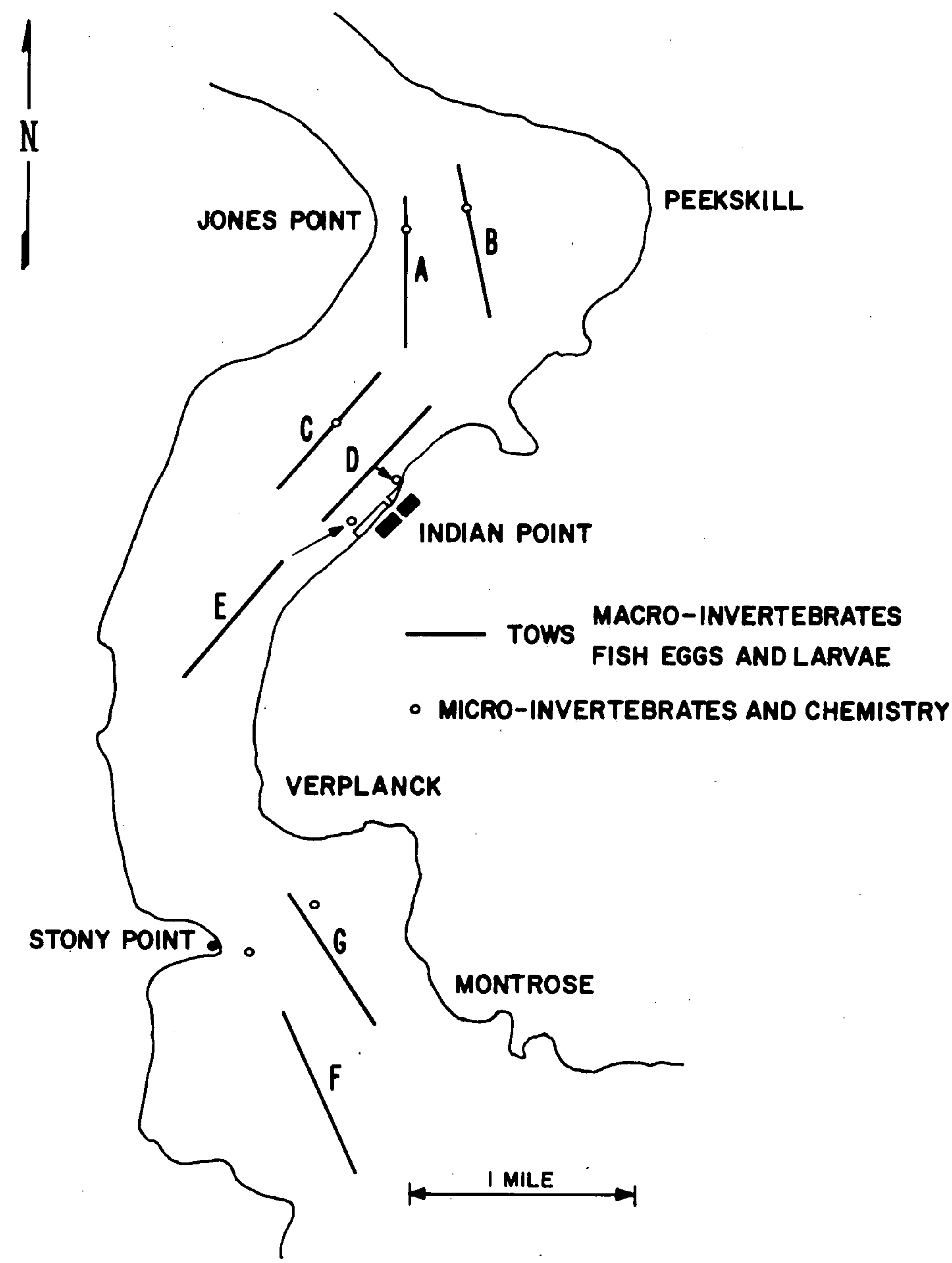
Within each of these major groups, a few species have consistently dominated the collections. Copepods have been dominated by two calanoids, *Acartia tonsa* and *Eurytemora affinis*; and to a lesser extent by the cyclopoids *Diacyclops bicuspidatus* and *Halicyclops fosteri*. The most abundant cladocerans have been *Bosmina longirostris* and *Diaphanosoma brachyurum*, while *Centropyxis* spp. and *Difflugia* spp. have remained the most abundant protozoans. Dominance among the rotifers has shifted since the beginning of the study but was apparently unrelated to plant operation. In 1971 the most common rotifer was *Brachionus angularis*; however, in 1974 it was replaced by *Notholca accuminata*. *N. accuminata* and *Keratella* spp. were co-dominant in 1975, both comprising about 25% of the total rotifers, while in 1976 *Keratella* alone was dominant (NYU 1973, 1974, 1976a, 1977a, 1977b). A complete list of taxa collected (Table 3-2, Appendix D) shows that the species composition has been consistent throughout the course of the study.

5.4 Abundance and Distribution

A comparison of the total microzooplankton abundance among the years sampled indicated that the magnitude of peak abundances and the seasonal abundance patterns have remained stable (Figures 5-2 through 5-5). These seasonal trends may be summarized as follows. The rotifers peaked in abundance during the early spring, and usually dominated the microzooplankton community at

*Data are not available for 1972. No microzooplankton field studies were performed in 1973.

Figure 5-1. NEW YORK UNIVERSITY HUDSON RIVER SAMPLING STATIONS



Source: NYU 1973

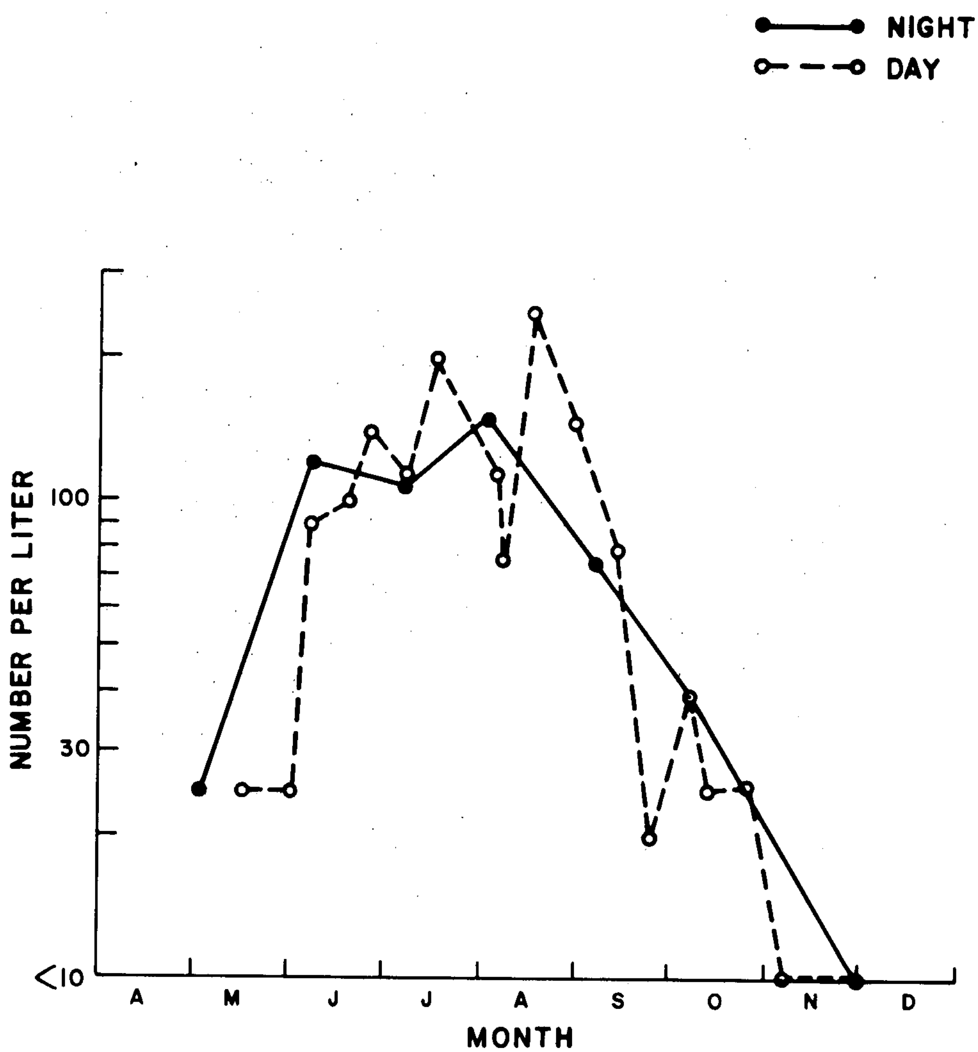


Fig. 5-2. MEAN NUMBER PER LITER OF MICROZOOPLANKTON COLLECTED IN 1971 (ALL STATIONS COMBINED)

Source: NYU 1973

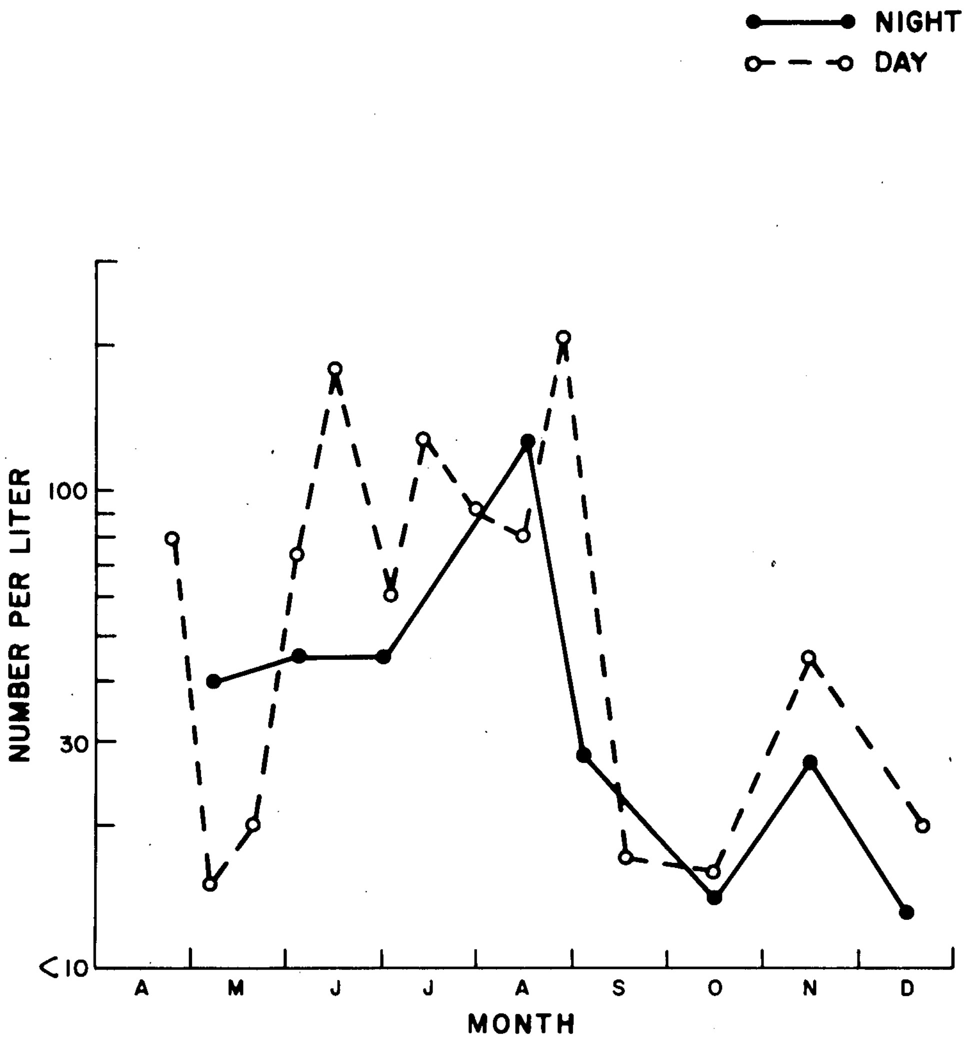


Fig. 5-3. MEAN NUMBER PER LITER OF MICROZOOPLANKTON COLLECTED IN 1974 (ALL STATIONS COMBINED)

Source: NYU 1976a

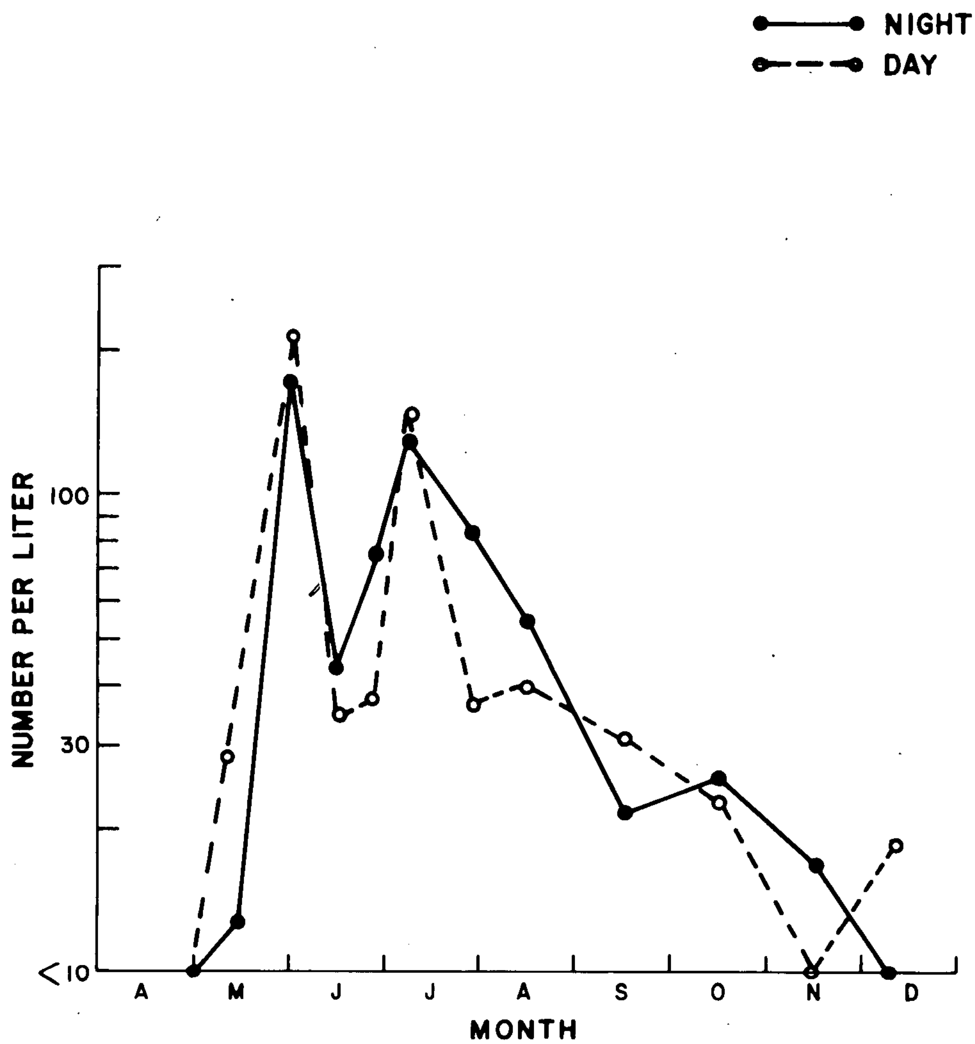


Fig. 5-4. MEAN NUMBER PER LITER OF MICROZOOPLANKTON COLLECTED IN 1975 (ALL STATIONS COMBINED)

Source: NYU 1977a

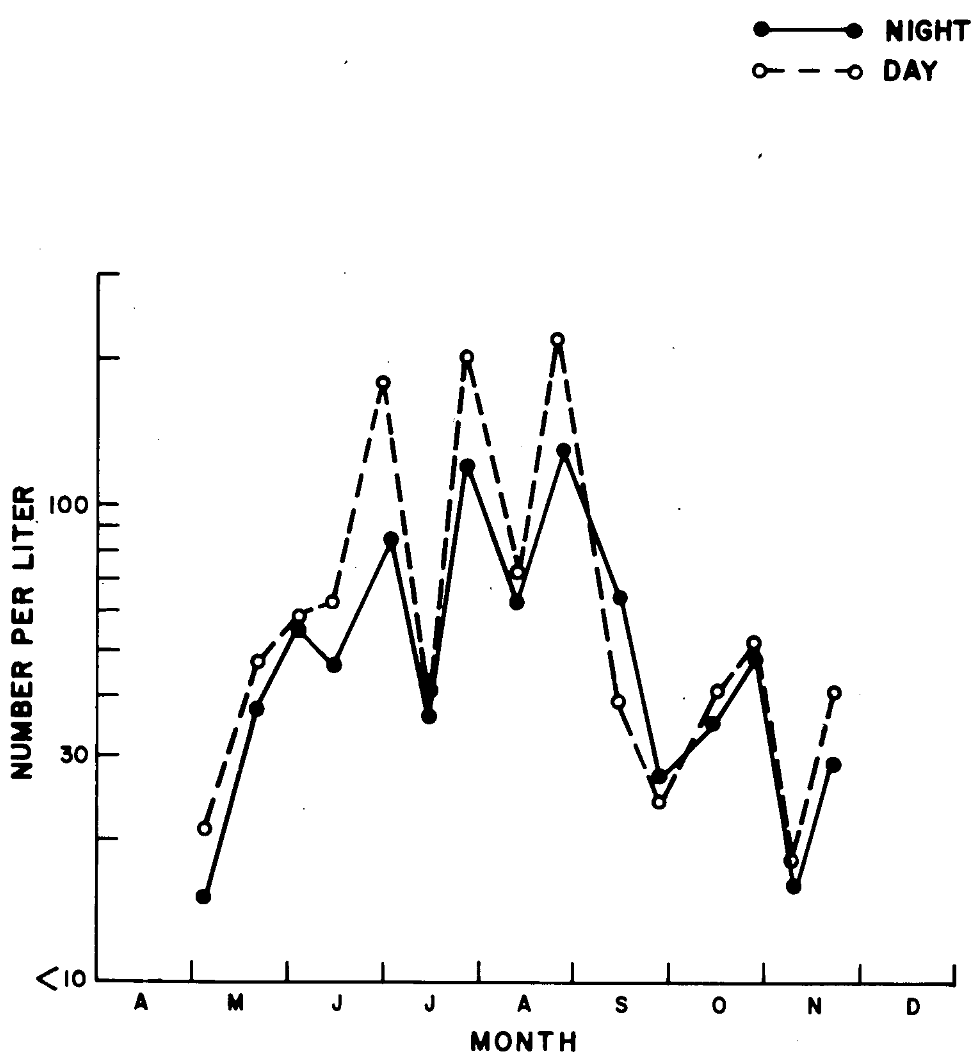


Fig. 5-5.
MEAN NUMBER PER LITER
OF MICROZOOPLANKTON COLLECTED IN 1976
(ALL STATIONS COMBINED)

Source: NYU 1977b

that time. Also present during that period were the copepods H. fosteri, D. bicuspidatus, and E. affinis, as well as the cladocerans B. longirostris, D. brachyurum. Although peak abundance for all these taxa were generally observed in early summer, their continued presence in the Indian Point vicinity depended primarily upon the location of the salt front. As the salt front moved into the area during late summer-early fall, the marine-estuarine copepod A. tonsa became very abundant, displacing the less salt-tolerant H. fosteri, D. biscuspidatus, B. longirostris, and D. brachyurum. These oligohaline taxa remained relatively abundant in the water mass above the salt front. The abundance of the estuarine E. affinis in the Indian Point area was not altered noticeably by the movement of the salt front. The protozoans generally exhibited peak abundances during the late summer (NYU 1973, 1974, 1976a, 1977a, 1977b).

Both near field (NYU 1973, 1974, 1976a, 1977a, 1977b) and far-field (LMS 1974; Orange and Rockland 1977) data indicated similar patterns in the seasonal variability of the composition, diversity, abundance and distribution of microzooplankton from Indian Point to Haverstraw Bay for the study years. Statistical analyses of microzooplankton data collected at the standard sampling stations indicated that in most cases there were no detectable effects of station location on abundance (Section 3.3, Appendix D). In those instances in which differences in abundance were found, there was no indications that the discharge plume had exerted any effect.

5.5 Thermal Tolerance Studies

To determine the limits of temperature tolerance for selected members of the microzooplankton community, laboratory bioassay experiments were performed (NYU 1973, 1974, 1976b). The organisms were exposed for varying durations to several different temperature levels representative of plume-entrainment conditions. Details of the laboratory procedures used in the thermal tolerance studies are found in Section 3.4, Appendix D.

The results of a series of laboratory survival experiments, including a 24 hour latent study examination, indicated that all the organisms tested (A. tonsa, E. affinis, Bosmina spp., Halicyclops spp., Leptodora spp., Ectinosoma spp. and Canuella spp.) had excellent survival at those time-temperature exposures they could potentially experience in the thermal plume (Tables 5-1 through 5-3). In view of the relatively high survival for all the species tested in the laboratory at levels closely corresponding to the maximum discharge temperatures, it is predicted that mortality under actual operating conditions would result in no appreciable adverse effect on the microzooplankton BIP.

Table 5-1. Latent Survival of Various Microzooplankton Exposed to Elevated Temperatures for 30 minutes.

Organism	No. of Organisms	Ambient Temp. °C	Test Temp. °C	ΔT °C	Percent * Survival
Acartia tonsa	65	15.6	31.7	16.1	95
	33	22.2	33.3	11.1	100
Eurytemora affinis	6	1.7	26.7	25.0	83
	32	6.7	27.2	20.5	94
	38	6.7	33.3	26.6	0 **
	57	13.9	29.4	15.5	100
	79	14.4	32.8	18.4	13 **
	52	18.9	32.8	13.9	88.5
	36	22.2	33.3	11.1	97
Bosmina sp.	29	1.7	33.3	31.6	65.5
	16	20.6	33.9	13.3	87.5
	31	25.9	34.2	8.3	93.5
Halicyclops sp.	12	13.9	33.9	20	83
	33	13.9	30.0	16.1	100
	48	18.9	33.9	15.0	100
	9	20.6	33.9	13.3	100
	72	25.9	33.9	8.0	100

Table 5-1 (Cont'd)

Organism	No. of Organisms	Ambient Temp. °C	Test Temp. °C	Δ T °C	Percent * Survival
Cyclopoids (Mesocyclops spp and Cyclops bicuspidatus)	30	3.1	30.0	26.9	50
	16	12.2	32.8	20.6	62.5
	24	20.6	31.7	11.1	100
	11	20.6	32.8	12.2	100
	10	24.4	32.8	8.4	100
Ectinosoma spp	13	15.6	32.2	16.6	100
Canuella spp	21	15.6	31.7	16.1	100
	61	18.9	32.8	13.9	100
	72	22.2	33.3	11.1	100
Leptodora sp.	18	23	33.9	10.9	100
	33	23	35.0	12.0	84.7
	65	23	36.7	13.7	82.3
	20	23	38.6	15.6	0.0 **
	32	23	23	0	100

* Survival determined one hour following end of exposure

** These data points, although valid tests, represent conditions in excess of what would be experienced under actual plume conditions

Source: Derived from NYU 1973, 1974

Table 5-2. Survival of *Acartia tonsa* after exposure to elevated temperatures for various times. Ambient temperature = 25-26°C.

Test Temp °C	% Survival 1 hr. after exposure – Exposure Time: 5 min	15 min	30 min	60 min	% Survival 24 hr. after exposure – Exposure Time: 5 min	15 min	30 min	60 min
29.0	**			98.3 (58)				82.8 (50)
31.0	92.2 *(26)	95.7 (33)	100.0 (15)	100.0 (68)	88.5 (26)	78.3 (23)	72.2 (54)	85.3 (68)
33.0	100.0 (74)	100.0 (33)	100.0 (31)	100.0 (144)	66.2 (74)	54.5 (33)	61.3 (31)	77.1 (144)
34.0	100.0 (39)	96.9 (32)	95.9 (130)	95.2 (83)	61.5 (39)	37.5 (32)	69.4 (49)	31.3 (48)
34.5	94.4 (18)	81.8 (11)	93.1 (29)	77.8 (54)	88.9 (18)	54.5 (11)	55.2 (29)	20.4 (54)
35.0	79.2 (24)	61.5 (26)	56.5 (23)	69.6 (23)	50.0 (24)	46.2 (26)	26.1 (23)	34.8 (23)
35.5			70.0 (20)	41.7 (24)				
36.0			5.3 (38)	0.0 (32)				0.0 (60)

* (Number of organisms)
** All blank spaces indicate no experiments conducted.

Source: NYU 1976b

Table 5-3. Survival of *Eurytemora affinis* after exposure to elevated temperatures for various times.

Test Temp °C	Ambient Temp °C	% Survival 1 hr. after exposure — Exposure Time: 5 min	15 min	30 min	60 min	% Survival 24 hr. after exposure — Exposure Time: 5 min	15 min	30 min	60 min
24.5	20.0	**			52.4 *(21)				28.6 (21)
26.5	20.0				99.0 (390)				92.6 (390)
29.0	25-26				100.0 (48)				94.4 (36)
31.0	25-26				95.5 (45)				56.0 (25)
33.0	25-26				100.0 (117)				
34.0	25-26				94.9 (39)				
34.5	25-26	100 (15)	76.9 (13)	38.8 (8)	19.3 (57)	33.3 (11)	23.1 (13)	16.7 (18)	5.9 (34)
36.0	25-26	100 (12)	34.5 (29)	2.4 (42)	0.0 (37)	0.0 (12)	0.0 (29)	0.0 (42)	0.0 (37)

* (Number of organisms)
** All blank spaces indicate no experiments conducted.

Source: NYU 1976b

5.6 Rationale - Thermal Plume Effects on the Microzooplankton Community of the Hudson River in the Vicinity of Indian Point

The microzooplankton studies have indicated that the occurrence and abundance of dominant species and community changes associated with salt front intrusions have followed a consistent pattern over the years studied. Statistical analysis of abundance data revealed that the plume stations are not significantly different from the other river stations. The absence of discernible effects attributable to the plant discharge, combined with the recurrent presence of similar taxonomic compositions and successional trends over the years, denote a stable microzooplankton community. There would not be any potential for appreciable harm to the BIP of fish and shellfish under such conditions.

The thermal tolerance studies showed that microzooplankters commonly found in the lower estuary could survive time-temperature dosages equal to or greater than those to which they would be exposed. The plume does not, therefore, present a lethal barrier to the free movement of these organisms.

SECTION 6 - HABITAT FORMERS

The Indian Point area is considered of "low potential impact" for habitat formers because the region is essentially devoid of significant concentrations of all such fauna and flora. Colonial macroinvertebrates or assemblages of organisms which produce an exogenous skeleton (e.g. coral) that could provide a substrate for interaction of other trophic levels do not form a significant portion of the Hudson River ecosystem. Furthermore, the limited light penetration restricts the abundance of rooted aquatic vegetation in the nearshore zone.

There are no major stands of submerged aquatic vegetation in the Indian Point vicinity, nor are any marshland areas in the Hudson River within the plume's range of influence. In addition, since these factors limiting habitat-former presence are natural and not man-made, there is no real possibility that these conditions may be relieved so as to allow habitat formers to establish themselves within the area.

SECTION 7 - SHELLFISH/MACROINVERTEBRATES

The macroinvertebrate organisms occupy an important ecological position within the lower Hudson River estuarine food web. As primary and secondary consumers, they act as a link between energy sources (detritus and phytoplankton) and higher consumer levels (fish and other vertebrates).

The macroinvertebrate community of the Hudson River estuary is strongly influenced by the saltwater and freshwater regimes. In the lower estuary, the community is characteristic of one found in a marine environment, while in the upper estuary the community is characteristic of a freshwater environment. The middle portion of the estuary is an area in transition, with the saltwater mixing with the freshwater. This area supports both marine and freshwater organisms, as well as those typical of a brackish environment.

The macroinvertebrates display a great deal of variability in their habitat selection. Depending upon biological and physicochemical factors such as life stage, season, or time of day, estuarine macroinvertebrates may be either benthic, epibenthic or planktonic. Their primary habitats, the bottom and the water column, required different sampling techniques and thus two different sampling programs evolved. Therefore, the following discussion of the macroinvertebrates will be divided into two sections; the benthos and the macrozooplankton.

7.1 Decision Criteria

The shellfish/macroinvertebrate section should demonstrate that no appreciable harm to the BIP occurs as a result of macroinvertebrate community changes caused by the heated discharge. Several decision criteria may be used to determine the likelihood of such an event. These are to show that appreciable harm will not result from;

1. Reduction in the standing crop,

2. Reduction in the components of diversity, and

3. Passage of drifting fauna through the thermal plume.

Meeting these three criteria ensures that the heated discharge will not cause appreciable harm to the macroinvertebrate BIP. These criteria are fundamentally the same as those stated in Section 3.3.4.1 of the TGM with the following exceptions;

1. TGM criterion #3 (Drift) indicates that "...the discharge of cooling water equal to 30% or more of the

7-day, 10-year low flow of a river or stream would be cause for concern..." However, since Indian Point is located on a estuary, the river flow is tidal and has a freshwater flow component. The water circulated by the station is a mixture of salt and freshwater representing a maximum of 2.8% of the river flow (Con Edison 1977b). Therefore, the 30% clause stated above is not applicable at Indian Point.

2. TGM criterion #4 (Critical functions) excludes the discharge of any waste heat into most estuarine sites since "they are areas of critical function, serving as spawning and nursery sites for important shellfish and/or macroinvertebrate fauna, and thus are considered as zero allowable impact areas." The fact that the plant discharges into an estuary is not, by itself, sufficient justification to assume that appreciable harm will result. If in evaluating the potential impact on each biotic category it can be demonstrated that appreciable harm is not produced as a result of the thermal discharge, this assures the protection and propagation of the fish, shellfish and wildlife BIP. The TGM's "zero allowable impact" should not, therefore, automatically and arbitrarily exclude 316(a) consideration for all estuarine sites. In the case of Indian Point, TGM criterion #4 is inappropriate and is not discussed.

7.2 Macrozooplankton

7.2.1 Introduction

Macrozooplankton studies were conducted in the Indian Point vicinity from 1971 through 1976 except 1973 (see Section 4.3). This section examines the yearly, seasonal and diel changes in the macrozooplankton community to determine the effects of the Indian Point thermal discharge on this group. Laboratory studies were also conducted on the major macrozooplankton taxa to determine their thermal tolerances. The results of other laboratory investigations into the effects of temperature rise on Neomysis americana, Gammarus spp., and Crangon septemspinosa (the three macroinvertebrate RIS) were presented in Sections 3.5, 3.6 and 3.7.

Macrozooplankton samples were collected from seven river stations, designated A-G (Figure 5-1). At each station, a ten minute tow was simultaneously made at three depths; bottom, middle and surface. A summary of field collection parameters appears in Table 7-1. Detailed discussions of field procedures may be found in Section 4.6, Appendix D.

Table 7-1. Macrozooplankton/Ichthyoplankton Sampling Frequency and Net Dimensions

Year		Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Flow Meter	Mesh Size (mm)	Length (meters)	Diameter (meters)
		Number of times samples were collected in each month										Net Dimensions		
1971 [a]	Day		7	9	8	5	4	4	1	1				
	Night		2	2	2	3	2	2			No	571	3.8	0.5
1972 [a]	Day	4	8	9	9	4	2	3	2	2				
	Night	1	4	3	3	3	1	2	1		No	571	3.8	0.5
1974 [b]	Day	1	4	2	2	2	1	1	1	1				
	Night		3	2	2	2	1	1	1	1	Yes	571	3.8	0.5
1975 [c]	Day	2	4	5	3	2	1	1	1	1				
	Night	1	4	4	4	2	1	1	1	1	Yes	571	3.8	0.5
1976 [d]	Day	1	4	5	4	2	1	1	1	1				
	Night	1	4	4	5	2	1	1	1	1	Yes	571	3.8	0.5

Source: Derived from a NYU 1974; b NYU 1976a; c NYU 1977a; d NYU 1977b.

7.2.2 Community Composition

A total of 32 taxonomic forms belonging to five phyla have been collected from the Indian Point vicinity (NYU 1977b). Comparisons among years sampled indicated that the taxa composition remained essentially the same throughout (Table 4-4, Appendix D). From 1972 through 1976, three taxa were consistently the most abundant. These were Gammarus spp., Monoculodes edwardsi, and Neomysis americana (Table 7-2).

7.2.3 Abundance and Distribution

Environmental factors such as salinity, temperature, dissolved oxygen, food supply, competition and predation, among others, play major roles in determining the abundance and distribution of aquatic organisms. Distinct seasonal variations in total macrozooplankton abundance were found to be related to the prevailing salinity regime and temporal differences among individual taxa life cycles.

Total macrozooplankton abundance generally increased during the spring and summer, peaked in late summer and declined rapidly by late fall. These fluctuations in the total macrozooplankton population actually represented a summation of the variation in individual taxa abundance throughout the year. Specifically, Gammarus spp. and Chaoborus spp. showed increased abundances during the spring and into summer. During the late summer, the abundance of N. americana, C. septemspinosa and M. edwardsi increased as the salt front moved into the Indian Point area. An examination of monthly abundances revealed that these trends were quite consistent (NYU 1973, 1974, 1976a, 1977a, 1977b; Figures 4-8, 4-9 and 4-10, Appendix D).

On a daily basis total macrozooplankton were found in greatest abundance near the bottom, with the vertical distribution being somewhat more uniform at night than during the day (Figures 4-11, 4-12 and 4-13, Appendix D). In all study years, the abundance of macrozooplankton was found to be greater at the bottom of the water column in both day and night collections. Also, the total abundance was found to be significantly greater during the night than during the day. These patterns are probably attributable to the fact that the macrozooplankton community of the lower Hudson River estuary is dominated by epibenthic organisms. During the day these organisms are close to or in the bottom sediments; at night they migrate upwards. An examination of the data showed that these findings were consistent with the observed distribution for both total macrozooplankton and individual taxa abundances (NYU 1973, 1974, 1976a, 1977a, 1977b).

Statistical analyses of total macrozooplankton and individual taxa abundance data revealed significant differences among

Table 7-2. Macrozooplankton abundance in pooled river samples during each year. Data are mean numbers caught per 1000 m^3.

	Day			
Year	1972	1974	1975	1976
Total	5598	9675	8269	6611
Gammarus	4463	2546	1841	2545
Monoculodes	206	830	1235	155
Neomysis	814	3127	2786	1160

	Night			
Year	1972	1974	1975	1976
Total	21412	24627	28131	21112
Gammarus	18057	7858	7175	7517
Monoculodes	491	2596	4269	2782
Neomysis	2376	5709	6314	5877

Source: Derived from NYU 1974, 1976a, 1977a, 1977b.

stations, depths and dates in both day and night collections (Tables 4-5 through 4-16, Appendix D). Although significant differences among stations occasionally occurred for each of the three major species, no consistent trend appeared that would indicate that there was any difference in abundance among the sampling stations (NYU 1973, 1974, 1976a, 1977a, 1977b).

7.2.4 Thermal Tolerance Studies

Laboratory experiments were performed from 1971 to 1977 to investigate some of the physiological effects of increased temperature on key macrozooplankton organisms (NYU 1973, 1974, 1976a, 1976b, 1977a, 1977b). The results of the studies on *M. edwardsi* and *Chaoborus* spp. are discussed here; those for *N. americana*, *Gammarus* spp. and *C. septemspinosa* are presented in Sections 3.5, 3.6 and 3.7, respectively.

The upper lethal temperature ranges were investigated by exposing test organisms for varying durations to temperatures above that at which they were acclimated. Information on collection procedures, holding and test conditions, and criteria used to establish viability appear in Sections 4.1 and 4.2, Appendix D. These tests emphasized acclimation temperatures representative of the warmest months, since it is during these times when organisms are most likely to be stressed by entrainment in the discharge plume. The results presented in Tables 7-3 and 7-4 indicate that both *M. edwardsi* and *Chaoborus* spp. can tolerate temperatures in excess of those that they would be expected to experience if entrained in the Indian Point plume. Both organisms (Figures 4-14 and 4-15, Appendix D) exhibited threshold-like responses to higher temperatures in that the TL50 values were generally less than 2°C higher than the TL95 values.

7.3 Rationale - Thermal Plume Effects on the Macrozooplankton Community of the Hudson River in the Vicinity of Indian Point

The results presented in this section are intended to address the decision criteria listed in Section 7.1. This summary discusses how these results may be applied towards meeting the stated decision criteria.

Criterion 1 - No Reduction in Standing Crop

Total macrozooplankton abundance remained at a fairly stable level as indicated in data collected from 1972 through 1976. Although some individual taxa showed considerable variation in abundance over several years, these fluctuations are not unusual in dynamic estuarine ecosystems (Thayer et al. 1974). When examined on a yearly basis, each year's total and individual taxa abundance did not reveal any trend in macrozooplankton standing

Table 7-3. TL95 and TL50 (^{o}C) of *Monoculodes edwardsi* in 5-minute and 30-minute exposures at summer ambient temperatures. ($25^{o}C$).*

TL95*		TL50*	
5 min	30 min	5 min	30 min
35.5	34.8	37.3	36.3

* after initial exposure organisms were held for 24 hours at the ambient temperature ($25^{o}C$), then mortalities were tabulated.

Source: Derived from NYU 1973.

Table 7-4. Survival of *Chaoborus* spp. collected at Indian Point and exposed to elevated temperatures for 30 minutes

Number of Organisms	Ambient Temperature (°C)	Test Temperature (°C)	ΔT (°C)	Percent Survival After one Hour
22	25.3	34.5	9.2	100
19	25.3	37.8	12.5	100
13	25.3	38.9	13.6	100
17	25.3	41.1	15.8	76.2
29	25.3	41.7	16.4	4.25
21	25.3	25.3	0	100

Source: Derived from NYU 1974.

crop estimates that could be associated with the operation of the Indian Point station.

Criterion 2 - No Reduction in Components of Diversity

Species composition has remained essentially unchanged throughout the years of study, although there was a slight overall increase in the total number of taxa collected. In terms of abundance, the community has consistently been dominated by three macrozooplankters; *Gammarus* spp., *Monoculodes edwardsi*, and *Neomysis americana*. There has been no apparent alteration in the seasonal or daily cycles exhibited by these organisms.

Criterion 3 - Passage of Drifting Fauna Through the Thermal Plume

Laboratory studies have demonstrated that except for *N. americana*, the major macrozooplankters survived thermal conditions more severe than they would encounter if they became entrained in the discharge plume. In the case of *N. americana*, some mortality could occur at the highest summer ambient temperatures. This is examined more fully in Section 3.5.

7.4 Benthos

7.4.1 Introduction

Benthic studies were initiated on the Hudson River estuary in the vicinity of Indian Point in August of 1969. The original study, from mid-1969 through 1970, was designed to provide baseline information on abundance and composition of the benthic community (Raytheon 1971). In 1972 benthic studies recommenced and continued through 1974 (TI 1976c). The first year of these new studies, 1972, served to gather information over a broad area in terms of species composition, relative abundance, diversity, and seasonal responses to physical and chemical variations. In 1973 and 1974, the studies were refined by establishing test areas within the effluent plume to provide direct comparisons to control sites. Particle size and temperature analyses were performed on the sediment in the test and control areas to characterize the effect of the heated discharge on each habitat.

In the following discussion, emphasis is placed on those studies conducted in 1973 and 1974, since the most comprehenisve benthic collections were made in those years. Sampling procedures used to determine the composition of the benthic community in the Indian Point area are summarized in Table 7-5. These procedures are more fully explained in Section 4.7, Appendix D.

Table 7-5. Information on Sampling Dates and Equipment in Macrobenthic Studies

Time Period*	Contractor	Number of Stations	Sampler Type	Surface Area of Sampler	Sieve Mesh Size
Aug. - Dec. 1969	Raytheon	14	Emory grab	0.025 m^2	300 μm x 500 μm
Jan. - Oct. 1970	Raytheon	14	Emory grab	0.025 m^2	300 μm x 500 μm
April - Dec. 1972	Texas Instruments	7	Petersen dredge	0.1 m^2	250 μm
April - Dec. 1973	Texas Instruments	6 in control area 6 in test area	Petersen dredge	0.1 m^2	500 μm
April - Dec. 1974	Texas Instruments	6 in control area 6 in test area	Petersen dredge	0.1 m^2	500 μm

* Samples collected once per month

Source: Derived from Raytheon 1970, 1971; TI 1972, 1974, 1975b, 1976c

7.4.2 Study Area

Abiotic differences in the test and control areas were examined by sediment particle-size and in situ thermal analyses (Sections 4.8 and 4.9, Appendix D; TI 1976c). The bottom sediments of both areas were predominantly silt-clay (<63um) mixed with some sand and pebbles (Table 7-6). The test area contained slightly higher percentages of gravel and silt-clay, while the control area was generally sandier.

From April through December of 1974, simultaneous in situ measurements of the sediment temperature at 1 cm depth and the water temperature at 2.5 and 30 cm above the sediment-water interface were taken. In both the test and control areas, all of the sediment temperatures were higher than the overlying water, although the differences were relatively small. No significant differences among individual stations or between the test and control areas were detected. This indicated that the thermal plume had no apparent effect on the temperature of the sediment during the period examined (Table 7-7).

7.4.3 Taxonomic Composition

Collections from the macrobenthic infaunal community of the Indian Point region from April 1969 to October 1970 consisted of 23 taxa representing six phyla (Table 4-17, Appendix D; Raytheon 1971). This assemblage was dominated in numbers of taxa by the Crustacea (8), Annelida (5) and the Mollusca (2). The more extensive collections of April 1972 to December 1974 consisted of 86 taxa representing nine phyla (Table 4-18, Appendix D; TI 1976c). This assemblage was dominated in numbers of taxa by the Crustacea (30), Insecta (19), and Annelida (14). Although dissimilarities in sampling techniques between the two studies limited quantitative comparisons, it was found that most of the taxa identified in the Raytheon study were also found in the TI study.

Community diversity values (Tables 4-19 and 4-20, Appendix D) in the Indian Point vicinity were relatively low reflecting the dominance of a few organisms, primarily Limnodrilus spp. and Amnicola spp. (TI 1976c). Low species diversity is characteristic of a soft-bottom, physically stressed (salinity) benthic community such as is found at Indian Point (Sanders 1968; Boesch 1976). Statistical analyses indicated no significant differences in diversity among the seven survey stations during 1972 or between the test and control areas during 1973 and 1974 (Table 4-21, Appendix D).

Table 7-6. Mean Particle-Size Composition of Sediments in Test and Control Areas, October and November 1973

		Particle Size (mm)								
	Station	> 8	4-8	2-4	1-2	0.5-1	0.25-0.5	0.125-0.25	.0 63-0.125	<.0 63
Test	A	14.8	6.8	3.8	3.0	1.5	8.1	3.9	5.5	54.4
	B	0	0.9	0.8	2.4	1.4	11.7	6.7	8.2	67.9
	C	3.2	3.9	2.3	2.8	0.8	3.7	3.9	5.0	74.4
	D	1.5	0.8	0.6	1.4	0.8	4.3	4.4	9.2	81.5
	E	0	0	0.04	2.4	0.8	2.2	2.8	7.9	83.8
	F	0	0.7	1.5	0.6	0.6	2.9	2.9	5.0	87.8
	Mean	3.25	2.18	1.51	2.10	0.98	5.48	4.1	6.8	74.97
Control	M	5.2	2.7	3.4	3.5	1.9	14.3	19.9	10.4	41.3
	N	4.1	13.8	11.2	12.0	3.6	7.7	10.1	10.9	31.6
	O	0.3	0.5	0.4	0.8	0.7	11.1	9.8	7.0	62.0
	P	3.7	3.6	1.9	1.3	4.2	5.5	10.8	7.9	64.4
	Q	0	0	1.6	0.4	0.3	1.6	3.9	10.0	82.6
	R	0.7	2.1	1.2	0.5	0.4	3.8	9.1	7.7	78.7
	Mean	2.33	3.78	3.28	3.08	1.85	7.33	10.6	8.98	60.1

Source: TI 1976c.

Table 7-7. Mean *In Situ* Water and Sediment Temperature ($^{\circ}C$) for Test and Control Areas during 1974

		April	May	June	July	August	Sep	Oct	Nov	Dec	Annual Mean
Test	Sediment	4.2	12.8	18.8	26.0	25.0	24.0	18.8	11.9	6.8	16.48
	Water										
	2.5 cm	3.5	12.3	17.8	24.0	24.5	24.0	18.7	11.6	6.3	15.86
	30 cm	3.5	12.0	17.8	24.0	24.0	24.0	18.5	11.5	6.3	15.73
Control	Sediment	5.2	12.7	20.0	25.3	24.8	24.5	17.0	14.0	4.8	16.48
	Water										
	2.5 cm	4.2	12.0	19.0	24.3	24.3	24.2	17.1	13.7	4.3	15.90
	30 cm	4.2	12.0	19.0	24.3	24.0	26.0	16.8	13.3	4.3	15.99

Source: TI 1976 c.

7.4.4 Abundance and Distribution

Shifts in benthic community composition and abundance have shown a relationship with the duration of the salt front in the area. In 1969-1970, there was comparatively little rainfall in the Hudson River watershed, causing the salt front to extend into and beyond the Indian Point region for a longer period of time than in previous years (TI 1976c). During this period, the benthic community was dominated by halophilic forms. A shorter exposure to the salt front in 1971-1972 resulted in a shift to dominance by species less salt-tolerant (TI 1976c). The benthos then reverted to domination by halophilic forms by 1974 due to increased salt water intrusion in 1973 and 1974 (Tables 4-22 through 4-25, Appendix D). It was also indicated that there were considerable fluctuations in the abundance of certain taxa from year to year. Such variations are generally characteristic of benthic communities in temperate estuarine systems (Boesch 1973). The total number of taxa and annual mean number of specimens per square meter increased from 1973 to 1974. In particular, numbers of *Balanus improvisus*, *Amnicola* sp., *Congeria leucophaeta* and *Rhithropanopeus harrisi*, all annually reproducing species which had been present in relatively low numbers during 1973, increased in 1974. Other species such as *Scolecolepides viridis* showed progressive increases in 1973 and 1974 over their 1972 population levels. These greater abundances apparently reflected the influence of the greater duration of the salt front in the Indian Point area during the later years (TI 1976c).

Analysis of combined 1973-1974 major taxa abundance data indicated that there were no consistent patterns of differences between test and control stations (Table 4-26, Appendix D). However chironomid larvae were found to be more abundant in the test area stations than in the control area stations. In many instances this analysis also indicated significant differences among some stations for the major taxa. However these differences were generally localized (microhabitat differences) and appeared unrelated to the discharge plume (TI 1976c).

Examination of the biomass data for the years 1972-1974 indicates a trend towards a general increase in biomass in the study area, with the year 1974 showing a marked increase (Figure 4-18, Appendix D). Annual patterns of fluctuations were consistent, with mean weights decreasing from the initial sampling period in April to a low level during the summer period. This was followed by a late summer-early autumn increase, and with the onset of winter, a decrease. The pattern during the 1973 season was somewhat different, with no spring depression and little autumnal increase (TI 1976c).

7.4.5 Rationale - Thermal Plume Effects on the Benthic Community of the Hudson River in the Vicinity of Indian Point

The hydrothermal analyses indicated that the plume does not come into extensive contact with the bottom sediments and would thus not be expected to affect benthic organisms. Thermal studies performed while Unit No. 2 was in operation showed that the discharge plume did not cause an increase in the temperature of the sediments. With respect to the specific decision criteria listed in Section 7.1, it was found that there was no apparent alteration in any aspect of the benthic community that was attributable to the discharge plume.

Criterion 1 - No Reduction in Standing Crop

Individual taxa, as well as the entire benthic faunal assemblage showed wide fluctuations in abundance when examined over the years studied. During the most intensively studied period, from 1972 through 1974, there was an increase in both abundance and biomass (gm/cm^2 wet weight). The considerable variability noted in standing crop assessments is not unusual in dynamic ecosystems (Boesch 1976), and is felt to be representative of constantly occurring natural changes within the estuary. Comparison of abundances between test and control stations for the combined 1973-1974 data showed significant differences for certain taxa, but no trend toward total standing crop reduction.

Criterion 2 - No Reduction in Components of Diversity

Faunal changes throughout the study period have been consistently associated with seasonal or salt front variables. Overall, there have been relatively few changes; the dominant benthic taxa have remained the same. These diversity values showed little change during the study period, and no significant differences were noted between the test and control areas.

Criterion 3 - Passage of Drifting Fauna Through The Thermal Plume

All the information on this topic has been previously addressed in macrozooplankton, Section 7.2.

SECTION 8 - FISH

In the Hudson River estuary, fish comprise the highest level in the aquatic food chain. The interrelationships are complex, but zooplankton are the largest segment of the food web for most larval and juvenile fishes and these groups in turn, contribute a substantial portion to the adult fish diet. Fish utilize the Indian Point area for a variety of purposes including spawning, growth/development and as a migratory pathway. The most frequently collected species (e.g. bay anchovy and blueback herring) were generally found in the vicinity only at specific times of year, corresponding to population movements asociated with reproductive activity or onset of winter.

8.1 Decision Criteria

It is suggested that the fish section of a 316(a) demonstration will be judged successful if it can be shown that the local fish community will not suffer appreciable harm as a result of:

1. Direct or indirect mortality from cold shocks;
2. Direct or indirect mortality from excess heat;
3. Reduced reproductive success or growth due to plant discharges;
4. Exclusion from unacceptably large areas; or
5. Blockage of migration.

Information was presented in Section 3 that indicated that the RIS would not suffer appreciable harm through any of the five mechanisms listed above. It is expected that the remainder of the fish community will similarly not be adversely affected by the discharge.

8.2 Introduction

The most comprehensive studies on the Hudson River fish community were initiated in 1971. Specific program efforts were directed towards describing the effects of plant operation on the abundance, distribution and variety of fishes at standard sampling stations and determining various characteristics of age structure, growth, reproduction and food habits of selected species. The results of these studies have been extensively documented (TI 1976b; Con Edison 1977b; NYU 1977b) and will only be briefly discussed here. A summary of fish collection methodologies appears in Table 8-1.

8.3 Ichthyoplankton

Twenty-seven species have been collected since 1971, with the bay anchovy, Anchoa mitchilli, generally predominating each year on a numerical basis (NYU 1977b). The relative abundances of egg through juvenile stages found in the Indian Point area are given in Table 8-2. The occurrence and abundance of planktonic fish are dependent on the spawning locations selected by the adults, the physical characteristics of the eggs produced, the habitat preferences of the mobile older forms, and the physicochemical factors existing in the river at the time of collection. The temporal and spatial distribution and abundance of these ichthyoplankton is treated extensively elsewhere (Con Edison 1977b).

Overall, the species composition was consistent throughout the five years of study, although there was considerable fluctuation in the annual presence (Table 8-3) of many species' larval stages. Six taxa (anchovy, clupeids, striped bass, white perch, cyprinids and hogchoker) were represented by all life stages during the study (Atlantic tomcod would have also been represented if sampling were performed during the winter). Other than these six taxa, only the American eel, rainbow smelt and weakfish were observed in relative abundances greater than two percent (Table 8-2).

The vertical distribution of striped bass ichthyoplankton was also examined. It was found that the eggs, yolk-sac larvae and larvae stages were concentrated in mid-level and bottom samples during the daytime (NYU 1977a; 1977b). In general, analyses of nighttime collections indicated that all these stages were more evenly distributed within the water column at this time, although there were occasions when bottom strata abundances were significantly greater than those found for mid-level or surface depths (NYU 1977b).

8.4 Juveniles and Adults

Table 8-4 contains the species composition of fishes in the Indian Point vicinity that were collected with seine and trawl gear from 1972 through 1976. The juvenile and adult fish community consisted of 61 species; 29 of which were freshwater residents, 17 were marine, seven were estuarine, seven were anadromous and one was catadromous. Thirteen species predominated in collections made during this period; striped bass, white perch, Atlantic tomcod, spottail shiner, alewife, bay anchovy, American shad (Alosa sapidissima), blueback herring (Alosa aestivalis), bluefish (Pomatomas saltatrix), hogchocker (Trinectes maculatus), banded killifish (Fundulus diaphanus), tesselated darter (Etheostoma olmstedi) and pumpkinseed (Lepomis gibbosus). Most of these species exhibited seasonal abundance

Table 8-1. Fish collection methodology employed in the Indian Point vicinity from 1971-1976

Life Stage	Gear	Locations	Frequency	Dates Employed	Biological Characteristics Obtained
Ichthyoplankton (eggs, larvae)	0.5m diameter ring net (571 um mesh)	Standard stations A-G (Fig. 5-1)	(See Table 7-1)	1971-1976*	Abundance, length frequency
Juveniles and Adults	100 ft. (30.5m) beach seine	Standard stations 8-12, 20-21 (Fig. 8-1)	(See Table 5-1, Appendix D)	1972-1976**	Abundance, length frequency, fecundity samples for striped bass and white perch
Juveniles and Adults	Mid-water, surface, and bottom trawls	Standard stations 1-7 (Fig. 8-1)	(See Table 5-5, Appendix D)	1972-1976	Abundance, length frequency

* During 1973 sampling was conducted only on four transects in front of Indian Point, Unit 1-2 See Fig. 5-1, Appendix D.

** Standard stations 20 and 21 added during 1974

Table 8-2. Percent relative abundance of fish eggs, larvae and juveniles occurring in the Hudson River between mile 39.0 and mile 47.0 for 1971 to 1976. Data for 1973 were not available for all species.

Species	Eggs 1971	Eggs 1972	Eggs 1974	Eggs 1975	Eggs 1976	Yolk-sac Larvae 1971	Yolk-sac Larvae 1972	Yolk-sac Larvae 1974	Yolk-sac Larvae 1975	Yolk-sac Larvae 1976
Anchovy	----	----	95.9	98.7	94.0	----	----	16.3	35.5	25.8
Clupeids[1]	7.2	1.1	+	+	+	16.6	6.8	3.9	2.6	5.0
Striped bass	92.7	87.2	3.1	1.2	5.6	55.6	65.6	54.8	43.3	51.6
White perch	+	0.8	0.5	0.1	0.3	22.2	6.6	22.7	15.3	7.7
Tomcod	----	----	----	----	----	----	13.1	----	+	0.1
Darter	----	----	----	----	----	4.0	4.9	1.7	1.6	7.0
Cyprinids[2]	----	+	0.5	+	+	1.6	1.9	0.6	0.9	2.6
Hogchoker	----	10.9	----	----	----	----	0.1	0.1	+	----
Yellow perch	----	----	----	----	----	----	+	----	+	0.1
Weakfish	----	----	----	----	----	----	----	----	----	----
Smelt	----	----	----	----	----	----	----	----	0.7	0.1
Silversides	----	----	----	----	----	----	----	----	----	----
American eel	----	----	----	----	----	----	----	----	----	----
Pipefish	----	----	----	----	----	----	----	----	----	----
Centrarchid	----	----	----	----	----	----	----	----	----	----
Goby sp.	----	----	----	----	----	----	----	----	----	----
Sturgeon	----	----	----	----	----	----	----	----	----	----
Windowpane flounder	----	----	----	----	----	----	----	----	----	----
Killifish	----	----	----	----	----	----	----	----	----	----
White catfish	----	----	----	----	----	----	----	----	----	----
Shad[1]	----	----	----	----	----	+	+	+	+	+
Menhaden	----	----	----	----	----	----	----	----	----	----
Crevalle Jack	----	----	----	----	----	----	----	----	----	----

Table 8-2 (cont'd.)

Species	Larvae 1971	Larvae 1972	Larvae 1974	Larvae 1975	Larvae 1976	Juveniles 1971	Juveniles 1972	Juveniles 1974	Juveniles 1975	Juveniles 1976
Anchovy	51.2	30.8	69.8	42.1	39.4	99.8	57.4	68.7	49.0	44.9
Clupeids[1]	10.7	47.8	7.9	10.9	40.8	+	3.4	1.4	2.2	6.1
Striped bass	14.3	7.1	12.2	21.8	8.1	+	7.3	0.4	0.2	4.6
White perch	21.8	8.0	9.4	23.6	8.1	+	30.1	0.1	1.2	3.5
Tomcod	----	5.2	----	+	2.4	+	----	9.6	16.0	9.8
Darter	0.1	0.4	0.1	0.3	0.2	----	+	----	0.5	----
Cyprinids[2]	+	0.4	0.2	0.3	0.3	----	+	+	----	----
Hogchoker	+	0.3	0.1	0.2	+	+	1.7	2.0	2.5	0.8
Yellow perch	+	0.8	+	+	+	----	----	----	----	----
Weakfish	----	+	0.1	+	0.1	----	+	2.7	0.5	1.4
Smelt	1.2	----	0.1	0.4	0.4	+	+	2.7	4.8	2.6
Silversides	0.2	+	0.1	+	+	----	----	0.2	----	----
American eel	----	----	----	----	----	+	+	12.9	20.5	25.4
Pipefish	----	----	----	----	----	+	----	0.4	1.2	+
Centrarchid	----	----	+	+	+	----	----	----	----	----
Goby sp.	----	----	+	----	+	----	----	----	----	----
Sturgeon[3]	----	+	----	+	+	+	----	----	----	----
Windowpane flounder	----	----	----	+	----	----	----	----	----	----
Killifish	----	----	----	----	+	+	----	----	1.0	+
White catfish	----	----	----	----	----	----	----	----	0.2	0.5
Shad[1]	----	----	+	+	0.1	----	----	----	----	0.4
Menhaden	+	----	----	----	----	----	----	----	----	----
Crevalle Jack	----	----	----	----	----	+	----	----	----	----

\+ indicates less than 0.1 percent.

1 The clupeids included alewife, blueback herring and shad. The eggs are presumed to be alewife because of time of occurrence and size. The shad are presumed to be present in larval and juvenile stages for years 1971 and 1972. The yolk-sac larvae stage for shad is easily identified due to its size in the sample(9 to 10 mm) for all years from 1971 to 1975. For years 1974 and 1975 shad were present only as yolk-sac larvae and larvae (fish) in the samples.

2 The cyprinids included spottail shiner and an unknown cyprinid species.

3 The sturgeon larvae shown for 1972, 1975 and 1976 may include Atlantic sturgeon or shortnose sturgeon or both. The juvenile sturgeon shown in 1971 was an Atlantic sturgeon.

Source: derived from NYU 1977b

Table 8-3. Species comparisons from 1971 to 1976

Species	1971	1972	1973	1974	1975	1976
Anchovy	+	+	+	+	+	+
Clupeids[1]	+	+	+	+	+	+
Striped bass	+	+	+	+	+	+
White perch	+	+	+	+	+	+
Tomcod	+	+	+	+	+	+
Darters	+	+	+	+	+	+
Cyprinids[2]	+	+	+	+	+	+
Hogchoker	+	+	+	+	+	+
Yellow perch	+	+	+	+	+	+
Smelt	+	+	+	+	+	+
Silversides[3]	+	+	+	+	+	+
American eel	+	+	+	+	+	+
Pipefish	+	-	+	+	+	+
Killifish[4]	+	-	+	-	+	+
Crevalle jack	+	-	-	-	-	-
Menhaden	+	-	-	-	-	-
Weakfish	-	+	+	+	+	+
Atlantic Sturgeon[5]	+	+	-	-	+	+
Centrarchid	-	-	+	+	+	+
Silver perch	-	-	+	-	-	-
White catfish	-	-	+	-	+	+
Stickleback	-	-	+	-	-	-
Goby	-	-	-	+	-	+
Windowpane flounder	-	-	-	-	+	-
TOTALS	21	19	23	20	23	24

1 The clupeids included alewife, blueback herring and shad.

2 The cyprinids included spottail shiner and an unknown cyprinid species.

3 The silversides included Atlantic silverside and Tidewater silverside.

4 The killifish included banded killifish and mummichog during 1976.

5 The sturgeon shown for 1972, 1975 and 1976 may include Atlantic sturgeon or shortnose sturgeon or both.

Source: NYU 1977b

Table 8-4. Fishes Collected in Standard-Station Samples, Yearly and by Gear, Indian Point Region, Hudson River Estuary, New York, 1972-76.

Species	Principal Usage of Estuary ‡	Beach Seine 72	73	74	75	76	Surface Trawl 72	73	74	75	76	Bottom Trawl 72	73	74	75	76
STURGEONS - ACIPENSERIDAE																
Shortnose Sturgeon	M-F Life resident; spawning (Sp)	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
Atlantic Sturgeon	M-F Resident during early years; larger adults anadromous; spawning (Sp)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
FRESHWATER EELS - ANGUILLIDAE																
American eel	M-F Catadromous; nursery adult feeding	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+
HERRINGS - CLUPEIDAE																
*Blueback herring	M-F Anadromous; spawning (Sp); nursery (Sp-F)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
*Alewife	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
*American Shad	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+
Atlantic menhaden	M-F Nursery (Sp-S); adult feeding lower estuary	+	-	+	-	+	+	+	+	+	+	+	-	+	+	+
Gizzard Shad	M-F Nursery (S-W)	+	-	+	+	+	-	-	-	+	+	-	-	+	+	+
ANCHOVIES - ENGRAULIDAE																
*Bay anchovy	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
TROUTS - SALMONIDAE																
Brown trout	F Life resident (tributary streams)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
SMELTS - OSMERIDAE																
Rainbow smelt	M-F Anadromous; spawning (Sp); nursery (S-F)	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+
PIKES - ESOCIDAE																
Redfin pickerel	F Life resident; spawning (W-Sp)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Chain pickerel	F Life resident; spawning (W-Sp)	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Northern pike	F Life resident (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
MINNOWS & CARPS - CYPRINIDAE																
Goldfish	F Life resident; spawning (Sp)	+	+	+	+	+	-	-	-	-	-	+	+	+	-	-
Carp	F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+
Silvery minnow	F Life resident; spawning (Sp)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Golden shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Emerald shiner	F Life resident; spawning (Sp-S)	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
*Spottail shiner	F Life resident; spawning (Sp-S)	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+
Spotfin shiner	F Life resident; (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Bridle shiner	F Life resident; (Sp-S)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Common shiner	F Life resident; (tributary streams)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Redfin shiner	F (1)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Blacknose dace	F Life resident (tributary streams)	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
SUCKERS - CATOSTOMIDAE																
White sucker	F Life resident; spawning (Sp)	+	+	+	+	+	-	-	-	-	-	-	-	+	+	-
FRESHWATER CATFISHES - ICTALURIDAE																
White catfish	F Life resident; spawning (Sp)	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+
Brown bullhead	F Life resident; spawning (Sp-S)	+	+	+	+	+	+	-	-	-	-	+	+	+	+	+
Black bullhead	F Life resident; spawning (Sp)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
CODS - GADIDAE																
*Atlantic Tomcod	M-F Spawning (W); nursery (Sp-F); adult feeding	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+
NEEDLEFISHES - BELONIDAE																
Atlantic needlefish	M-F Nursery (S); adult feeding (S)	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-
KILLIFISHES - CYPRINODONTIDAE																
*Banded killifish	F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	-	+	-	-	-	+	-
Mummichog	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
SILVERSIDES - ATHERINIDAE																
Tidewater silverside	M-F Life resident; spawning (Sp-S)	-	-	+	+	+	-	-	+	-	-	-	-	-	-	-
Atlantic silverside	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	-	+	+	-	-	-	-	-	-	-
Rough silverside	M Nursery (S-F)	-	-	-	+	+	-	-	-	+	-	-	-	-	-	-
STICKLEBACKS - GASTEROSTEIDAE																
Fourspine stickleback	M-F Life resident; spawning (Sp-S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Brook stickleback	F Life resident; (tributary streams)	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Threespine stickleback	M-F Life resident; spawning (Sp)	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
PIPEFISHES & SEAHORSES - SYNGNATHIDAE																
Northern pipefish	M-F Nursery (S); adult feeding (S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
TEMPERATE BASSES - PERCICHTHYIDAE																
*White perch	M-F Anadromous; spawning (Sp-S) nursery (Sp-F); feeding (Sp-F)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
*Striped Bass	M-F Anadromous; spawning (Sp) nursery (S-F) feeding	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SUNFISHES - CENTRARCHIDAE																
Rock bass	F Life resident; spawning (S)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Red breast sunfish	F Life resident; spawning (S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
*Pumpkinseed	F Life resident; spawning (S)	+	+	+	+	+	-	-	+	-	-	+	+	+	-	+
Bluegill	F Life resident; spawning (S)	+	+	+	+	+	+	-	+	+	-	+	+	-	-	-
Green sunfish	F Life resident; (tributary streams)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Largemouth bass	F Life resident; spawning (S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Black crappie	F Life resident; spawning (S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
PERCHES - PERCIDAE																
*Tessellated darter	F Life resident; spawning (Sp)	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+
Yellow perch	F Life resident; spawning (Sp)	+	+	+	+	+	-	-	-	-	-	+	+	-	-	+
BLUEFISHES - POMATOMIDAE																
*Bluefish	M-F Nursery (S); yearling feeding (S-F)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
JACKS & POMPANOS - CARANGIDAE																
Crevalle jack	M-F Nursery (S)	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
DRUMS - SCIAENIDAE																
Weakfish	M-F Marine spawner; nursery (S)	-	+	+	-	-	-	+	-	-	-	+	+	+	+	+
Spot	M-F Nursery (S)	-	+	-	-	+	-	-	-	-	+	-	-	-	-	+
Atlantic croaker	M-F Nursery (F)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
MULLETS - MUGILIDAE																
Striped mullet	M Nursery (S-F)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
White mullet	M Nursery (S-F)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
BUTTERFISHES - STROMATEIDAE																
Butterfish	M Incidental	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
LEFTEYE FLOUNDERS - BOTHIDAE																
Summer flounder	M Nursery (S-F)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
SOLES - SOLEIDAE																
*Hogchoker	M-F Life resident; spawning (S)	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+

‡ General Salinity distributions: F = limited to fresh or low-salinity waters; M = limited to marine or brackish waters; M-F = occurs in both marine and fresh waters (euryhaline); SP = Spring, S = Summer, F = Fall, W = Winter.
* Common Indian Point fish fauna
+ = present; - = absent; (1) = Probable misidentification.
SOURCE: TI 1976 b,1977a

patterns. Spring samples were characterized by the presence of adult alewives and blueback herring moving up the Hudson River to spawn, and by increasing catches of resident estuarine species such as white perch and tesselated darter. Summer samples were dominated by young-of-the-year, including marine forms such as bluefish. Fall samples reflected decreasing catches of resident species as well as downriver migrations by young-of-the-year of anadromous and estuarine species (TI 1976b).

Local abundance of most species is strongly influenced by seasonal changes in temperature and salinity. Movements of striped bass, white perch and Atlantic tomcod, among others within the estuary were associated with changes in the location of the salt front. Striped bass, bluefish, blueback herring, and bay anchovy were relatively more abundant at beach seine stations with little or no vegetative cover and near open water. Stations with vegetation and located in protected areas away from the open river were characterized by high relative abundance of white perch, alewife, banded killifish, spottail shiner and pumpkinseed (TI 1976b). These abundance patterns were consistently observed even though certain stations were within the direct influence of the Indian Point discharge plume (e.g., station 10 in Figure 8-1 is in close proximity to the discharge structure yet showed c/f results as high as the topographically similar station 11 across the river). This suggests that habitat and not the thermal discharge is probably the primary factor responsible for the distribution of fishes in the Indian Point area.

8.5 Rationale - Field Observations of Thermal Plume Effects on the Fish Community of the Hudson River in the Vicinity of Indian Point.

There is no evidence that operation of the Indian Point generating station with once-through cooling has adversely affected the fish populations inhabiting or utilizing the Indian Point area. No detectable alterations in species composition or relative abundance that can be attributed to plant operations has occurred in the fish community.

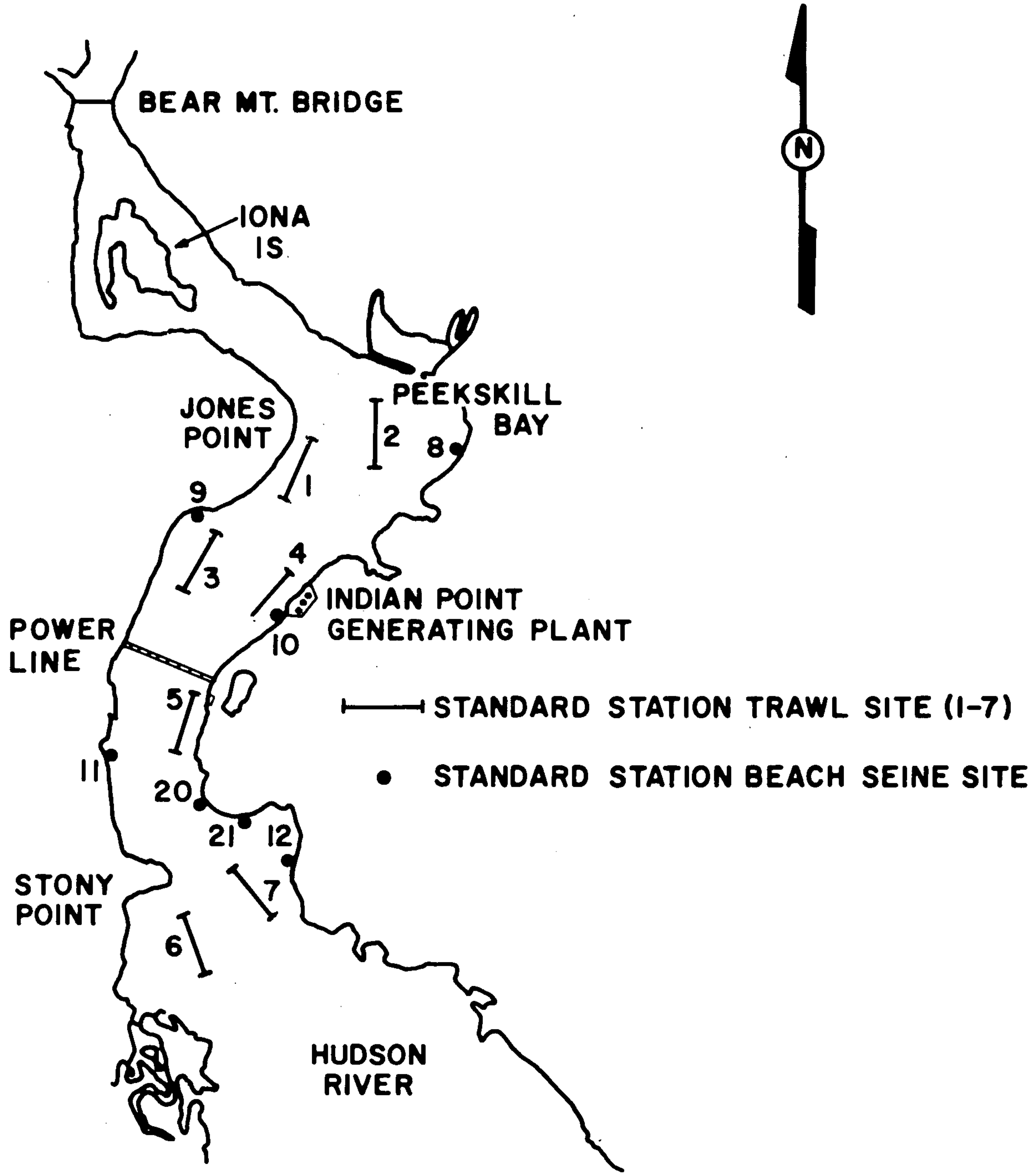


Figure 8-1. Standard Fisheries Stations
Indian Point Ecological Study

Source: TI 1976a.

SECTION 9 - OTHER VERTEBRATE WILDLIFE

The effects of the thermal discharge of the Indian Point plant on vertebrate wildlife other than fish are considered to be of "low potential impact" because the plume does not impact large or unique populations of wildlife. The plume does not attract migratory waterfowl nor does it encourage them to stay in the area through the winter. There are no threatened or endangered wildlife species in the area of Indian Point.

SECTION 10 - HYDROTHERMAL ANALYSES

The purpose of the hydrothermal analyses is to provide information on the observed and predicted temperature characteristics of the Hudson River in the vicinity of the Indian Point station which can be used as a basis for biological impact assessment. Specifically, the objectives of this section are;

1) To present general representations of the thermal plumes observed at the Indian Point station indicating their general size, configuration, and tidal patterns,

2) To determine such geometric characteristics as cross-sectional areas, surface areas, volumes, and maximum lateral and longitudinal lengths of selected plumes during various seasons and tidal phases,

3) To indicate what percentages the areas and volumes of water subjected to selected temperature rises in the near field region of the station represent with respect to the overall dimensions of the river in the same region,

4) To show what temperature changes in the thermal regime of the river are caused by the discharge of warmed circulating water, and how these changes relate to the New York State thermal criteria for cross-sectional area and surface width,

5) To scale up selected plumes which were observed under conditions of less than maximum thermal loading to provide a representation of full capacity operating conditions, and

6) To show the effect of the shape of the plume on the overall temperature distribution.

Detailed supportive information is provided in Appendix D, including power generation statistics (Section 1.1), plant operating characteristics (Section 1.2), time-temperature profiles (Section 1.3), usage of chlorine and other chemicals (Sections 1.4 and 1.5), dissolved oxygen concentrations (Section 1.6), hydrologic data (Section 1.7), ambient temperature analyses (Section 1.8), recirculation (Section 1.9), intake and receiving water features (Section 1.10), outfall configuration and operation (Section 1.11), and plume data references (Section 1.12). A discussion of the thermal survey program and physical and mathematical models used at Indian Point is presented in attachment 3, Appendix D.

10.1 Plant Operating Characteristics

10.1.1 Cooling Water System

Cooling water from the Hudson River enters the Indian Point Station through the Units Nos. 2 and 3 intakes, is pumped through the condensers and returns to the river via a common discharge canal located south of Unit No. 3 (Figure 10-1). Each unit has six circulating water pumps and six service water pumps. The circulating water system is designed to operate at either 100% flow or at 60% flow. When the ambient water temperature is above 40°F (non-winter condition) the pumps operate so that the maximum cooling water flow for each unit is 840,000 gpm (1871.5 cfs). During the winter, 40% of the cooling water is returned to the circulating water pumps, without passing through the condenser, thereby reducing the maximum intake for each unit to 504,000 gpm (1123 cfs). This reduced flow condition, required when the water temperature is 40°F or less, results in a decrease in intake volume to mitigate impingement during the winter months. Service water is drawn through a separate intake forebay in the center of each intake and, after utilization is discharged into a common canal. The maximum total service water flow for each unit is 30,000 gpm (67 cfs) making the combined maximum (cooling water + service water) flow for Units Nos. 2 and 3 1,740,000 gpm (3877 cfs).

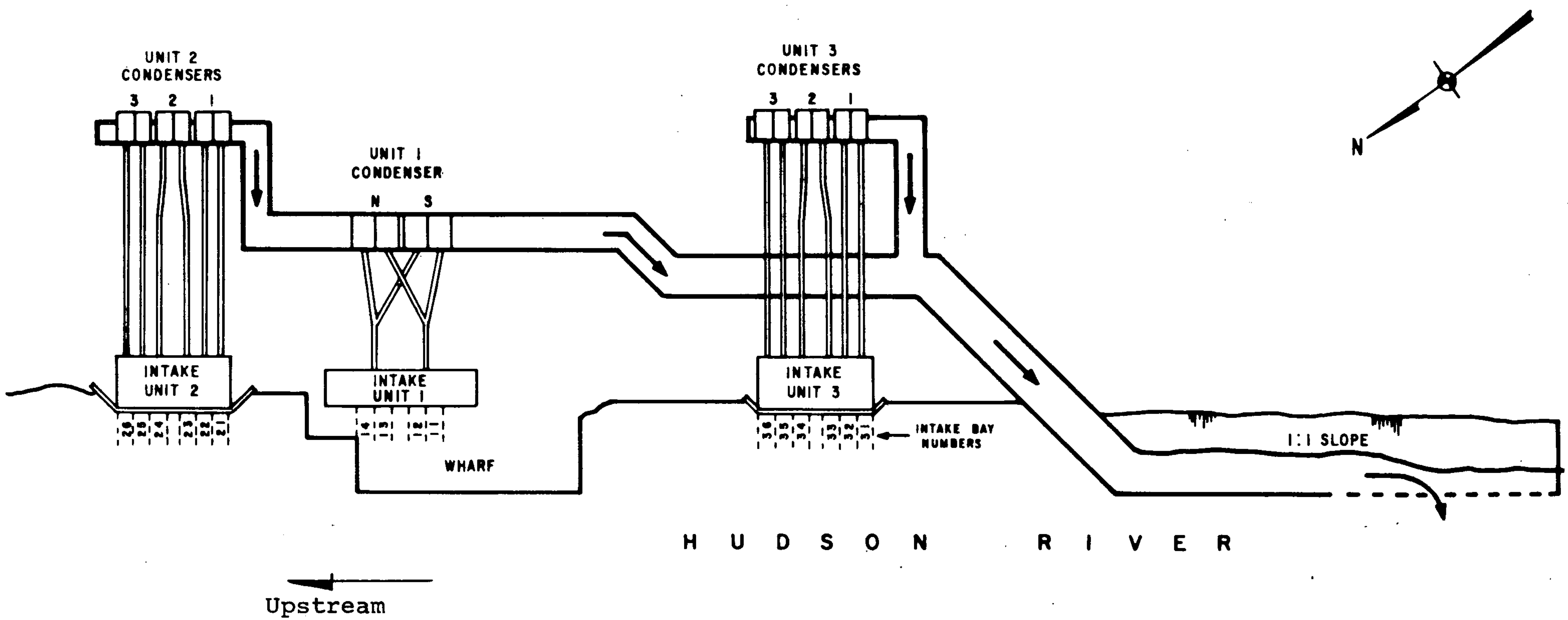
After passing through the plant, the circulating water from the station enters a discharge canal which is designed for the combined flow of all three units. The combined discharge is released to the Hudson River via an outfall structure located south of Unit No. 3 (Figure 10-2). The structure consists of 12 ports submerged to a depth of 12 feet (center to surface) at mean low water. The first upstream port is approximately 600 feet from the Indian Point Unit No. 3 intake and the length of total port section is approximately 252 feet. Monthly average total discharge for Units Nos. 2 and 3 are presented in Table 10-1 for the years 1973 through 1977. Flow rates for Unit No. 1 are also shown for the same period. A summary of pump operation is given in Tables 10-2 and 10-3.

10.1.2 Transit Time and Temperature Rise

10.1.2.1 Transit Time

Cooling water transit times traveling from condenser inlet to river outfall for Units Nos. 2 and 3 operating at full pumping capacity range from 8.5 to 9.7 minutes for Unit No. 2 and from 5.2 to 5.6 minutes for Unit No. 3, depending upon the number of pumps operating at Unit No. 1.

CIRCULATING WATER SYSTEM



Schematic

Figure 10-1. INDIAN POINT STATION
CIRCULATING WATER SYSTEM

Source: Con Edison 1977b

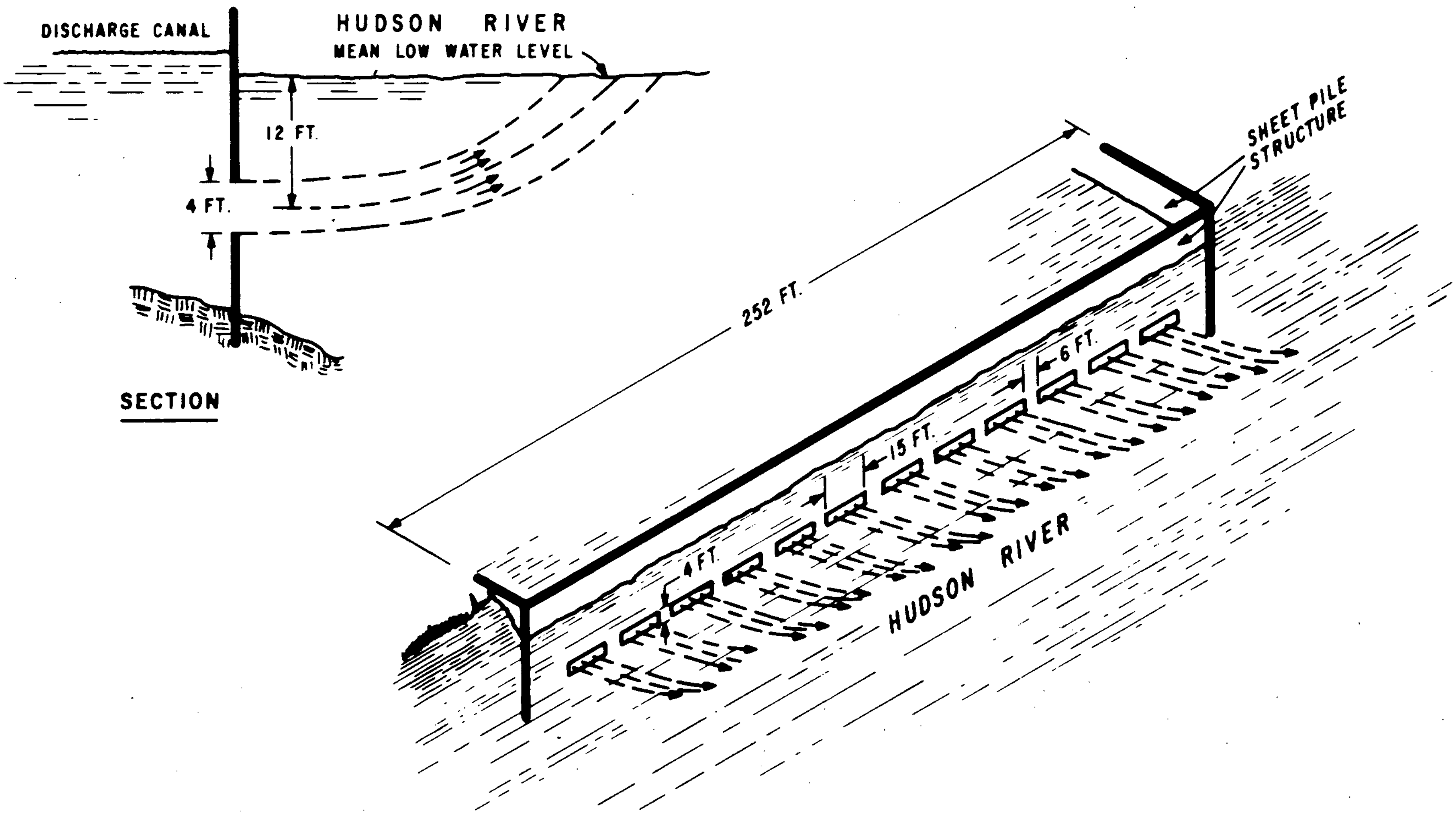


Figure 10-2. Diagrammatic Sketch of Indian Point Discharge Structure.
Source: Con Edison 1974

Table 10-1. Historical Operation of the Indian Point Station
Monthly Average Unit Total Discharge
in Thousands of GPM

UNIT NO. 1

Design: 2 Condenser, 2 Circulating pumps at 140,000 gpm each. 2 Service pumps at 16,000 gpm each and 4 Service pumps at 1500 gpm each

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973	46.6	38.0	38.0	38.0	152.2	88.0	64.5	54.7	51.8	82.4	86.7	92.0
1974	120.8	165.1	167.1	178.2	223.9	290.1	265.2	297.3	300.1	290.5	137.5	184.9
1975	135.8	135.5	135.8	126.1	78.5	93.0	70.2	53.2	4.5	19.6	20.5	61.7
1976	114.5	24.3	0	0	0	0	0	108.3	56.9	0	26.4	0
1977	0	0	0	0	0	248.0	169.0	127.4	189.4	90.5	103.1	85.7

UNIT NO. 2

Design: 3 Condensers, 6 Circulating pumps at 140,000 gpm each, 6 Service pumps at 5000 gpm each

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973	13.8	69.0	327.1	189.1	130.1	305.1	727.6	501.4	338.1	373.1	121.2	74.3
1974	105.6	93.7	186.4	349.2	573.8	755.2	698.9	729.3	733.7	549.4	400.3	270.5
1975	298.3	337.9	180.5	514.0	703.6	848.8	780.0	575.7	743.5	466.5	645.0	649.2
1976	472.6	475.0	484.8	26.4	0	79.1	0	0	197.4	633.8	107.8	303.6
1977	348.1	370.2	425.1	244.2	521.2	815.3	77.2	632.1	861.8	729.9	583.4	525.0

UNIT NO. 3

Design: 3 Condensers, 6 Circulating pumps at 140,000 gpm each, 6 Service pumps at 5000 gpm each

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1976	-	193.8	150.8	328.4	508.7	573.1	633.4	669.1	490.0	620.8	599.8	438.6
1977	431.8	418.4	487.3	614.5	825.9	829.8	827.5	864.2	862.4	317.6	0	395.0

Source: Monthly submittals to NYSDEC pursuant to requirements established in FWPCA Section 401.

Table 10-2. Historical Operation of Indian Point Station Number of Days in Month for which the stated Number of Pumps Operated at Unit No. 2

Year	No. of Pumps	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	% of Year
1974	0	31	28	12	–	–	–	–	–	–	–	–	–	71	19.5
	1	–	–	1	3	2	–	3	–	–	5	–	–	14	3.8
	2	–	–	7	1	4	–	1	1	2	5	–	–	21	5.8
	3	–	–	–	5	–	–	–	–	–	–	1	26	32	8.8
	4	–	–	3	8	5	2	–	4	–	–	7	5	34	9.3
	5	–	–	7	9	13	4	3	–	14	21	22	–	93	25.5
	6	–	–	1	4	7	24	24	26	14	–	–	–	100	27.4
1975	0	–	–	–	–	–	–	2	9	–	–	–	–	11	3.0
	1	1	1	5	–	–	–	–	–	1	6	1	–	15	4.1
	2	–	–	21	2	–	–	–	–	–	5	–	–	28	7.7
	3	10	–	1	1	–	–	–	–	–	3	1	–	16	4.4
	4	20	27	4	16	1	–	–	–	–	–	1	–	69	18.9
	5	–	–	–	11	30	–	–	–	12	17	27	11	108	29.6
	6	–	–	–	–	–	30	29	22	17	–	–	20	118	32.3
1976	0	–	–	–	26	31	16	31	31	14	–	17	7	173	47.4
	1	–	–	–	4	–	14	–	–	4	–	2	1	25	6.8
	2	–	–	–	–	–	–	–	–	–	–	10	–	10	2.7
	3	–	3	–	–	–	–	–	–	5	1	–	1	10	2.7
	4	1	–	–	–	–	–	–	–	3	7	–	7	18	4.9
	5	5	–	2	–	–	–	–	–	3	12	1	9	31	8.5
	6	25	26	29	–	–	–	–	–	1	11	–	6	98	2.7
1977	0	–	1	–	16	13	–	28	3	–	–	–	–	61	16.7
	1	1	1	–	–	–	–	–	4	–	–	–	–	6	1.6
	2	–	–	3	2	–	–	–	1	–	–	–	–	6	1.6
	3	1	–	–	1	–	–	1	–	–	1	–	–	4	1.1
	4	21	4	–	–	–	1	–	–	–	1	–	–	27	7.4
	5	8	22	28	7	–	–	–	1	–	2	4	1	73	20.0
	6	–	–	–	4	18	29	2	22	30	27	26	30	188	51.5

Source: Monthly submittals to NYSDEC pursuant to requirements established in FWPCA Section 401

Table 10-3.

Historical Operation of Indian Point Station
Number of Days in Month for which the stated
Number of Pumps operated at Unit No. 3

	No. of Pumps	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	% of Year
1976	0	31	5	-	-	-	-	-	-	-	-	-	-	36	9.9
	1	-	12	25	5	3	-	-	-	-	-	-	-	45	12.3
	2	-	4	6	7	-	-	3	-	15	2	-	-	37	10.1
	3	-	8	-	18	3	4	1	-	-	-	-	2	36	9.9
	4	-	-	-	-	24	17	-	25	1	1	1	-	69	18.9
	5	-	-	-	-	-	9	27	6	14	28	20	29	133	36.4
	6	-	-	-	-	-	-	-	-	-	9	-	9		2.5
1977	0	-	-	-	-	-	-	-	-	-	19	30	13	62	17.0
	1	-	-	-	3	-	-	-	-	-	2	-	-	5	1.4
	2	-	-	-	1	-	-	-	-	-	1	-	1	3	0.8
	3	-	-	-	1	-	-	-	-	-	2	-	-	3	0.8
	4	-	2	-	-	-	1	-	-	-	-	-	-	3	0.8
	5	31	26	9	-	-	-	-	-	-	-	-	1	67	18.4
	6	-	-	22	25	31	29	31	31	30	7	-	16	222	60.8

Source: Monthly submittals to NYSDEC pursuant to requirements established in FWPCA Section 401.

Time-temperature profiles traveling from condenser inlet to river outfall and out to the 4°F temperature rise isotherm are presented in Figures 1-14 through 1-16, Appendix D, for Units Nos. 2 and 3 operating at full flow for flood, ebb and slack tides, respectively. At full capacity the total transit times to the 4°F temperature rise isotherm are 147, 105 and 172 minutes for Unit No. 2 at flood, ebb and slack tides, respectively. Slightly shorter times are found for Unit No. 3.

10.1.2.2 Condenser Temperature Rise

The condenser temperature rise is dependent upon the rate of condenser cooling water flow, the amount of waste heat rejection to the condenser, and the ambient river temperature. Predicted condenser temperature rises based on condenser performance calculations for various operating conditions and river temperatures are presented in Tables 1-2 and 1-3, Appendix D for Units Nos. 2 and 3, respectively.

At Unit No. 2, with six pumps operating at full flow and the unit at 100% capacity, the predicted condenser temperature rise ranges from 15.8 to 16.1°F, depending upon river temperature. During 100% capacity winter operation, with the unit operating at 60% flow capacity (i.e. 40% recirculation), the predicted condenser temperature rise is approximately 26.5°F. At Unit No. 3, the condenser temperature rise ranges from 17.1 to 17.4°F for 100% capacity with six pumps operating at full flow. During the winter conditions, the rise is approximately 29°F.

10.1.2.3 System Temperature Rise

The temperature rise across the circulating water system (CWS) (from the intakes through the discharge canal) can be computed by combining the individual condenser temperature rises and flow rates for Units Nos. 2 and 3. When service water and Unit No. 1 dilution water are not included, these computed temperature rises represent theoretical maxima. For the non-winter condition with both units operating at full flow and 100% capacity, these temperature rises range from 16.5 to 16.7°F depending upon ambient river temperature. During the winter with both Units operating at 60% flow and 100% capacity the CWS temperature rise is approximately 27.5°F.

Normal flow operation of the Indian Point Station is with six circulating water pumps at each of Units Nos. 2 and 3, operating at either full or reduced flow. Reduction to 60% of flow is specified by the ETSR when the intake water temperature is less than 40°F to mitigate impingement. Flow may also be reduced when the intake water temperature is greater than 40°F provided the NYS thermal criteria are not contravened. In addition, at least three service water pumps usually operate at each unit.

Circulators may be taken out of operation under the following circumstances: 1) for scheduled or unscheduled outages, 2) as a corrective action to mitigate impingement, 3) for normal maintenance or repairs and 4) in the event a travelling or fixed screen is damaged.

With less than six circulators in operation, predicted condenser temperature rises would be higher (see Tables 1-2 and 1-3, Appendix D) resulting in a higher CWS temperature rise. Temperature rises under this condition are limited by the NRC ETSR's.

Daily intake and discharge temperatures together with daily average temperature rises across the CWS recorded during the period October 1973 (monitoring initiated) through December 1977 are presented in Attachment 1 of Appendix D. Ranges of daily average intake and discharge temperatures and daily average temperature rises are presented in Tables 10-4, 10-5 and 10-6, respectively, for the same period. The maximum instantaneous discharge temperature and the maximum daily average discharge temperature recorded during this period were 97.8 and 96.0°F, respectively on August 6, 1976. The ETSR's limit the maximum discharge canal water temperature to 98°F during June through September when all pumps are operating.

10.1.3 <u>Heat Rejection Rates</u>

The amount of heat rejected to the condenser is primarily dependent upon the electrical output of the power plant. Predicted heat rejection rates based on turbine performance analysis for Indian Point Units Nos. 2 and 3 for various operating conditions and temperature rises are presented in Tables 1-4 and 1-5 of Appendix D. At Unit No. 2, with six pumps operating at full flow and the Unit at 100% capacity, the predicted maximum heat rejection rate is approximately 6.7 billion BTU's per hour. The heat rejection rate at Unit No. 3 for 100% capacity with six pumps operating is approximately 7.3 billion BTU's per hour.

Total heat rejected to the river on a daily basis is presented in Attachment 1 of Appendix D for the period October 1973 through December 1977 for the entire station. The range of daily average heat rejected in BTU's per hour is presented in Table 10-7 for the same period. The daily average heat rejection rates presented in Table 10-7 may be higher than those predicted from turbine performance analysis since heat rejected in the service water is included. The ETSR limit the heat rejected into the river with the discharged cooling water to a maximum of 16.3 x 10^9 BTU's per hour.

Table 10-4. Historical Operation of the Indian Point Station Range of Daily Average Intake Water Temperature in ^{O}F

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973										60.0-71.0	49.0-59.8	32.0-48.0
1974	31.0-32.5	31.4-32.6	32.0-39.4	38.9 51.5	52.5-61.2	61.0-70.2	71.0-76.1	75.8-79.0	68.7-77.8	56.5-68.0	43.8-56.0	35.0-40.5
1975	31.0-35.8	33.1-35.2	34.3-39.5	38.7-48.2	49.3-67.6	68.4-75.0	76.8-80.1		66.1-79.0	54.2-66.2	44.0-54.9	32.1-46.8
1976	31.0-33.1	30.0-34.7	35.9-42.2	42.0-51.0	51.5-60.7	59.3-73.0	73.2-77.7	73.9-75.9	68.3-74.5	49.5-68.1	40.7-50.6	33.2-39.7
1977	31.7-34.5	33.5-35.8	34.9-40.0	40.6-52.6	52.8-65.6	65.8-73.0	73.5-79.7	77.0-80.4	68.2-79.2	51.2-78.5	43.7-53.7	33.0-42.8

Source: Con Edison 1973-1977.

Table 10-5. Historical Operation of the Indian Point Station
Range of Daily Average Discharge Canal
Water Temperature in ^{o}F

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973										60.0-89.6	49.7-60.0	33.3-49.0
1974	33.0-50.2	33.2-53.0	43.5-60.8	50.5-66.4	55.0-74.2	68.1-85.5	76.6-90.2	80.2-92.5	77.3-87.5	64.5-77.0	53.4-72.4	50.4-66.1
1975	50.4-64.7	33.9-57.2	35.4-40.7	39.6-68.4	52.5-85.5	73.2-88.5	80.7-93.4	77.5-93.4	69.9-91.8	55.2-80.8	57.8-74.9	37.8-65.2
1976	31.0-51.6	30.0-57.0	43.4-65.6	43.0-55.7	51.5-77.5	61.8-90.7	74.1-92.9	78.7-96.0	70.5-89.0	63.1-86.8	58.5-69.1	48.0-76.7
1977	47.2-74.6	55.4-77.3	51.3-68.7	50.4-73.7	67.5-80.9	75.6-92.1	86.1-95.4	87.3-96.0	84.0-94.9	67.4-86.2	68.7-76.6	46.0-66.8

Source: Con Edison 1973-1977.

Table 10-6. Historical Operation of the Indian Point Station

Range of Daily Average Temperature Rise

Across Station Circulating Water System in °F

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973										0-14.0	0.2-1.6	0.1-1.8
1974	0.8-18.1	1.4-20.5	6.4-26.7	5.8-23.5	0.6-13.9	5.6-15.8	0.9-15.0	5.2-14.2	4.0-14.5	2.1-15.0	0.0-24.3	14.8-27.3
1975	17.7-27.4	0.9-23.0	0.6-1.2	0.6-21.1	1.2-22.8	4.1-16.0	0.3-14.7	0.0-14.7	2.9-15.6	0.0-16.3	0.0-24.0	1.6-20.3
1976	0.0-20.5	0.0-23.4	1.2-23.1	0.2-5.2	0.0-15.6	0.2-21.6	0.2-17.4	3.0-17.4	0.0-14.8	6.5-27.1	9.4-28.0	12.7-39.5
1977	14.2-41.7	20.5-42.9	15.7-33.1	1.5-30.5	9.7-19.3	9.9-20.2	4.4-20.1	9.4-16.3	12.6-16.8	11.2-31.5	17.5-26.0	10.6-24.5

Source: Con Edison 1973-1977.

Table 10-7. Historical Operation of the Indian Point Station Range of Daily Average Station Heat Rejection to River In Billions of BTU's per Hour

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1973										0.00-3.74	0.00-0.23	0.01-0.12
1974	0.06-5.45	0.02-2.34	1.17-5.39	1.09-6.57	0.01-7.89	2.03-8.18	0.25-8.53	1.58-8.11	1.86-7.67	0.00-7.67	0.12-6.13	3.63-8.62
1975	4.14-5.46	0.09-5.71	0.06-0.27	0.10-9.23	0.18-8.53	1.96-7.64	0.05-7.48	0.00-7.44	0.87-6.68	0.00-6.48	0.00-8.94	2.90-7.35
1976	0.00-7.46	0.00-6.82	0.25 8.02	0.04-1.22	0.00-5.03	0.06-8.12	0.03-6.60	0.62-6.54	0.00-6.48	2.48-15.7	2.88-8.29	4.54 15.4
1977	5.75-16.9	8.86-15.0	5.49-14.5	2.94---	6.74-14.5	9.9-16.0	1.16-13.9	6.75-14.2	12.4-16.2	5.76-15.3	7.15-8.50	5.65-14.3

Source: Con Edison 1973-1977.

10.1.4 Recirculation

The degree of recirculation of the discharge water to the intakes at the Indian Point station has been examined using physical hydraulic model dye studies (LaSalle 1976), actual dye studies conducted during the October 1974 intensive thermal survey (Dames & Moore and Con Edison 1976) and through an analysis of October 1976 intake and discharge temperatures measured with Units Nos. 2 and 3 operating at nearly full capacity (Con Edison 1977d).

Calculations of recirculation using physical hydraulic model dye studies indicated that approximately 7.7% of the effluent water would make its way back into the cooling water intakes over a complete tidal cycle with all three units operating at full flow.

Results of actual dye studies conducted during October 1974 showed recirculation ranging from 0% during ebb and LWS to 5 and 6% during flood and HWS, respectively. During these studies, Units Nos. 1 and 2 were operating at an average electrical generation of 275 Mw(e) and 875 Mw(e), respectively.

The extent of recirculation with the combined operation of Units Nos. 2 and 3 was estimated from October 1976 survey data. The average percent recirculation at Units Nos. 2 and 3 was as follows:

Tidal Phase	Unit No. 2	Unit No. 3
Ebb	4.4	7.0
LWS	6.0	2.3
Flood	12.6	9.2
HWS	9.4	12.1

As expected, reciruclation is greater during flood and HWS.

The USNRC ETSR indicates that during normal operation of the Indian Point station, the temperature differential across the station circulating water system should not exceed 16.5°F, and that this temperature includes the effects of recirculation.

10.2 Thermal Survey Program

Since operation of Indian Point Unit No. 2 began in 1973, a total of 15 routine and intensive thermal surveys have been conducted by Con Edison. A routine thermal survey generally consists of measurements of the intensity and extent of the Indian Point plume over five successive tidal phases (i.e. maximum ebb, low water slack, maximum flood, high water slack and maximum ebb). An intensive thermal survey consists of similar measurements conducted over four or five successive tidal cycles for three or four days. These 15 surveys constituted a comprehensive field monitoring program which was formulated to ascertain the characteristics of the Indian Point thermal plume.

In 1973, a preliminary survey of the Indian Point thermal plume was conducted to formulate a design basis for subsequent surveys. Surveys began in 1974 and were conducted during the months of May, June, July, August, September, October and November. During 1974 and 1975, surveys were conducted with Indian Point Units Nos. 1 and 2 operating alone or in combination. Intensive thermal surveys were conducted in August and October, 1974 and in May 1975. In 1976, the October survey was the first to be conducted with both Units Nos. 2 and 3 in operation. In 1977, surveys were performed in May, June, August and September.

10.2.1 Plant Operating Conditions

Details of the 1974, 1975 and 1976 surveys have been reported to NYSDEC and USNRC. The 1977 surveys, with the exception of the May 1977 survey, are presently being analyzed and are not presently available.

Actual average operating conditions during each survey period including the station capacity during the plume mappings, maximum available capacity at the time of each survey, cooling water and service water flow rates and the amount of heat released to the river are summarized in Table 10-8.

During the surveys from May 1974 through May 1977 the average capacity of the station ranged from 703 to 1900 MWe (gross) while average discharge rates ranged from 861,000 to 1,860,000 gpm. Average heat rejected to the river ranged from 4.88 to 16.3 billions of BTU's per hour.

During 1974, both Unit Nos. 1 and 2 were in operation through October 31. The maximum station capacity available was 1191 MWe gross. Surveys were conducted with average station capacities ranging from 65 to 95% of maximum. After October 31, 1974 and through 1975, only Unit No. 2 operated, and surveys conducted in November, April and May 1975 were at 78, 100 and 99% of capacity respectively (maximum available: 906 MWe gross). The October 1976 survey was the first to be conducted with both Units Nos. 2 and 3 in operation. At this time, the station was at 87% of capacity (maximum 1906 MWe gross) while the May 1977 survey was conducted at nearly 100% capacity.

Detailed operating characteristics for each of the thermal surveys are presented in Appendix C, Volume I.

Table 10-8. Average Plant Operating Conditions During Indian Point Thermal Surveys

Survey Date	Capacity During Plume Mappings MW(e) gross	Maximum Available Capacity MW(e) gross	% of Maximum	Cooling Water + Service Water Flow (gpm)	Heat Release in BTU's/Hr. X 10^9
(5/31/74)	1,085	1191	91.1	1,160,000	6.85
(6/13/74)	975	1191	81.9	1,020,000	8.00
(7/17/74)	777	1191	65.2	1,020,000	6.46
(8/20-24/74)	1,012	1191	84.5	1,162,000	6.97
(9/24/74)	1,135	1191	95.2	1,022,000	6.78
(10/22-25/74)	1,160	1191	97.4	1,022,000	7.46
(11/20/74)	703	906	77.6	430,500	4.88
(4/23/75	905	906	99.9	861,000	9.23
(5/13-15/75)	900	906	99.3	861,000	6.46
(10/14-15/76)	1,660	1906	87.1	1,295,000	14.76
(5/25/77)	1,900	1906	99.7	1,859,900	16.3

NOTE: Data for the June 1977, August 1977 and September 1977 surveys not yet available.

Source: Dames & Moore and Con Edison 1974-1976; Con Edison 1977d; Con Edison 1978.

10.2.2 Thermal Plume Characteristics

The thermal plume patterns arising from the discharge of a heated effluent into a tidal estuary such as the Hudson River are influenced by such factors as the interaction of the ocean tides, the upstream influx of salt water, local circulation phenomena caused by salinity gradients, variations in estuarine morphology, local meteorology, and the configuration of the outfall structure. The shape of the Indian Point plume assumed one of four typical patterns which are related to the major phases of the tidal cycle; flood, high water slack (HWS), ebb and low water slack (LWS). Figure 10-3 depicts these patterns to which the plumes observed at the Indian Point Station during the 1974 through 1977 surveys have essentially conformed.

During flood tide, the major portion of the plume is directed upstream while during ebb tide it is directed downstream. The two slack periods are characterized by patterns tending to be concentric about the discharge structure, with the HWS plume having an upstream tail and the LWS plume having a downstream tail.

10.2.3 Plume Configuration

During the survey period from May 1974 through May 1977 the 2°F excess temperature isotherm was never observed to extend further south than Stony Point Bay (approximately 3.4 miles south of the Indian Point Station), nor further north than the Fish Island - Roa Hook area (approximately 2.4 miles north of the station, Figure 10-4). The volume of water contained within this segment, of which only the upper most strata are directly affected by the discharge plume, is approximately 112,500 acre-feet (with a surface area of approximately 3400 acres). This volume is referred to as the "near-field region". Average depth within the region ranges from approximately 28 feet near Stony Point Bay to 57 feet near Fish Island (Figure 10-5).

Surface areas of the 3, 4 and 6°F excess temperature isotherms at various depths for three seasonally representative surveys (Section 10.4.2) are presented in Table 10-9.

The configuration of the Indian Point plume with corresponding tidal patterns is indicated in Volume II, Appendix C and may be generally described as follows:

1) Flood Tide

   During flood tide the plume is directed upstream of the discharge remaining in the eastern portion (discharge side) of the river for several hundred feet and is

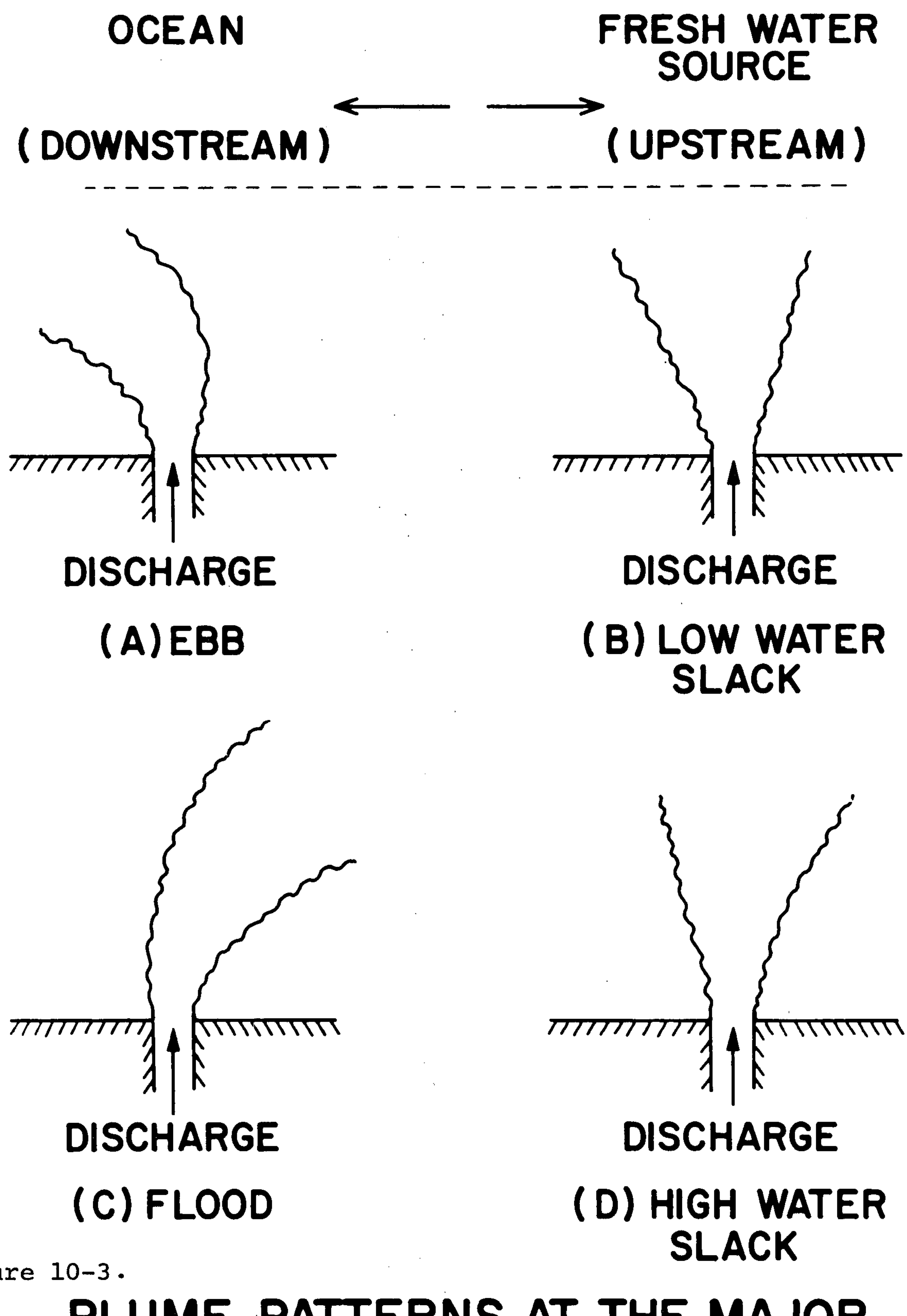


Figure 10-3.

PLUME PATTERNS AT THE MAJOR PHASES OF THE TIDAL CYCLE

Source: Dames & Moore and Con Edison 1976.

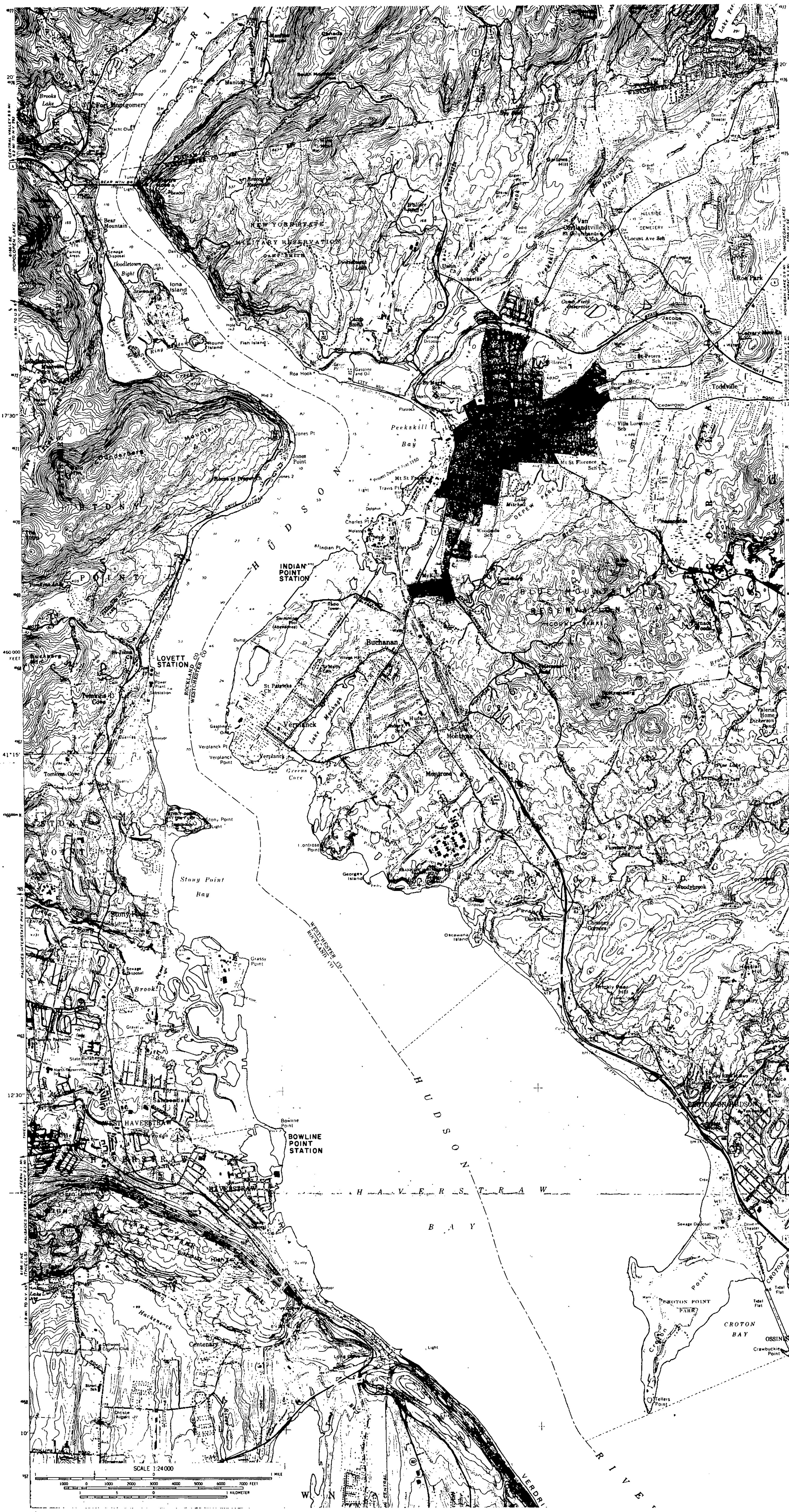


Figure 10-4. HUDSON RIVER VALLEY IN VICINITY OF INDIAN POINT STATION

Source: PEEKSKILL AND HAVERSTRAW QUADRANGLE, U.S.GEOLOGICAL SURVEY

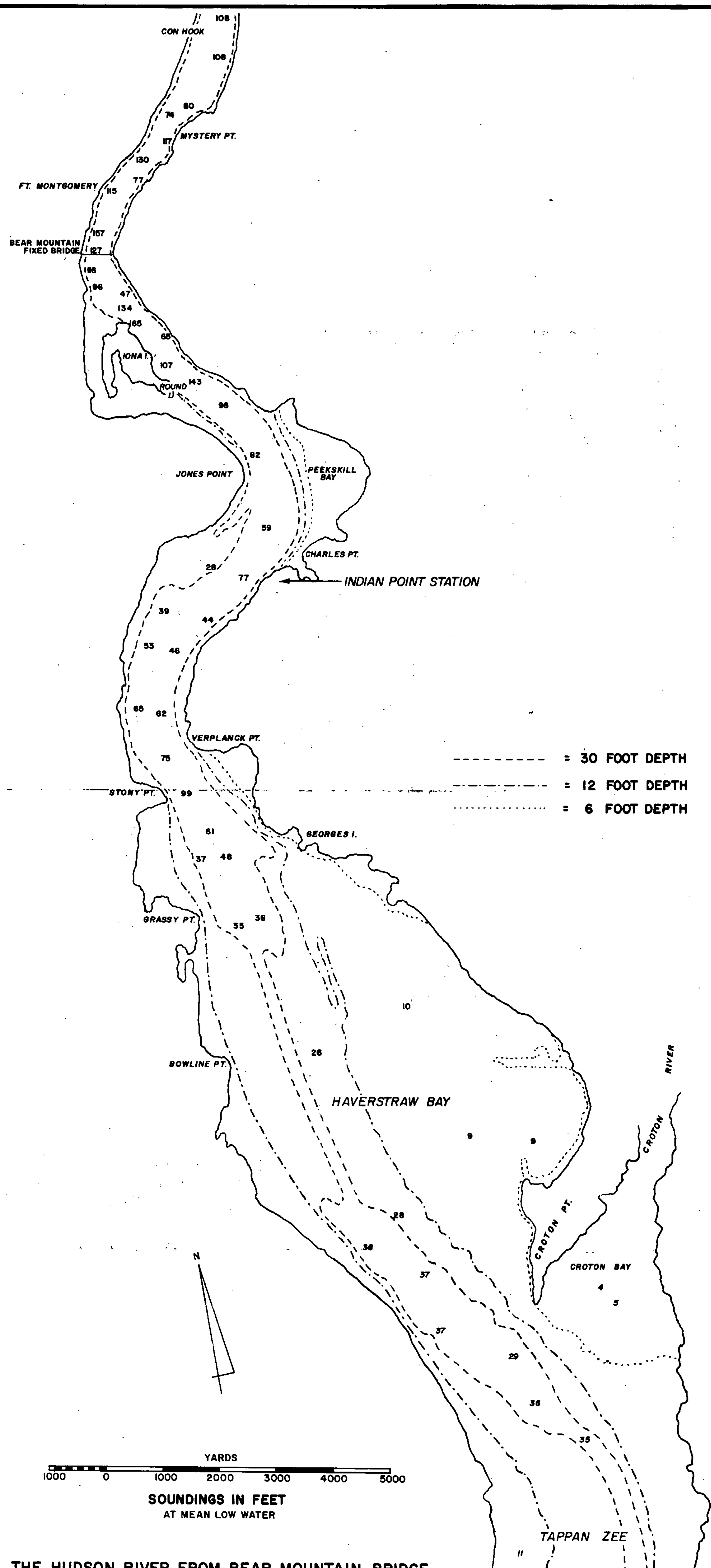


Figure 10.5. THE HUDSON RIVER FROM BEAR MOUNTAIN BRIDGE TO CROTON POINT
SOURCE: USC & GS CHART Nº 282

Table 10-9. Areas Contained Within Excess Temperature Rise Isotherms at Various Depths (in Acres)

	Ebb			LWS			Flood			HWS		
Isotherm	3°	4°	6°	3°	4°	6°	3°	4°	6°	3°	4°	6°
Depth in Feet	Autumn Condition October 1976 Data											
0	230	162	77	148	102	39	147	61	17	-	-	-
3	174	101	16	130	83	23	113	40	11	-	-	-
6	42	26	9	82	45	13	74	24	10	-	-	-
10	27	11	3	44	14	9	61	16	6	-	-	-
13	-	-	-	9	7	2	31	3	4	-	-	-
19	-	-	-	2	1	.6	20	-	2	-	-	-
	Spring Condition May 1977 Data											
0	237	146	51	47	31	10	149	56	4	41	32	6
3	51	46	20	34	24	-	37	38	-	28	24	4
6	34	27	13	24	19	7	23	19	3	21	15	2
10	17	15	7	18	12	2	18	13	-	9	6	1
16	11	7	4	9	4	-	7	5	1	4	3	.6
22	3	3	2	2	1	1	4	3	-	2	1.6	-
	Summer Condition August 1974 Data											
0	297	111	23	358	113	22	466	163	25	226	131	39
3	184	61	17	68	48	6	321	96	13	190	100	27
6	58	19	12	22	12	3	150	14	10	124	56	13
10	30	-	7	-	-	-	20	5	6	64	24	9
15.5	14	5	3	-	-	-	13	-	4	42	17	4
21	9	-	-	-	-	-	8	-	2	10	4	3

dispersed laterally to the north as the river widens before reaching Peekskill Bay.

During the surveys conducted from May 1974 through May 1977, ambient river temperatures at Indian Point during flood tides ranged from 44.5 to 78.8°F. Gross station output ranged from 703 to 1,900 MWe of generating capacity. Analyses of excess temperature isotherms equal to or less than 4°F above ambient indicated that the maximum lateral extents (widths) of these isotherms ranged from 380 to 1,550 feet. (Field temperatures were generally plotted in 0.5°F increments, so that it was often convenient to analyze an excess temperature isotherm less than the 4°F specified by the New York State thermal criteria. For example, if the ambient temperature were 58.9°F, the 3.6°F excess temperature isotherm was examined; if it were 71.1°F, the 3.4°F isotherm was analyzed. These widths and cross-sectional areas would be greater than those contained within the 4°F excess temperature isotherm). The maximum widths were most frequently observed at transects located north of the discharge canal and up to approximately 3,600 feet north of the discharge. The above values given as percents of the total river width in the Indian Point region ranged from 7.6 to 33%. Similarly, cross-sectional areas contained within the ≤ 4°F excess temperature isotherms analysed during the same survey period ranged from 3,200 to 24,000 square feet or from 2.0 to 15.0% of the total river cross sectional area (Table 10-10).

2) High Water Slack

During high water slack, the plume tends to proceed straight out into the river perpendicular to the east shore. The tail of the plume, depending upon local hydrological and meteorological conditions, may be directed either slightly upstream or downstream.

Ambient river temperatures at Indian Point during high water slack tides ranged from 44.8 to 79.0°F. Maximum lateral extents (widths) of the ≤ 4°F excess temperature isotherms ranged from 390 to 2260 feet, or from 7.8 to 49.2% of the total river width. These maximum widths were most frequently observed in the immediate vicinity of the discharge canal. Cross-sectional areas contained within the ≤ 4°F isotherms analysed ranged from 6,000 to 45,000 square feet or from 3.8 to 28.0% of the total river cross-sectional areas. Most of these maximum cross-sections occurred near the discharge canal (Table 10-11).

Table 10-10. Exesss Temperature Analysis in the Indian Point Area during Flood Tide

Survey Date	Ambient Temperature (°F)	Temp. Rise Isotherm Analysed (°F)	Max. Lateral Extent of Isotherm (ft.)	% of Total Lateral Extent	Max. Cross-Sectional Area Contained Within Isotherm (ft^2)	% of Total Cross-Sectional Area
31 May 1974	62.5	3.4	750	15.0	3,200	2.0
13 Jun. 1974	69.1	3.4	1050	21.0	22,400	14.0
17 Jul. 1974	76.8	3.2	1000	20	24,000	15.0
20 Aug. 1974	78.4	3.6	850	17.0		
21 Aug. 1974	78.8	3.7	630	14	15,360	9.6
23 Aug. 1974	78.7	3.8	950	19	19,360	12.1
24 Aug. 1974	78.7	3.8	800	16		
24 Sep. 1974	71.0	3.0	920	18	24,000	15.0
22 Oct. 1974	59.0	3.5	735	16		
23 Oct. 1974	57.6	3.4	965	21	16,160	10.1
24 Oct. 1974	57.8	3.7	1500	30		
25 Oct. 1974	56.9	3.6	1550	33	19,040	11.9
20 Nov. 1974	49.6	3.4	820	16	16,000	10.0
23 Apr. 1975	44.5	3.5	500	10	11,200	7.0
13 May 1975	54.5	3.5	550	11	8,320	5.2
14 May 1975	54.5	3.1	380	7.6	7,520	4.7
15 May 1975	55.9	3.1	670	13.4	6,240	3.9
14 Oct. 1976	60.7	4.0	780	15.3	14,080	8.8
25 May 1977	64.2	4.0	690	13.8	18,400	11.5

Source: Dames & Moore and Con Edison 1974-1976: Con Edison 1977d; Con Edison 1978.

Table 10-11. Excess Temperature Analysis in the Indian Point Area during High Water Slack

Survey Date	Ambient Temperature (°F)	Temp. Rise Isotherm Analysed (°F)	Max. Lateral Extent of Isotherm (ft.)	% of Total Lateral Extent	Max. Cross-Sectional Area Contained Within Isotherm (ft^2)	% of Total Cross-Sectional Area
31 May 1974	62.5	3.4	1000	20.0	8,000	5.0
13 Jun. 1974	68.4	3.4	1000	20.0	14,400	9.0
17 Jul. 1974	76.8	3.2	1300	26	20,800	13
20 Aug. 1974	79.0	3.5	1650	33		
21 Aug. 1974	79.4	3.6	1550	31	22,880	14.3
23 Aug. 1974	78.7	3.8	1650	33	22,560	14.1
24 Aug. 1974	78.7	3.8	1500	30		
24 Sep. 1974	71.0	3.0	1500	30	45,000	28.0
22 Oct. 1974	59.3	3.2	1150	23		
23 Oct. 1974	57.9	3.1	1000	20	29,280	18.3
24 Oct. 1974	58.0	3.5	1100	22		
25 Oct. 1974	57.4	3.6	1650	33	27,680	17.3
20 Nov. 1974	49.6	3.4	1700	34	16,000	10.0
23 Apr. 1975	44.8	3.2	1100	21	8,500	5.0
13 May 1975	54.5	3.5	470	9.4	6,000	3.8
14 May 1975	55.0	4.0	390	7.8	7,800	4.9
15 May 1975	55.9	3.1	1630	32.6	20,480	12.8
15 Oct. 1976	60.8	3.9	2260	49.2	13,000	9.0
25 May 1977	65.2	3.9/3.8	1500	30.6	12,000	7.5

Source: Dames & Moore and Con Edison 1974-1976; Con Edison 1977d; Con Edison 1978.

3) Ebb Tide

During ebb tide the plume is directed downstream of the discharge remaining in the eastern portions of the river for several hundred feet downstream and is dispersed laterally to the south as the river narrows near Verplanck Point.

Ambient river temperatures in the Indian Point area during ebb tides ranged from 44.2 to 79.0°F. Maximum lateral extents (widths) the ≤ 4°F isotherms ranged from 330 to 1860 feet, or from 6.7 to 40% of the total river width. These maximum widths were most frequently observed south of the discharge canal ranging from a few hundred feet to approximately 2,400 feet downstream. Cross-sectional areas contained within the ≤ 4°F isotherms ranged from 2,240 to 12,000 square feet or from 1.4 to 8.0% of the total river cross-sectional areas. These maximum cross-sectional areas were frequently observed a few hundred feet south of the discharge (Table 10-12).

4) Low Water Slack

During low water slack the plume is directed outward from the discharge spreading across the discharge transect and possessing a minor downstream tail. Ambient river temperatures in the Indian Point area during low water slack tides ranged from 44.0 to 79.3°F. Maximum lateral extents (widths) of the ≤ 4°F isotherms ranged from 440 to 2,650 feet, or from 8.9 to 53% of the total river width.

Cross-sectional areas contained within the ≤ 4°F isotherms ranged from 6,400 to 32,000 square feet or from 4 to 20% of the total river cross-sectional areas. These maximum cross-sectional areas occurred frequently at the discharge canal transect and downstream to about 1,000 feet south of the discharge (Table 10-13).

10.3 State Thermal Criteria Compliance

Comparisons of results obtained during the thermal surveys with the New York State thermal criteria for surface width and cross-sectional area showed that the the Indian Point thermal plume lies within these criteria. The maximum lateral extent of the ≤ 4°F excess temperature isotherms as a percentages of the total river width, and the maximum cross-sectional areas contained within these isotherms as percentages of the total cross-section

Table 10-12. Excess Temperature Analysis in the Indian Point Area during Ebb Tide

Survey Date	Ambient Temperature (°F)	Temp. Rise Isotherm Analysed (°F)	Max. Lateral Extent of Isotherm (ft.)	% of Total Lateral Extent	Max. Cross-Sectional Area Contained Within Isotherm (ft^2)	% of Total Cross-Sectional Area
31 May 1974	61.8	3.0/3.2	1250	25.0	9,600	6.0
13 Jun. 1974	67.9	3.8/3.6	1850	37.0	11,200	7.0
17 Jul. 1974	77.2	3.8	1300	40	12,000	8.0
20 Aug. 1974	78.7	3.8	800	20		
21 Aug. 1974	79.1	3.4	800	21	7,360	4.6
23 Aug. 1974	79.0	3.5	950	19	10,880	6.8
24 Aug. 1974	78.9	3.6	600	12		
24 Sep. 1974	71.0	4.0	950	21	8,000	5.0
22 Oct. 1974	58.9	3.6	1100	29		
23 Oct. 1974	57.8	3.9	1250	25	10,400	6.5
24 Oct. 1974	57.9	3.6	1860	49		
25 Oct. 1974	57.2	3.8	700	14	9,600	6.0
20 Nov. 1974	49.6	3.4	730	22	8,000	5.0
23 Apr. 1975	44.2	3.8	450	9	2,600	2.0
13 May 1975	54.9	3.1	500	10	4,600	2.9
14 May 1975	55.0	4.0	330	6.7	2,240	1.4
15 May 1975	55.8	3.2	340	6.8	4,640	2.9
14 Oct. 1976	61.5	4.0	900	24	7,000	5.4
15 Oct. 1976	61.1	3.9	900	18.2	8,700	5.4
25 May 1977	62.9	4.0/3.1	1260	25.2	9,280	5.8

Source: Dames & Moore and Con Edison 1974-1976; Con Edison 1977d; Con Edison 1978.

Table 10-13. Excess Temperature Analysis in the Indian Point Area during Low Water Slack

Survey Date	Ambient Temperature (°F)	Temp. Rise Isotherm Analysed (°F)	Max. Lateral Extent of Isotherm (ft.)	% of Total Lateral Extent	Max. Cross-Sectional Area Contained Within Isotherm (ft^2)	% of Total Cross-Sectional Area
31 May 1974	61.8	3.1/3.3	2300	46.0	30,400	19.0
13 Jun. 1974	68.1	3.9	2400	48.0	25,600	16.0
17 Jul. 1974	77.2	2.8	1500	30	20,000	13
20 Aug. 1974	77.9	3.6	1100	22		
21 Aug. 1974	78.2	3.8	800	16	12,480	7.8
23 Aug. 1974	78.9	3.6	1300	26	15,840	9.9
24 Aug. 1974	79.3	3.7	1600	32		
24 Sep. 1974	71.0	4.0	1750	35	32,000	20.0
22 Oct. 1974	58.9	3.6	1850	37		
23 Oct. 1974	57.6	3.9	2650	53	29,440	18.4
24 Oct. 1974	57.8	3.7	1850	37		
25 Oct. 1974	69.9	3.6	855	19	6,880	4.3
20 Nov. 1974	49.6	3.4	2600	52	32,000	20.0
23 Apr. 1975	44.0	4.0	850	17	6,400	4.0
13 May 1975	54.4	3.6	460	9.2	10,080	6.3
14 May 1975	55.1	3.9	440	8.9	6,720	4.2
15 May 1975	55.9	3.1	800	16.0	7,680	4.8
14 Oct. 1976	61.5	4.0	2550	49.4	16,300	10.2
15 Oct. 1976	60.7	4.0	1400	30.0	9,600	6.0
25 May 1977	62.4	4.0/3.6	1235	24.7	22,240	13.9

Source: Dames & Moore and Con Edison 1974-1976; Con Edison 1977d; Con Edison 1978.

area are given below. The thermal criteria for the 4°F excess temperature isotherm are shown for comparison:

Tidal Phase	% Lateral Extent	NYS Thermal Criterion % Lateral Extent	% X-Sec. Area	NYS Thermal Criterion % X-Sec. Area
Flood	7.6 - 33	67	2.0 - 15.0	50
HWS	7.8 - 49.2	67	3.8 - 28.0	50
Ebb	6.7 - 40.0	67	1.4 - 8.0	50
LWS	8.9 - 53.0	67	4.0 - 20.0	50

In addition, with the exception noted below, the 90°F surface criterion was not contravened. During the four day August 1974 intensive survey, surface temperatures in excess of 90°F were recorded on four different occasions in the immediate area of the outfall structure. The surface temperature recorded ranged from 90.2 to 91.6°F, with an average of 90.6°F. The areas in excess of the 90°F isotherm were less than 3/4 of an acre, with an average area of about 1/3 of an acre.

10.4 Plume Variation with Operating Conditions

10.4.1 Scale-up Procedure

The methodology used in predicting thermal plume patterns for both Indian Point Unit Nos. 2 and 3 operating at full capacity is based on field survey data and a mathematical scaling relation. The scaling relation, developed by Battelle-Columbus Laboratories for the Indian Point plant (Con Edison 1972; Bloom 1972), states that volumes of water contained within a specified excess temperature isotherm under conditions of different condenser temperature rise and cooling water flow are approximately related by a proportionality factor which is the product of the square of the excess temperature ratio and the 3/2 power of the cooling water flow ratio. That is,

$$V_A = ((T_2-T_1)_A/(T_2-T_1)_B)^2 (Q_A/Q_B)^{1.5} V_B$$

Where:

V_A = volume bounded by isotherm ΔT for Case A (ft ^{3})
V_B = volume bounded by isotherm ΔT for Case B (ft ^{3})
(T_2-T_1) = cooling water excess temperature for Case A (°F)
(T_2-T_1) = cooling water excess temperature for Case B (°F)
Q_A = cooling water flow rate for Case A (gpm)
Q_B = cooling water flow rate for Case B (gpm)

This equation was used to estimate the volumes of water contained within the 3, 4 and 6°F excess temperature isotherms under maximum plant operating conditions during various seasons. Estimates of the dimensions of plumes representing the maximum operating cases were then developed.

10.4.2 Thermal Plume Magnitudes

From the field data available, the May 1977, August 1974 and October 1976 surveys were selected as representative of spring, summer and autumn conditions, respectively. The primary consideration in establishing which surveys were selected for the scale-up procedure was the magnitude of the thermal plume during each survey period. The magnitude of the plume depends upon plant operating capacity (Table 10-8) and the hydrological and meteorological conditions in the area. Examination of survey data indicated that the largest plumes in each season as measured for both volume and area, were recorded during the May 1977, August 1974 and October 1974 surveys.

Volumes of water in cubic feet contained within the 3, 4 and 6°F excess temperature isotherms under actual and full capacity operating conditions for spring, summer and autumn were computed and are provided in Table 10-14. These volumes are also listed as percentages of the total water volume in the nearfield region (Table 10-15).

10.5 Interaction of Lovett and Indian Point Plumes

The potential interaction between the Lovett and Indian Point thermal plumes was examined during the October 1976 survey. During this survey Units Nos. 2 and 3 operated at nearly full capacity and the Lovett station operated at a power output of approximately 180 Mw.

The potential for plume interaction occurs primarily during the flood and ebb tidal phases. Data obtained during the October 1976 survey showed that there was no detectable temperature change (of at least 1°F) between the westernmost Indian Point isotherm and the west shore during flood tide, indicating no detectable interaction. During ebb tide, the maximum potential for interaction occurs and involves the fringes of the Indian

Table 10-14. Volumes Contained Within Excess Temperature Isotherms (in Acre-ft x 10^3)

	3°F		4°F		6°F	
	Actual	Scaled	Actual	Scaled	Actual	Scaled
Autumn						
Flood	2.75	3.17	.315	.367	.298	.344
HWS	-	-	-	-	-	-
Ebb	1.79	2.30	.643	.803	.333	.420
LWS	2.39	2.39	.597	.597	.478	.478
Summer						
Flood	2.47	4.71	.358	.684	.227	.432
HWS	2.18	4.36	.404	.836	.298	.606
Ebb	1.52	3.04	.271	.562	.200	.399
LWS	.482	1.81	.145	.539	.039	.147
Spring (No Scaling Required)						
Flood	1.28		.397		.057	
HWS	.652		.223		.085	
Ebb	1.70		.716		.544	
LWS	.934		.275		.158	

Table 10-15. Volumes Contained Within Excess Temperature Isotherms as Percentages of Near Field Volume

	3°F Actual	3°F Scaled	4°F Actual	4°F Scaled	6°F Actual	6°F Scaled
Autumn						
Flood	2.4	2.8	0.3	0.3	0.3	0.3
HWS	-	-	-	-	-	-
Ebb	1.6	2.0	0.6	0.7	0.3	0.4
LWS	2.1	2.1	0.5	0.5	0.4	0.4
Summer						
Flood	2.2	4.2	0.3	0.6	0.2	0.4
HWS	1.9	3.9	0.4	0.7	0.3	0.5
Ebb	1.3	2.7	0.2	0.5	0.2	0.4
LWS	0.4	1.6	0.1	0.5	.03	0.1
Spring						
Flood	1.1		0.4		.05	
HWS	0.6		0.2		.07	
Ebb	1.5		0.6		0.5	
LWS	0.8		0.2		0.1	

Point plume merging with the fringes of the Lovett plume south of the transmission lines. Temperatures in the upper layer remained relatively constant near the fringes with a rise of about a degree evident only near the Lovett station.

SECTION 11 - COST-BENEFIT ANALYSIS FOR CLOSED-CYCLE COOLING AT THE INDIAN POINT GENERATING STATION

Incorporated by reference into this 316(a) demonstration are Exhibits 21 and 28 in Docket II-C/WP-77-1 of the consolidated adjudicatory hearing for the major Hudson River electric generating stations, respectively entitled "Indian Point Generating Station: Engineering, Environmental (Nonbiological), and Economic Aspects of a Closed-Cycle Cooling System" and "Report on Cost-Benefit Analysis of Operation of Hudson River Steam-Electric Units with Once-Through and Closed-Cycle Cooling Systems." These exhibits show that the installation of cooling towers will entail capital costs of $111,000,000 at Indian Point Unit No. 2 and $123,000,000 at Unit No. 3. Annual levelized revenue requirements would be $37,000,000 and $36,000,000 for Units Nos. 2 and 3, respectively.

This demonstration shows that the thermal discharge from the Indian Point plants have not interfered with the protection and propagation of a balanced indigenous community of shellfish, fish, and wildlife in and on this waterbody. Consequently, the installation of cooling towers at these plants to drastically reduce the thermal discharge would entail incurring great economic costs to achieve no (or insignificant) benefit to the aquatic biota. Therefore, it can only be concluded that the costs of installing closed-cycle cooling at the Indian Point plants are wholly disproportionate to the benefits to be achieved from the reduction of the thermal discharge from this plant.