NUREG/CR-2220
Volume I
ORNL/NUREG/TM-385/V1

ornl

OAK RIDGE NATIONAL LABORATORY

UNION CARBIDE

THE IMPACT OF ENTRAINMENT AND IMPINGEMENT ON FISH POPULATIONS IN THE HUDSON RIVER ESTUARY

VOLUME I

Entrainment Impact Estimates For Six Fish Populations Inhabiting the Hudson River Estuary

J. Boreman
L. W. Barnthouse
D. S. Vaughan
C. P. Goodyear
S. W. Christensen
K. D. Kumar
B. L. Kirk
W. Van Winkle

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1790

Prepared for
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Under Interagency Agreement No. DOE 40-550-75

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISCLAIMER

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161

Available from

GPO Sales Program
Division of Technical Information and Document Control
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

NUREG/CR-2220
Volume I
ORNL/NUREG/TM-385/V1
Distribution Category-RE

Contract No. W-7405-eng-26

THE IMPACT OF ENTRAINMENT AND IMPINGEMENT ON FISH POPULATIONS IN THE HUDSON RIVER ESTUARY

VOLUME I

Entrainment Impact Estimates For Six Fish Populations Inhabiting the Hudson River Estuary

J. Boreman,[1] L. W. Barnthouse, D. S. Vaughan,
C. P. Goodyear,[2] S. W. Christensen, K. D. Kumar,
B. L. Kirk, and W. Van Winkle

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1790

[1]Northeast Fisheries Center, National Marine Fisheries Service,
Woods Hole, Massachusetts 02543.

[2]National Fish Center--Leetown, U.S. Fish and Wildlife Service,
Route 3, P.O. Box 41, Kearneysville, West Virginia 25430.

Manuscript Completed - September 1981
Date Published - January 1982

Prepared for
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C 20555
Under Interagency Agreement No. DOE 40-550-75

NRC FIN B0165

TASK: Methods to Assess Impacts on Hudson River Striped Bass

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

ACKNOWLEDGMENTS

We thank Drs. G. F. Cada and C. C. Coutant (ORNL), Paul Rago (National Power Plant Team), Marcia Mulkey (NRC), and Barry Cohen, Tom Fikslin, Henry Gluckstern, and Jonathan Strong (EPA Region V) for their careful review of the testimony published in this report.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

FOREWORD

On December 19, 1980, with the signing of an out-of-court settlement agreement, a three-year adjudicatory hearing on the effects of electric power generation on the Hudson River was ended. The purpose of this hearing had been to determine whether six cooling towers, required by the various Environmental Protection Agency (EPA) permits, should be built at three power plants on the Hudson River in New York in order to mitigate the impacts of entrainment and impingement on estuarine fish populations. In addition to terminating the EPA hearings, the settlement resolved regulatory disputes between the utility companies and several other federal agencies, including the U.S. Nuclear Regulatory Commission (NRC).

Staff of the Environmental Sciences Division at Oak Ridge National Laboratory (ORNL) were asked to participate in the EPA hearings because of previous work on entrainment and impingement performed for NRC in connection with the licensing of Indian Point Units 2 and 3, the largest generating units on the Hudson River. ORNL Staff prepared and submitted, in May 1979, numerous individual pieces of written direct testimony for EPA as part of these hearings. Some of these pieces of testimony were coauthored with individuals from the National Power Plant Team of the U. S. Fish and Wildlife Service and from EPA. The purpose of this three-volume report is to publish these individual pieces of testimony involving ORNL staff in a manner that will assure a broader distribution to the scientific community, government agencies, and other interested parties.

Volume I is concerned with the estimation of the direct (or annual) entrainment impact of the power plants on populations of striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy in the Hudson River. Entrainment impact results from the killing of fish eggs, larvae, and young juveniles that are contained in the cooling water cycled through a power plant. An "Empirical Transport Model" is presented as the means of obtaining a conditional entrainment mortality rate (which represents the fraction of a year class which would be killed due to

entrainment in the absence of density-dependent mortality). Most of Volume I is concerned with the estimation of several parameters required by the model: physical input parameters (e.g., power-plant withdrawal flow rates); the longitudinal distribution of ichthyoplankton in time and space; the duration of susceptibility of the vulnerable organisms; the "W-factors," which express the ratios of densities of organisms in power plant intakes to densities in the river; and the entrainment mortality factors, which express the probability that an organism will be killed if it is entrained. Once these values are obtained, the model is used to estimate entrainment impact for both historical conditions and projected conditions.

Volume II contains four exhibits relating to impingement impacts and three critiques of certain aspects of the utilities' case. The first exhibit is a quantitative evaluation of four sources of bias (collection efficiency, reimpingement, impingement on inoperative screens, and impingement survival) affecting estimates of the number of fish killed at Hudson River power plants. The two following exhibits contain, respectively, a detailed assessment of the impact of impingement on the Hudson River white perch population and estimates of conditional impingement mortality rates for seven Hudson River fish populations. The fourth exhibit is an evaluation of the engineering feasibility and potential biological effectiveness of several types of modified intake structures proposed as alternatives to cooling towers for reducing impingement impacts. The remainder of Volume II consists of critical evaluations of the utilities' empirical evidence for the existence of density-dependent growth in young-of-the-year striped bass and white perch, of their estimate of the age-composition of the striped bass spawning stock in the Hudson River, and of their use of the Lawler, Matusky, and Skelly (LMS) Real-Time Life Cycle Model to estimate the impact of entrainment and impingement on the Hudson River striped bass population.

Volume III addresses the validity of the utilities' use of the Ricker stock-recruitment model to extrapolate the combined entrainment-impingement losses of young fish to reductions in the equilibrium population size of adult fish. In our testimony, a

methodology was developed and applied to address a single fundamental question: if the Ricker model really did apply to the Hudson River striped bass population, could the utilities' estimates, based on curve-fitting, of the parameter alpha (which controls the impact) be considered reliable? The present Volume III includes, in addition, an analysis of the efficacy of an alternative means of estimating alpha, termed the technique of prior estimation of beta (used by the utilities in a report prepared for regulatory hearings on the Cornwall Pumped Storage Project). Our validation methodology should also be useful in evaluating inferences drawn in the literature from fits of stock-recruitment models to data obtained from other fish stocks.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

ABSTRACT

BOREMAN, J., L. W. BARNTHOUSE, D. S. VAUGHAN, C. P. GOODYEAR, S. W. CHRISTENSEN, K. D. KUMAR, B. L. KIRK, and W. VAN WINKLE. 1981. Entrainment impact estimates for six fish populations inhabiting the Hudson River Estuary. Volume I. The Impact of Entrainment and Impingement on Fish Populations in the Hudson River Estuary. ORNL/NUREG/TM-385/V1 and NUREG/CR-2220. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This volume is concerned with the estimation of the direct (or annual) entrainment impact of power plants on populations of striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy in the Hudson River estuary. Entrainment impact results from the killing of fish eggs, larvae, and young juveniles that are contained in the cooling water cycled through a power plant. An Empirical Transport Model (ETM) is presented as the means of estimating a conditional entrainment mortality rate (defined as the fraction of a year class which would be killed due to entrainment in the absence of any other source of mortality).

Most of this volume is concerned with the estimation of several parameters required by the ETM: physical input parameters (e.g., power-plant withdrawal flow rates); the longitudinal distribution of ichthyoplankton in time and space; the duration of susceptibility of the vulnerable organisms; the W-factors, which express the ratios of densities of organisms in power plant intakes to densities of organisms in the river; and the entrainment mortality factors (f-factors), which express the probability that an organism will be killed if it is entrained. Once these values are obtained, the ETM is used to estimate entrainment impact for both historical and projected conditions.

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

SUMMARY

The first step in assessing how losses due to entrainment mortality may affect the future well-being of a fish population is calculating the conditional entrainment mortality imposed by power plants on that population. The conditional entrainment mortality rate is defined as the fraction of a population which would be killed due to entrainment in the absence of any other source of mortality. In this exhibit, historical and projected conditional entrainment mortality rates are estimated for six fish populations inhabiting the Hudson River estuary: striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy.

Chapter I, entitled "Mathematical Methods Used in Estimating Conditional Entrainment Mortality Rates of Six Hudson River Fish Populations," presents the Empirical Transport Model (ETM), which is the mathematical method used in this exhibit. Appendix A, which is available under separate cover, describes the derivation of the ETM in greater detail and provides a hypothetical example of how the model operates.

Chapter II of this exhibit is entitled "Physical Input Parameter Values Used to Estimate Conditional Entrainment Mortality Rates for Six Hudson River Fish Populations." This chapter presents the physical input parameter values used in the ETM. The physical parameters are the river region volumes, historical and projected power plant withdrawal flow rates, and the proportion of power plant water withdrawn from each river region. These values are used for ETM analyses of all six fish populations.

Chapter III is entitled "Spatial Distributions of Entrainable Life Stages of Six Hudson River Fish Populations." These distributions are used as input to the ETM and are based on 1974 and 1975 Texas Instruments Inc. (TI) field data.

Chapter IV, entitled "Durations of the Entrainment Intervals and Entrainment Periods for Six Hudson River Fish Populations," presents values used in the ETM for the total period of time individual members

of a given population take to grow through entrainable life stages (entrainment interval) and the range of calendar dates that entrainable individuals are present in the Hudson River (entrainment period).

Chapter V is entitled "W-Factors for Hudson River Ichthyoplankton Entrained at Bowline, Lovett, Indian Point, Roseton, and Danskammer." This chapter presents two alternative methods of calculating the W-factors (ratios of power plant intake organism densities to river densities) used in the ETM. Appendix B, which accompanies this chapter, discusses the sources of data used to compute W-factors using the two methods.

Chapter VI, entitled "Estimating the Ratio of Power Plant Intake Organism Densities to River Densities Using the River Data Methodology," presents a third approach to estimating W-factors. This approach was used when lack of sufficient data prohibited use of either of the two approaches in Chapter V.

Chapter VII is entitled "Entrainment Mortality Factors for Hudson River Ichthyoplankton at Bowline Point, Lovett, Indian Point, Roseton, and Danskammer Point Power Plants." Appendices C-F accompany this chapter and provide the sources of data and mathematical justifications for the entrainment mortality factors (f-factors) as they are used in the ETM. Appendix P, which also relates to this topic, summarizes indirect or sublethal effects and describes a method of incorporating such effects into entrainment mortality factor calculations.

Chapter VIII presents the results of the ETM runs using the input parameter values described in Chapters II-VII. Appendices G-O, which accompany this chapter, list detailed ETM run results for each of the six fish populations.

TABLE OF CONTENTS

CHAPTER I
MATHEMATICAL METHODS USED IN ESTIMATING CONDITIONAL ENTRAINMENT MORTALITY RATES OF SIX HUDSON RIVER FISH POPULATIONS

Joint Testimony of

John Boreman, Ph.D.
C. Phillip Goodyear, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

and

Sigurd W. Christensen, Ph.D.

Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

Mathematical methods are used in this testimony for estimating the conditional entrainment mortality rates imposed by Hudson River power plants on six fish populations (striped bass, white perch, blueback herring/alewife, American shad, Atlantic tomcod, and bay anchovy). Conditional entrainment mortality rates are estimated by using the Empirical Transport Model (ETM) developed by Boreman et al. (1978). This reference, denoted herein as Appendix A, is available under separate cover (see "References Cited" section); it provides more complete detail on the mathematical basis and application of the model. The purpose of this chapter is to present the mathematical formulation of the ETM, as used in this exhibit, discuss the physical and biological input parameters that are necessary to use the model, assess several assumptions implicit in the model, and compare the ETM to the models used by the utilities to estimate conditional entrainment mortality rates.

2. MATHEMATICAL BASIS OF THE ETM

The ETM can be used to estimate the conditional entrainment mortality rate of fish populations inhabiting the Hudson River. The ETM, which is essentially a mathematical equation, relies on knowledge of the morphometry of the water body; power plant water withdrawal flow rates; the probability that an entrained organism will survive plant passage; and the duration, distribution, and relative abundance of entrainable life stages. A distinguishing feature of the ETM is that the distribution and movement of entrainable organisms among regions of the water body is defined by information derived from field samples. By using such information, the ETM avoids the difficulties often associated with hydrodynamic transport models, such as the Real-Time Life Cycle Model (RTLCM) developed by Lawler, Matusky and Skelly Engineers (LMS 1975), which rely on hydrodynamic principles and equations to define organism movement. Swartzman et al. (1978) discuss

problems associated with applying hydrodynamic models to biological data in order to assess power plant impacts.

The ETM formulation used in this testimony is a "Type II" ETM (p. 11, Boreman et al. 1978), which is applicable when time-dependent spatial distribution data are not available for each age group of the selected fish population. This condition prevails when distribution data are categorized by life stage rather than calendar age. As such, the observed spatial distributions over the entire entrainment period (the period of time during which entrainable life stages are present in the water body) are averaged over all weeks for each life stage, with each week's contribution weighted by its relative abundance. The resultant parameter values can be used to calculate the conditional entrainment mortality rate as follows (p. 13, Boreman et al. 1978):

$$m_T = 1 - \sum_{s=1}^{S} R_s \left\{ \prod_{j=0}^{J} \left[\prod_{\ell=1}^{L} \left(\sum_{k=1}^{K} D_{k\ell} e^{-E_{s+j,k\ell} C_{j\ell} t} \right) \right] \right\} \qquad \text{(I-1)}$$

where m_T = total conditional entrainment mortality rate,

s = week of the spawning period,

S = total number of weeks in the spawning period,

R_s = proportion of total eggs spawned that are spawned in week s,

j = age $0,1,2,\ldots,J$ (in weeks),

J = oldest entrainable age, also the duration of the entrainment interval (in weeks),

ℓ = life stage $1,2,3,\ldots,L$,

L = total number of entrainable life stages,

k = region $1,2,\ldots,K$,

K = total number of regions within the water body,

$D_{k\ell}$ = average proportion of the total standing crop of life stage ℓ individuals in region k during the entrainment period,

$E_{s+j,k\ell}$ = instantaneous entrainment mortality rate constant of life stage ℓ individuals during week s+j in region k (units: per day),

$C_{j\ell}$ = proportion of age j individuals in life stage ℓ, and

t = duration of the model time step (7 days).

Calculation of the instantaneous entrainment mortality rate (E) requires specifying power plant flow rates, region volumes, and susceptibility of individuals within a region to withdrawal by power plants and subsequent mortality due to plant passage. These parameters are expressed mathematically as follows:

$$E_{s+j,k\ell} = \frac{P_{s+j,k}\ f_{s+j,k\ell}\ W_{s+j,k\ell}}{V_k} \qquad \text{(I-2)}$$

where $P_{s+j,k}$ = power plant water withdrawal flow rate from region k during week s+j (units: per day),

$f_{s+j,k\ell}$ = fraction of life stage ℓ individuals entering the intake that are eventually killed by plant passage occurring during week s+j in region k,

$W_{s+j,k\ell}$ = ratio of the average intake concentration to average region concentration of life stage ℓ individuals during week s+j in region k, and

V_k = volume of region k (assumed constant throughout the entrainment period).

Figure I-1 is a schematic diagram that illustrates operation of the ETM.

Physical data necessary for the ETM are the number of geographic regions within the water body and their respective volumes, as well as the power plant withdrawal flow rates from each region. Necessary bilogical data include the distribution of entrainable organisms, by age or life stage, among the water body regions; the ratio of average intake to average regional concentrations of organisms (entrainment susceptibility factor, herein called the W-factor); the fraction of organisms entering the intake that is eventually killed by plant

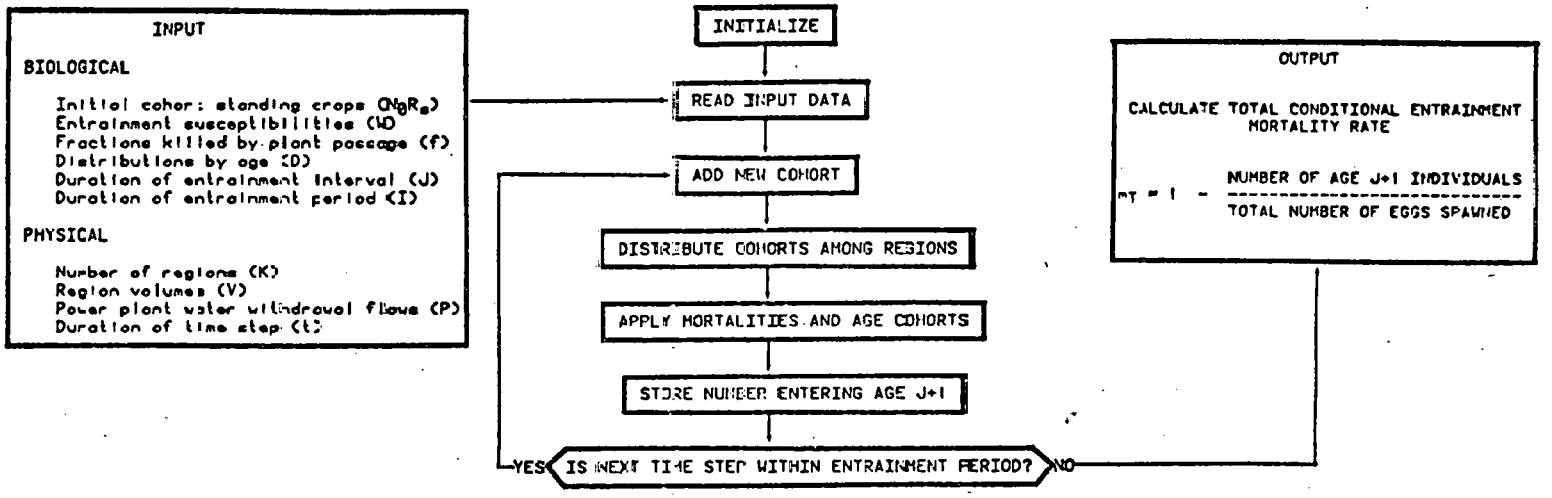

Figure I-1. Schematic diagram of the Empirical Transport Model (ETM) based on equation I-1. See text for explanation of symbols.

passage (herein called the f-factor); and the temporal distribution of egg deposition or recruitment to the first vulnerable life stage. In addition, selection of entrainment periods and entrainment intervals for each population is necessary. Subsequent chapters of this testimony (Chapters II-VII) present more detailed definitions of each input parameter variable used in the ETM, as well as derivations of population-specific input parameter values.

3. ASSUMPTIONS UNDERLYING THE ETM

Several assumptions are implicit in the ETM. Violation of these assumptions may significantly reduce the accuracy of the estimate of the conditional entrainment mortality rate. Often the direction of the bias (whether the estimate is an overestimate or underestimate of the true conditional entrainment mortality rate) is known, but the degree of bias is not.

The first assumption, and probably the most critical one, is that the data used to establish spatial and temporal distributions are accurate. Problems associated with gear bias, species and life stage identification, sample design, and data interpretation reduce overall accuracy of the ETM estimate. However, such problems also reduce accuracy in estimates from any other methodology that incorporates distribution and vulnerability data derived from field samples, such as the RTLCM and empirical methods used by the utilities in exhibits UT-3, UT-4, UT-6, and UT-7.

A second assumption that is implicit in application of the ETM is that organisms move instantaneously among regions of the water body between time steps and do not move among regions within each time step. As such, near-field (i.e., within-region) depletion of organisms due to entrainment mortality within one region is not offset by movement of other organisms into the depleted region during a given time step. If the organism distribution data are collected during power plant operation, the data base for both the river-wide distribution and the W-factors inherently reflects the near-field depletion and the degree to which it is offset by organism movement during the time step.

If power plant effects are large enough in relation to organism movement during the period of data collection to have substantially altered the distribution patterns of the organisms (i.e., through localized reduction in standing crops), the ETM estimates will be biased low. In addition, if the ETM is used to estimate conditional mortality rates for projected power plant flow conditions that are different from those conditions corresponding to the period of data collection, further biases can be expected. The direction of these further biases will depend on many factors and can be controlled, to some extent, by making judicious choices for region size and length of the time intervals used in the model.

Another salient aspect of the ETM methodology is the assumption that the organism distribution parameter values are based on field measurements of the entire standing crop of each entrainable life stage. If some members of an entrainable life stage are located outside the area of sampling, then the ETM will overestimate the conditional entrainment mortality rate for the entire population. Nevertheless, it will still reflect the mortality rate of that portion of the population that remains within the sampled area.

A final assumption concerns the uniformity of natural mortality within the modeled system. The "Type II" ETM, as used in this testimony, implicitly assumes that the natural mortality rate of a given life stage is the same in all regions of the water body during the entire time that life stage is present within the entrainment period; that is, no differential natural mortality occurs among regions of the water body. If differential natural mortality does occur, and it is measureable, then a more generalized version of the ETM (Eq. 5, Boreman et al. 1978) can be utilized to calculate the conditional entrainment mortality rate. However, time- and age-dependent natural mortality rates dueing the entrainment periods for the six fish populations were not measured by the utilities' consultants or computed by us.

The "Type II" ETM also assumes that natural mortality rates are independent of population density. If density-dependent mechanisms such as cannibalism, or density-dependent forms of starvation or

predation are operative concurrently with reduction in numbers due to entrainment mortality, this assumption will not be realistic. Density-dependent mortality can be incorporated directly into ETM estimates by allowing the natural mortality rate during a given time step to be a function of the population size at the beginning of that time step, or incorporated indirectly by multiplying the final ETM estimate by a coefficient that accounts for compensatory capability of the population during the entrainment period. The former technique involves quantification of the density-dependent mortality function in space and time, which is generally beyond the present state-of-the-art and has not been undertaken for Hudson River fish stocks. The latter technique requires a prolonged series of appropriate stock and recruitment data (Christensen et al. 1977), which are not available for the six Hudson River fish populations. Since both techniques are extremely difficult to quantify even approximately, the level of confidence in the estimates would almost always be very low. An alternative to using either of these techniques when density-dependent mechanisms are known or assumed to be operative during the entrainment period is to make a judgment of the significance of the effect based on the conditional entrainment mortality rate estimate from the ETM.

4. COMPARISON OF THE ETM TO THE UTILITIES' EMPIRICAL MODELS

In their direct testimony, the utilities presented two empirical methodologies for calculating the conditional entrainment mortality rates of selected fish populations inhabiting the Hudson River. One methodology, developed by Texas Instruments, Inc. (TI) (p. 2-VI-3, Exhibit UT-3), compares the estimated number of each entrainable life stage "cropped" by entrainment during a specified time interval to the standing crop of ichthyoplankton present in the river ("adjusted" to account for incomplete recruitment of eggs to the entrainable population) during the same speciefied time interval. The second methodology, developed by LMS (pp. 9.1B-5 to 9.1B-10, exhibits UT-6 and UT-7) divides the total number of organisms entrained by a power plant

by the average standing crop of entrainable organisms during the entrainment period.

4.1 TI METHODOLOGY

The TI methdology adjusts for the fact that, before all eggs are spawned, the entrainment mortality imposed by power plants is only experienced by that part of the population present in the river and not the entire population of entrainable organisms that will be present after all the eggs are spawned. This adjustment for unspawned individuals, however, is not complemented by a necessary similar adjustment at the end of the entrainment period which would allow recruitment to the first non-entrainable life stage. The failure to use this complementary adjustment could result in an overestimate of the conditional entrainment mortality rate. As shown in subsequent chapters of this exhibit, however, when the TI methodology is applied, entrainment of all selected species is arbitrarily cut off before recruitment to the first non-vulnerable life stage is fully realized. Because of this, entrainment mortality is not accounted for at all after the cutoff date. Whether this approach overestimates or underestimates the conditional entrainment mortality rate will depend on the particular cutoff date used. The ETM, by using a cohort approach, allows for an explicit temporal distribution of recruitment to the first entrainable life stage similar to that used in the TI methodology, as well as an explicit temporal distribution of recruitment to the first non-vulnerable life stage, which the TI methodology lacks.

An assumption underlying the TI methodology is that, within each time interval during the entrainment period, the various entrainable life stages of a given species present in the water body during that time interval have exactly the same distribution patterns (Tr. 10340). In calculating their entrainment ratio (ratio of the number of organisms entrained to the standing crop in the river), TI combines organisms across life stages in both the numerator and the denominator. Thus, in any given week, it is the loss of the most

numerically abundant organisms which will govern the size of the ratio. The fact that the older, and hence less abundant organisms which are killed are individually more valuable to the population is not properly accounted for in an equation as simplistic as equation 2-VI-2 of Exhibit UT-3, unless all organisms have the same distribution regardless of age, and power plant impacts are spread evenly among the different ages.

The weakness of TI's approach is best illustrated with a simple example involving a hypothetical population. Suppose spawning occurred evenly over a four-week period with one billion eggs spawned each week, and there are three entrainable life stages (egg, larva, and juvenile) in the population, each lasting one week with a 90 percent mortality between each life stage. In the fourth week suppose that 60 percent of the juveniles were in a power plant region and the power plant killed 20 percent of all individuals in that region. Simple arithmetic shows that the loss of juveniles alone to this power plant represents a conditional mortality rate of 0.03 to the entire year-class. This number is derived by considering that, since spawning was evenly distributed through four weeks, one-fourth of the potential year-class exists as juveniles in week 4, and 60 percent of these are within the power plant region. Of this 60 percent, 20 percent are killed, therefore:

$$(0.25)(0.60)(0.20) = 0.03,$$

or 3 percent of the year-class is destroyed as juveniles in this week.

Assume, however, that the power plant is located downstream, while most spawning occurs upstream and only 10 percent of the eggs are found in the power plant region. For the sake of simplicity, also assume that no larvae are killed by the plant. Now it is possible to evaluate what TI's equation would calculate for that week.

Ten percent of the one billion eggs are located within the power plant region; 20 percent of these, or 20 million eggs, are killed. This represents an additional 0.5 percent loss to the total potential

year-class (0.25 x 0.10 x 0.20 = 0.005) and, between eggs and juveniles, 3.5 percent of the year-class has been killed. With 90 percent mortality between eggs and larvae and between larvae and juveniles, there will be 10 million juveniles in this week (week 4), 60 percent (6 million) are in the power plant region, and 20 percent of these (1.2 million) are killed.

The numerator of TI's entrainment ratio is the sum of the eggs and juveniles that are killed: 20 million eggs plus 1.2 million juveniles equals 21.2 million organisms. The denominator of TI's ratio is the total standing crop of organisms in the system: one billion eggs plus 100 million larvae plus 10 million juveniles, or 1.11×10^9 organisms. The ratio of these sums is 0.019. This ratio would form TI's estimate of the quantity m_i in their equation 2-VI-2 in Exhibit UT-3, which is defined as the "probability of death from entrainment during the i^{th} interval." If the power plant operated only during that one week, m_i would also be equal to TI's quantity m_T in equation 2-VI-1 of Exhibit UT-3, defined as the "conditional mortality rate due to entrainment."

Clearly, the estimate of 0.019 is a substantial underestimate of the true impact during that week (0.035). The cause of this difference is due to the different spatial distributions of eggs and juveniles. Although the juveniles are a more important component of the actual loss because each juvenile has a much higher survival value than each egg, their loss is masked by the loss of the more abundant eggs. The estimate of entrainment is thus governed disproportionately by the distribution of eggs.

The proper "conditional mortality rate due to entrainment" cannot, in general, be obtained from equations 2-VI-1 and 2-VI-2 in Exhibit UT-3. The desired conditional probability of entrainment mortality is defined as:

$$m_T \quad \frac{N_e}{N_o} \qquad \text{(I-3)}$$

where m_T = conditional mortality rate due to entrainment,
N_e = the number of non-entrainable fish produced with the power plant operating, and
N_o = the number of non-entrainable fish produced without the power plant operating.

In a situation where the probability of entrainment mortality differs for organisms of different ages, either due to different spatial distributions or different vulnerabilities to the power plant, Equation 2-VI-1 in Exhibit UT-3 will only be correct if the individual m_i components in Equation 2-VI-2 in Exhibit UT-3 have been calculated with proper weighting for the various life stages. That entire concept is missing from TI's "Empirical Entrainment Methodology", but not from the ETM.

The ETM addresses this concept by handling the distribution pattern and entrainment susceptibility of each life stage separately. The ETM approach is more realistic for two reasons: (1) life stages may have different vertical and longitudinal distribution characteristics, as well as differential susceptibility to power plant induced mortality, and (2) the total standing crops of the entrainable life stages that are present concurrently in the water body may vary by as much as several orders of magnitude.

4.2 LMS METHODOLOGY

Since intake samples are used, the LMS methodology implicitly assumes that sampling efficiencies of gear used at power plant intakes are equal to efficiencies of gear used to measure river-wide densities of organisms. Carpenter (1979) and Barnthouse et al. (Chapter V) show that the intake sample densities are biased when compared to densities obtained by river sampling and that direct comparisons reflect this bias. Consequently, the conditional entrainment mortality rates derived by the LMS methodology are biased estimates of the true values. The extent to which the true values are underestimated or overestimated depends on the degree of differential sampling efficiencies among the gear used at the power plant intakes and in the river.

4.3 ADDITIONAL CONSIDERATIONS

Additional differences among the ETM and utilities' estimates of conditional entrainment mortality rates are due to different values used for the input parameters in the various methodologies. Specifically, differences exist for power plant withdrawal flow rates (actual and projected), duration of the entrainment periods, the fractions of organisms entering the power plant intakes that are killed by plant passage, and the relationships between intake densities and near-field densities. These differences are discussed as each input parameter value used in the ETM analyses is introduced.

REFERENCES CITED

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1978. An empirical transport model for evaluating entrainment of aquatic organisms by power plants. U.S. Fish and Wildlife Serv. FWS/OBS-78/90. 67 pp.

Christensen, S. W., D. L. DeAngelis, and A. G. Clark. 1977. Development of a stock-progeny model for assessing power plant effects on fish populations. pp. 196-226. IN W. Van Winkle (ed.), Assessing the Effects of Power-Plant-Induced Mortality on Fish Population. Pergamon Press, New York. 380 pp.

Exhibit EPA-196. Carpenter, E. J. 1979. Sampling ichthyoplankton.

Exhibit UT-3. Supplement I to 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. T. McFadden and J. P. Lawler. Submitted to Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-4. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-6. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-7. Bowline Point Generating Station. Near-field effcts of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

Lawler, Matusky and Skelly, Engineers (LMS). 1975. Report on development of a real-time two dimensional model of the Hudson River striped bass population. Prepared under contract with Consolidated Edison Company of New York, Inc.

Swartzman, G. L., R. B. Deriso, and C. Cowan. 1978. Comparison of simulation models used in assessing the effects of power-plant-induced mortality on fish populations. U. S. Nuclear Regulatory Commission. NUREG/CR-0474. 155 pp.

CHAPTER II
PHYSICAL INPUT PARAMETER VALUES USED TO ESTIMATE CONDITIONAL ENTRAINMENT MORTALITY RATES FOR SIX HUDSON RIVER FISH POPULATIONS

Testimony of
John Boreman, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

Use of the Empirical Transport Model (ETM) for estimating the conditional entrainment mortality rate of fish populations requires selection of appropriate biological and physical input parameter values. Although the biological input parameters vary depending on the particular fish population being examined, the physical input parameter values used in the ETM are the same for all the populations. The physical input parameter values used in the ETM to estimate conditional entrainment mortality rates include water volumes of each region, power plant water withdrawal flow rates, and distribution of the power plant water withdrawal flow rates among regions.

2. REGION VOLUMES

Region volumes used in the ETM are listed in Table II-1. The regions were chosen to coincide with the stratified sampling scheme employed by TI in its Long River, beach seine, fall shoals, and bottom trawl surveys conducted during 1974 and 1975. The regions were defined by TI on the basis of morphometric characteristics such as depth, width, and extent of shoals (areas $\leq$ 6m deep) (p. 6.3, Exhibit UT-4).

The procedure TI used to estimate region volumes is presented in the First Multiplant Report (p. D-3, TI 1975). The volume of water in each of the three depth strata within each mile was calculated from the surface area and depths recorded on United States Geological Survey (USGS) maps of the river. Total surface area of each mile segment was obtained with the use of a polar planimeter. As such, volume estimates rely on accuracy of the USGS maps and the planimetric technique used on the maps. In addition, the shoreline used in the USGS maps represents conditions at mean low water. Therefore, the depth soundings used to estimate strata volumes are 1-2 feet below mean tidal depths, as noted in the legend of the USGS maps for the Hudson River. Since average river depth varies among regions, estimated volumes of the regions with

Table II-1. Water Volumes for the 12 Longitudinal Regions of the Hudson River Estuary[a]

Region	River Miles	Volume (m^3)
Yonkers (YK)	14-23	229,420,287
Tappan Zee (TZ)	24-33	321,811,465
Croton-Haverstraw (CH)	34-38	147,736,754
Indian Point (IP)	39-46	208,336,266
West Point (WP)	47-55	207,455,769
Cornwall (CW)	56-61	139,791,019
Poughkeepsie (PK)	62-76	298,133,444
Hyde Park (HP)	77-85	165,484,666
Kingston (KG)	86-93	141,469,879
Saugerties (SG)	94-106	176,295,711
Catskill (CK)	107-124	160,731,743
Albany (AL)	125-140	71,149,105

[a]supplied to EPA by Marcellus (1978)

shallow depths will be more biased by tidal conditions than deeper regions.

3. POWER PLANT WITHDRAWAL FLOW RATES

Several sets of power plant water withdrawal flow rates are used in the ETM analyses: historical (1974 and 1975) and projected. The historical flow rates, based on daily rates supplied to EPA by the utilities (Huggins 1977; Hutchison 1977; Marcellus 1977), are listed in tables II-2 and II-3 for 1974 and 1975, respectively. The rates in these tables are expressed as average daily withdrawal flows for each week.

Projected flows rates (Table II-4) were obtained from several sources. The once-through and closed-cycle cooling water withdrawal rates for Bowline, Indian Point units 2 and 3, and Roseton are based on the lifetime average flow conditions listed in tables A-1 through A-5 of Exhibit UT-3 and Marcellus (1979). Projected flow rates for Lovett units 4 and 5 and Danskammer units 3 and 4 are the averages of 1974 and 1975 values, as provided by the utilities (Huggins 1977, Hutchison 1977; Marcellus 1977). Lovett units 1-3, Danskammer units 1 and 2, and Indian Point Unit 1 are not included in the projections because they are expected to be used very little, if at all, in the future (p. 5-180, Barnthouse et al. 1977).

4. POWER PLANT FLOW RATE DISTRIBUTIONS AMONG REGIONS

Due to the tidal nature of the Hudson River estuary, the power plants may withdraw water from more than one region. Each power plant's water withdrawal is assumed to be directly related to the proportion of the tidal cycle when water "belonging" to a particular region is in front of the plant. In the Hudson River, the average tidal excursion distance is an estimated 13 miles (p. VI-12, TI 1975). The total withdrawal flow for each power plant is, therefore, distributed among the regions in the ETM according to the proportion of the volume of the 13 mile

Table II-2. Actual 1974 Water Withdrawal Flow Rates, Expressed as TCM/day, of Hudson River Power Plants Based on Average of Daily Flow Rates During Each Week

Interval	Bowline[a]	Lovett[a]	Indian Point[b]		Roseton[c]	Danskammer[c]
			Unit 1	Unit 2		
4/22-4/28	1697	1226	1036	1482	1219	1004
4/29-5/5	1722	1223	1234	3124	894	1307
5/6-5/12	1722	1223	710	2750	527	1131
5/13-5/19	1613	1223	947	1832	359	1209
5/20-5/26	0	1271	1638	3976	235	1341
5/27-6/2	0	1174	1621	4629	489	1335
6/3-6/9	1898	1296	1638	4432	373	1134
6/10-6/16	2492	1180	1640	3768	334	1013
6/17-6/23	3447	1333	1633	3914	349	1165
6/24-6/30	3155	1223	1414	4190	400	1145
7/1-7/7	3236	1343	1511	4430	345	1368
7/8-7/14	2822	1285	892	4433	380	1409
7/15-7/21	3445	1034	1646	3913	366	1477
7/22-7/28	3445	1222	1646	3666	1168	1654
7/29-8/4	3445	1159	1646	1300	1203	1686
8/5-8/11	3183	1291	1532	3599	2084	1629
8/12-8/18	3445	1350	1646	4510	1556	1527
8/19-8/25	3639	1251	1646	4613	2238	1627
8/26-9/1	3565	1410	1646	4688	2279	1573
9/2-9/8	3816	1233	1601	3839	1204	1513
9/9-9/15	3816	1250	1646	4200	604	1624
9/16-9/22	4112	1219	1646	4090	2190	1302
9/23-9/29	4186	1301	1646	3927	2144	1325
9/30-10/6	4186	778	1370	1617	2027	1648
10/7-10/13	4186	696	1646	2009	1561	1688
10/14-10/20	4186	939	1646	3913	175	1616
10/21-10/27	3690	998	1646	3913	0	1435
10/27-11/3	3567	939	1618	3609	537	1427

[a] supplied to EPA by Hutchison (1977)

[b] supplied to EPA by Marcellus (1977)

[c] supplied to EPA by Huggins (1977)

Table II-3. Actual 1975 Water Withdrawal Flow Rates, Expressed as TCM/day, of Hudson River Power Plants Based on Average of Daily Flow Rates During Each Week

Interval	Bowline[a]	Lovett[a]	Indian Point[b]		Roseton[c]	Danskammer[c]
			Unit 1	Unit 2		
3/2-3/8	2216	949	740	1272	2278	452
3/9-3/15	2802	839	740	752	2278	452
3/16-3/22	2802	758	740	791	2279	456
3/23-3/29	2802	839	740	983	2298	457
3/30-4/5	2802	821	740	1312	2279	452
4/6-4/12	2802	788	740	2375	2279	534
4/13-4/19	2802	684	704	2938	2296	452
4/20-4/26	2802	655	953	3420	2279	454
4/27-5/3	2986	655	33	3584	2565	789
5/4-5/10	2165	711	588	3699	2712	840
5/11-5/17	1447	760	796	3913	2657	882
5/18-5/24	1401	1367	312	3915	3058	880
5/25-5/31	1401	1223	185	4117	3004	1076
6/1-6/7	2368	1223	446	4492	2953	1427
6/8-6/14	2802	1197	713	4582	2274	1481
6/15-6/21	2802	1081	556	4714	2474	1551
6/22-6/28	2848	1278	450	4703	3058	1656
6/29-7/5	2802	1060	187	4453	2824	1619
7/6-7/12	2802	1151	222	4643	2824	1292
7/13-7/19	2802	1167	107	4688	2932	1424
7/20-7/26	3353	1253	565	4659	3011	1487
7/27-8/2	3429	1359	867	1756	3058	1519
8/3-8/9	3445	1250	705	117	2722	1634
8/10-8/16	3445	1205	32	4033	2125	1544
8/17-8/23	3362	1221	25	4390	2324	1547
8/24-8/30	3356	1216	270	4645	2279	1590
8/31-9/6	3445	1223	25	4715	2279	1494
9/7-9/13	3364	1235	25	3897	2279	1506
9/14-9/20	3445	634	25	3979	1928	1561
9/21-9/27	3445	589	25	3925	2283	1536
9/28-10/4	3323	943	55	3770	2427	1484
10/5-10/11	1723	1150	112	3925	2574	1177
10/12-10/18	1723	941	112	2995	2528	1352
10/19-10/25	1565	955	111	872	2309	1548
10/26-11/1	1608	1076	112	1789	2279	1307

[a]supplied to EPA by Hutchison (1977)
[b]supplied to EPA by Marcellus (1977)
[c]supplied to EPA by Huggins (1977)

Table II-4. Projected Water Withdrawal Flow Rates, Expressed as TCM/day, of Hudson River Power Plants

Interval	Bowline[a]	Lovett[b]	Indian Point[c] Units 2 & 3	Roseton[d]	Danskammer[b]
April	1543 (48)	917	8122 (508)	2061 (78)	482
May	2524 (78)	1061	6470 (434)	2644 (70)	720
June	3816 (87)	1164	6442 (439)	3034 (74)	945
July	4186 (87)	1133	9130 (543)	3482 (87)	1062
August	4186 (87)	1176	9123 (545)	3482 (87)	1237
September	3657 (83)	1030	7919 (542)	2730 (38)	1179
October	2544 (77)	903	6971 (484)	1780 (34)	1084

[a]from tables A-4 and A-5 of Exhibit UT-3 and Marcellus (1979)
[b]average of 1974 and 1975 values for units expected to be in operation
[c]from tables A-2 and A-3 of Exhibit UT-3 and Marcellus (1979)
[d]from Table A-1 of Exhibit UT-3 and Marcellus (1979)
Numbers in parentheses are average monthly flows with closed-cycle cooling conditions

segment surrounding each power plant intake that fails within each region. These proportions are listed in Table II-5.

5. REFERENCE CITED

Barnthouse, L. W., J. B. Cannon, S. G. Christensen, A. H. Eraslan, J. L Harris, K. H. Kim, M. E. LaVerne, H. A. McLain, B. D. Murphy, R. J. Raridon, T. H. Row, R. D. Sharp, and W. Van Winkle. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point Generating Station. Oak Ridge National Laboratory. ORNL/TM-5877/V2.

Exhibit UT-3. Supplement I to 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. T. McFadden and J. P. Lawler. Submitted to Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-4. 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. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. 1977.

Huggins, T. 1977 (pers. comm.). Letter to Henry Gluckstern (EPA) dated October 31, 1977.

Hutchison, J. B. 1977 (pers. comm.). Letter to C. Phillip Goodyear (FWS) dated October 27, 1977.

Marcellus, K. L. 1977 (pers. comm.). Letter to Henry Gluckstern (EPA) dated November 10, 1977.

Marcellus, K. L. 1978 (pers. comm.). Letter to Henry Gluckstern (EPA) dated April 12, 1978.

Marcellus, K. L. 1979 (pers. comm.). Letter to Henry Gluckstern (EPA) dated March 2, 1979.

Texas Instruments, Inc. (TI) 1975. First annual report for the multi-plant impact study of the Hudson River Estuary. Vols. I-II. Prepared under contract with Consolidated Edison Company of New York, Inc.

Table II-5. Proportion of Power Plant Cooling Water Flows Withdrawn from each Longitudinal Region of the Hudson River[a]

Region	Power Plant				
	Bowline	Lovett	Indian Point	Roseton	Danskammer
YK	0	0	0	0	0
TZ	0.271	0	0	0	0
CH	0.358	0.369	0.298	0	0
IP	0.371	0.549	0.562	0	0
WP	0	0.082	0.140	0	0
CW	0	0	0	0.273	0.196
PK	0	0	0	0.727	0.804
HP	0	0	0	0	0
KG	0	0	0	0	0
SG	0	0	0	0	0
CK	0	0	0	0	0
AL	0	0	0	0	0

[a]based on a 13 mile daily tidal excursion and river volume data (Table D-2, TI 1975)

CHAPTER III
SPATIAL DISTRIBUTIONS OF ENTRAINABLE LIFE STAGES OF SIX HUDSON RIVER FISH POPULATIONS

Testimony of
John Boreman, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

Susceptibility of an individual organism to withdrawal by power plants depends on the location of that individual within the water body in relation to the location of power plant intakes. This relationship may change during the individual's entrainable life stages as the individual changes its position within the water body either by movement or passive transport. The Empirical Transport Model (ETM), used in this exhibit to estimate the conditional entrainment mortality rates of six populations inhabiting the Hudson River estuary, accounts for differential susceptibility of individuals due to their location within the water body and movement of these individuals as they age. The parameter in the ETM that accomplishes this is the D parameter (equation I-1 in Chapter I of this exhibit). The D parameter is the proportion of the total standing crop of a life stage that is present within a specified region of the water body.

The "Type II" ETM used in this exhibit implicitly assumes that the distributions of each life stage may be different, but that the distribution of a given life stage remains constant throughout the period of occurrence of that life stage in the water body. To meet this assumption, the distribution of each life stage represents an average of the distributions of that life stage recorded during the period that it is present in the water body. The average is weighted by the relative abundance represented by each distribution to assure that the distributions of most members of a life stage influence the resultant average to the greatest extent.

2. DERIVATION OF PARAMETER VALUES

Egg and larval life stage distributions were derived from Texas Instruments, Inc. (TI) Long River Survey data. The TI sampling program was designed to sample ichthyoplankton in most of the Hudson River (RM 14-140). Life stage distributions of entrainable juveniles were derived from either the Long River Survey data or the Long River Survey

data used in conjunction with TI beach seine data, depending on the lateral and vertical distributions of juveniles that are characteristic for the species of concern.

Average regional density data for each entrainable life stage of the selected fish populations, based on 1974 and 1975 Long River surveys, were provided to EPA and its consultants by the utilities (Marcellus 1977, 1978, 1979). Only 1974 data were provided for the Hudson River population of American shad. A description of the methodology used by TI to calculate regional densities of each life stage of the selected populations is in the First Annual Multiplant Report (p.D-5, Vol. II, TI 1975).

The proportional distribution of a given life stage among regions was derived by multiplying the density of that life stage in each region during a specified time interval (sample week) by the respective region volume. The resultant weekly standing crops in each region were divided by the estimated weekly river-wide standing crop to derive the proportion of the estimated river-wide standing crop present in each region during that week. These proportions were then averaged across all weeks that life stage was present in Long River Survey collections, weighting by the river-wide standing crops estimated for the respective weeks.

For all fish populations except the Atlantic tomcod, which is a demersal species (Boreman 1979), the spatial distributions of entrainable juveniles were derived by adding the average weekly standing crop in each region, as estimated by the Long River Survey, to the average weekly shorezone standing crop, as estimated by the beach seine survey. Incorporation of beach seine data into the calculation of relative distributions for the more pelagic populations allows recognition of organism movement into the shorezone areas of the estuary during the juvenile life stage. As stated in the testimony on life histories (Boreman 1979), the relatively few juvenile tomcod caught in beach seines implies little movement of this species into the shorezone during its entrainment period.

The resultant regional standing crop sums were divided by the sum of the average river-wide standing crop plus the average total shorezone standing crops to derive the proportion of the entrainable juvenile life stage present within each region. The use of average weekly standing crops avoided the problems of non-comparability of data bases associated with the several non-overlapping sampling weeks of the two surveys. Beach seine data sometimes extended several weeks past the final week of Long River Survey data collection.

Standing crops estimated with the beach seine data were derived by multiplying the average regional catch per tow during a specified sample week by the average area swept by a tow. This product was divided by the shorezone surface area of the specified region (Table D-3, Vol. II, TI 1975). The same method of calculating shore zone standing crops was used by the utilities' consultants (p. D-9, Vol. II, TI 1975). The resulting average regional shorezone standing crops were then averaged across sample weeks, weighted by the total shorezone standing crop present in the river during each respective sample week.

Because of problems associated with gear avoidance, the standing crops derived by the above methodologies should not be regarded as absolute estimates of the true regional or river-wide standing crops. Rather, as used in the ETM, they are considered as direct indices of the true standing crops, necessitating an assumption that sampling gear catch efficiencies are equal in all regions of the water body. Factors that will affect the validity of this assumption are, for the most part, abiotic. The factors include salinity, tidal-induced motion, water temperature, and water body morphometry (Table 2, Bowles et al. 1978). However, no data are available that relate the influence of such factors present in the Hudson River to sampling gear catch efficiencies.

3. PARAMETER VALUES FOR SELECTED FISH POPULATIONS

Average entrainable life stage distributions used in the ETM to estimate the conditional entrainment mortality rates of selected fish

populations are listed in tables III-1 to III-6 for striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy, respectively. Table III-7 lists the dates of the TI beach seine data collections used in estimating the distribution of entrainable juveniles of all populations except Atlantic tomcod. Only day beach seine samples were used because night samples did not encompass the entire estuary.

As stated previously, the relatively low catch of Atlantic tomcod in beach seines coupled with the epibenthic characteristics of the juvenile life stage of this species precluded use of beach seine data in the derivation of the spatial distribution of that life stage. The time intervals of beach seine data collections used to estimate the distributions of entrainable juveniles of the other fish populations were chosen to represent the period when that life stage was present in the Hudson River. This interval extended more than several weeks past the last date of Long River Survey data collection only for the bay anchovy population, which essentially remains in the entrainable size range until maturity.

4. REFERENCES CITED

Boreman, J. 1979. Life histories of seven fish species that inhabit the Hudson River estuary. 94pp. Exhibit EPA -198.

Bowles, R. R., J. V. Merriner, and J. Boreman. Factors affecting accuracy of ichthyoplankton samples used in power plant entrainment studies. U.S. Fish and Wildl. Serv. FWS/OBS-76/20.7. 12 pp.

Marcellus, K. L. 1977 (pers. comm.). Letter to Henry Gluckstern (EPA) dated November 30, 1977.

Marcellus, K. L. 1978 (pers. comm.). Letter to Henry Gluckstern (EPA) dated June 23, 1978.

Marcellus, K. L. 1979 (pers. comm.). Letter to Henry Gluckstern (EPA) dated February 21, 1979.

Texas Instruments, Inc. (TI). 1975. First annual report for the multiplant impact study of the Hudson River estuary. Vols. II. Prepared under contract with Consolidated Edison Company of New York, Inc.

Table III-1. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stages of Striped Bass as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[a]	Post yolksac larva[a]	Entrainable juvenile[b]
1974	YK	0	0.14	0.07	0.62
	TZ	0.09	2.65	3.84	28.41
	CH	18.20	10.07	6.72	23.10
	IP	23.97	11.43	23.87	5.01
	WP	36.54	10.39	21.71	2.72
	CW	2.63	22.12	12.28	11.38
	PK	4.12	35.30	18.70	2.74
	HP	3.99	5.45	4.04	2.52
	KG	5.85	1.40	6.47	9.43
	SG	1.88	0.73	1.26	4.60
	CK	2.55	0.29	1.03	7.40
	AL	0.18	0.03	0.01	2.07
1975	YK	0	0.05	0.51	2.05
	TZ	0.32	4.34	2.24	32.27
	CH	6.43	9.97	9.31	26.84
	IP	35.71	23.02	34.46	9.13
	WP	38.24	23.62	20.19	2.05
	CW	9.22	11.12	10.99	6.64
	PK	4.99	12.82	13.65	8.59
	HP	2.36	9.75	3.98	2.53
	KG	0.48	2.38	3.39	3.73
	SG	0.98	2.83	0.82	4.24
	CK	1.19	0.09	0.46	1.72
	AL	0.08	0.01	0	0.21

[a] from TI Long River Survey data (Marcellus 1977)
[b] from TI Long River and beach seine survey data (Marcellus 1977)

Table III-2. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stages of White Perch as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[a]	Post yolksac larva[a]	Entrainable juvenile[b]
1974	YK	0	0.06	0.17	0
	TZ	8.07	17.56	4.38	2.76
	CH	47.03	12.36	3.58	1.18
	IP	1.37	2.89	15.50	2.02
	WP	5.18	6.02	12.34	1.57
	CW	4.10	4.24	10.19	3.85
	PK	3.91	6.99	19.32	11.89
	HP	0.63	13.09	13.66	8.24
	KG	1.53	13.40	15.34	15.98
	SG	7.91	14.85	3.12	42.25
	CK	4.47	6.93	2.29	6.89
	AL	15.80	1.61	0.11	3.37
1975	YK	0	0.22	0.37	0.31
	TZ	21.01	25.03	6.47	3.70
	CH	2.75	7.67	5.60	2.85
	IP	2.48	6.21	13.93	3.23
	WP	4.58	5.55	9.71	4.91
	CW	6.88	4.71	7.17	7.48
	PK	25.66	9.87	13.91	16.30
	HP	1.87	11.19	14.31	24.50
	KG	5.58	5.40	9.17	17.17
	SG	11.84	9.78	12.79	13.18
	CK	16.19	10.05	6.35	5.67
	AL	1.16	4.32	0.22	0.71

[a] from TI Long River Survey data (Marcellus 1977)
[b] from TI Long River and beach seine survey data (Marcellus 1977)

Table III-3. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stage of Alosa spp. (Blueback Herring and Alewife) as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[a]	Post yolksac larva[a]	Entrainable juvenile[b]
1974	YK	0	0	0.02	0.15
	TZ	0	0.10	0.49	0.20
	CH	0	0.17	0.47	1.42
	IP	0.02	0.03	1.52	0.08
	WP	0.02	0.34	1.79	5.22
	CW	0.01	0.18	4.24	7.61
	PK	0.22	9.39	9.11	7.48
	HP	0.62	2.36	7.94	6.34
	KG	0.79	8.91	21.22	28.29
	SG	3.93	20.27	26.98	3.45
	CK	5.29	21.71	17.09	34.66
	AL	89.10	36.54	9.13	5.10
1975	YK	0	0	0.02	0
	TZ	0	0.06	0.22	0
	CH	0	0.10	0.19	0
	IP	0.04	0.63	1.21	0.12
	WP	1.32	1.61	5.51	3.37
	CW	1.36	3.19	8.41	7.55
	PK	18.43	4.33	6.67	7.91
	HP	7.08	2.23	8.60	4.28
	KG	4.67	8.82	10.91	24.30
	SG	29.07	13.76	24.77	13.48
	CK	23.34	29.40	24.96	38.71
	AL	14.69	35.87	8.53	0.28

[a]from TI Long River Survey data (Marcellus 1977)
[b]from TI Long River and beach seine survey data (Marcellus 1977, 1979)

Table III-4. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stages of American Shad as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[a]	Post yolksac larva[a]	Entrainable juvenile[b]
1974	YK	0	0	0	2.68
	TZ	0	0	0.37	11.90
	CH	0	0	0.28	9.95
	IP	0.06	0	0.54	9.14
	WP	0	0.71	0.62	10.71
	CW	0	0.60	1.01	14.08
	PK	2.35	10.95	5.70	19.99
	HP	1.86	7.05	9.81	6.95
	KG	5.71	19.83	27.03	5.73
	SG	60.25	41.22	36.36	3.01
	CK	29.50	19.64	16.84	3.08
	AL	0.27	0	1.44	2.78

[a]from TI Long River Survey data (Marcellus 1977)
[b]from TI Long River and beach seine survey data (Marcellus 1977)

Table III-5. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stages of Atlantic Tomcod as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[b]	Post yolksac larva[b]	Entrainable juvenile[b]
1975	YK	-	15.02	58.81	42.20
	TZ	-	29.74	33.87	34.18
	CH	-	28.64	4.89	6.68
	IP	-	12.22	2.03	8.78
	WP	-	8.36	0.27	5.16
	CW	-	2.83	0.09	1.56
	PK	-	3.19	0.04	1.28
	HP	-	0	0	0.13
	KG	-	0	0	0.02
	SG	-	0	0	0.01
	CK	-	0	0	0
	AL	-	0	0	0

[a] no data available

[b] from TI Long River Survey data (Marcellus 1977)

Table III-6. Proportional Distributions, Expressed as Percentages, of Entrainable Life Stages of Bay Anchovy as Used in the ETM Analyses

Year	Region	Egg[a]	Yolksac larva[a]	Post yolksac larva[a]	Entrainable juvenile[b]
1974	YK	70.72	23.03	14.97	9.25
	TZ	21.19	68.00	42.49	35.04
	CH	4.62	8.97	24.68	38.71
	IP	2.80	0	15.53	10.60
	WP	0.67	0	1.34	1.04
	CW	0	0	0.58	5.13
	PK	0	0	0.23	0.10
	HP	0	0	0.03	0.02
	KG	0	0	0.03	0.07
	SG	0	0	0.01	0.01
	CK	0	0	0.01	0.03
	AL	0	0	0	0
1975	YK	49.24	0	18.01	16.84
	TZ	40.13	74.27	37.20	50.22
	CH	3.98	25.73	14.67	12.99
	IP	6.40	0	16.93	2.93
	WP	0.25	0	10.42	6.38
	CW	0	0	2.43	9.99
	PK	0	0	0.28	0.48
	HP	0	0	0.03	0.02
	KG	0	0	0.01	0.09
	SG	0	0	0.02	0.06
	CK	0	0	0	0
	AL	0	0	0	0

[a]from TI Long River Survey data (Marcellus 1978)
[b]from TI Long River and beach seine survey data (Marcellus 1978)

Table III-7. Dates of TI Beach Seine Collections (Day Only)[a] Used in Estimating the Proportional Distributions of the Entrainable Life Stages of Selected Hudson River Fish Populations

Population	Year	Dates
Striped bass	1974	6/16 - 8/10
	1975	6/15 - 8/9
White perch	1974	6/30 - 8/10
	1975	6/15 - 8/9
Alosa spp.[b]	1974	6/1 - 8/9
	1975	6/15 - 8/9
American shad	1974	6/2 - 8/10
Bay anchovy	1974	7/13 - 10/18
	1975	7/13 - 11/1

[a]provided to EPA by Marcellus (1977, 1979)
[b]Blueback herring and alewife combined

CHAPTER IV
DURATIONS OF THE ENTRAINMENT INTERVALS AND ENTRAINMENT PERIODS FOR SIX HUDSON RIVER FISH POPULATIONS

Testimony of
John Boreman, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

The total period during which entrainable organisms are present within the water body is termed the entrainment period. This period is the combination of the spawning period (period of egg deposition) and the average amount of time an individual takes to grow through its entrainable life stages. The latter period of time is termed the entrainment interval.

The vulnerability of an entrainable life stage of a given fish population to entrainment mortality depends, among other factors, on the duration of that life stage and the calendar time period during which members of that life stage are present in the water body. A life stage may be present in the water body much longer than its specified duration. This phenomenon occurs when spawning is not instantaneous, but is spread over an extended period. If physical conditions within the water body, such as power plant water withdrawal flow rates, vary during the entrainment period, then individuals of a given life stage may experience different entrainment mortality rates depending on when during the entrainment period they were spawned.

The Empirical Transport Model (ETM) handles the phenomenon of extended spawning by tracking the entrainment mortality of each cohort through its entrainment interval. A cohort is defined as a group of individuals spawned during the same model time step (week). The total conditional entrainment mortality rate is the combined conditional entrainment mortality rates of the cohorts, weighted for the fraction of the total number of individuals spawned during the entrainment period that each cohort represents.

2. DERIVATION OF PARAMETER VALUES

Average durations of entrainable life stages of selected fish populations inhabiting the Hudson River used in the ETM were derived

from literature sources and field data, as presented in the testimony on life histories of the populations (Boreman 1979). When a range of average life stage durations for a population was presented in the life histories testimony, the minimum value was used in the ETM. If these minimum values are below the actual average life stage durations, then the ETM will underestimate the conditional entrainment mortality rate of that life stage (with all other input variables held constant). The average entrainment interval for each fish population is the sum of the average durations of each entrainable life stage.

In the ETM analyses, the average entrainment interval is considered constant throughout the entrainment period for each population. Use of an average entrainment interval in the ETM underestimates the entrainment intervals of the early cohorts and overestimates the entrainment intervals of the later cohorts in each fish population modeled. If conditions that affect entrainment mortality vary during the entrainment period, then use of an average entrainment interval may lead to an overestimate or underestimate of the true conditional mortality rate, depending on how the conditions vary. However, only the egg (and in the case of striped bass the yolksac larval) life stage durations can be directly related to a physical condition in the water body (water temperature); durations of other life stages in relation to physical and biological conditions within the water body cannot be quantified due to lack of sufficient data. Therefore, average life stage durations are used for the older life stages and, as shown in the testimony on life histories (Boreman 1979), variation in egg and yolksac larval life stage durations from average values is relatively small (generally less than one day).

The entrainment period for each selected fish population, as it is used in the ETM analyses, begins when the first entrainable life stage appears in field samples and ends when the last cohort has reached the first non-entrainable life stage.

The spawning period for a fish population, as used in the ETM, is the number of weeks that eggs of that population were present in the Texas Instruments, Inc. (TI) Long River Survey samples for a given year. The proportion of eggs spawned during each week of the spawning period, and hence the proportion of the initial number of individuals represented by each cohort, is assumed equivalent to the estimated standing crop of eggs for that week divided by the estimated total standing crop of eggs summed over all weeks of the spawning period for that year. This method of calculating the temporal distribution of egg deposition does not work if sampling was conducted more than once per week (which it was not) or if the egg incubation period for a given population is longer than one week. Of the five fish populations for which a spawning period is used in the ETM analyses (tomcod egg entrainment is not calculated), the average egg incubation periods are equal to or less than one week, although Alosa spp. may have an egg incubation period as long as 10 days very early in the season (Table 14, Boreman 1979).

3. PARAMETER VALUES FOR SELECTED FISH POPULATIONS

Durations of the entrainable life stages of selected fish populations inhabiting the Hudson River are presented in Table IV-1. The values for each population were derived in the testimony on life histories (Boreman 1979) and represent average durations for the time periods when those life stages were present in the Hudson River. Where possible, values are specified separately for 1974 and 1975.

The 1974 and 1975 parameter values used in the ETM analyses for durations of the spawning periods and temporal deposition of eggs of the selected fish populations are listed in Tables IV-2 to IV-6 for striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, and bay anchovy. Since the 1974 Long River Survey began too late to sample Atlantic tomcod yolksac larvae, only 1975 data were used. The ETM analyses assume all Atlantic tomcod were recruited to the yolksac larval life stage before the first week of sampling in 1975. The peak

Table IV-1. Durations (in Days) of Entrainable Life Stages of Selected Fish Populations Inhabiting the Hudson River, as Used in the ETM Analyses[a]

Life stage	Year	Striped bass	White perch	Blueback herring/ Alewife	American shad	Atlantic tomcod	Bay anchovy
Eggs	1974	2.5	2	4	7	-	1
	1975	2	1.5	4	-	-	1
Yolksac larvae	1974	7	5	3	4	-	1
	1975	5.5	5	3	-	28	1
Post yolksac larvae	1974	28	28	28	21	-	30
	1975	28	35	28	-	42	30
Entrainable juveniles	1974	28	28	28	28	-	42
	1975	28	28	28	-	21	42
Entrainment interval	1974	65.5	63	63	60	-	74
	1975	63.5	69.5	63	-	91	74

[a] taken from Boreman (1979)

Table IV-2. Proportion of Striped Bass Eggs Spawned Each Week During 1974 and 1975 as Used in the ETM Analyses[a]

Year	Week	Proportion
1974	4/29 - 5/5	0.0025
	5/6 - 5/12	0.1226
	5/13 - 5/19	0.4189
	5/20 - 5/26	0.3875
	5/27 - 6/2	0.0541
	6/3 - 6/9	0.0047
	6/10 - 6/16	0.0046
	6/17 - 6/23	0.0034
	6/24 - 6/30	0.0017
1975	5/11 - 5/17	0.0309
	5/18 - 5/24	0.4952
	5/25 - 5/31	0.4115
	6/1 - 6/7	0.0470
	6/8 - 6/14	0.0008
	6/15 - 6/21	0.0052
	6/22 - 6/28	0.0094

[a]from Table 2 in Boreman (1979)

Table IV-3. Proportion of White Perch Eggs Spawned Each Week During 1974 and 1975 as Used in the ETM Analyses[a]

Year	Week	Proportion
1974	5/6 - 5/12	0.0001
	5/13 - 5/19	0.0433
	5/20 - 5/26	0.1626
	5/27 - 6/2	0.0950
	6/3 - 6/9	0.3633
	6/10 - 6/16	0.3153
	6/17 - 6/23	0.0106
	6/24 - 6/30	0.0091
	7/1 - 7/5	0.0007
1975	5/4 - 5/10	0.0012
	5/11 - 5/17	0.0382
	5/18 - 5/24	0.1567
	5/25 - 5/31	0.6149
	6/1 - 6/7	0.0917
	6/8 - 6/14	0.0160
	6/15 - 6/21	0.0737
	6/22 - 6/28	0.0073
	6/29 - 7/5	0.0003

[a]from Table 9 in Boreman (1979)

Table IV-4. Proportion of Alosa spp. (Blueback Herring and Alewife) Eggs Spawned Each Week During 1974 and 1975 as Used in the ETM Analyses[a]

Year	Week	Proportion
1974	4/29 - 5/5	0.0052
	5/6 - 5/12	0.0134
	5/13 - 5/19	0.0598
	5/20 - 5/26	0.8370
	5/27 - 6/2	0.0243
	6/3 - 6/9	0.0583
	6/10 - 6/16	0.0020
1975	4/21 - 4/27	0.0012
	4/28 - 5/3	0
	5/4 - 5/10	0.1237
	5/11 - 5/17	0.1631
	5/18 - 5/24	0.4300
	5/25 - 5/31	0.2779
	6/1 - 6/7	0.0023
	6/8 - 6/14	0.0001
	6/15 - 6/21	0.0017

[a]from Table 14 in Boreman (1979)

Table IV-5. Proportion of American Shad Eggs Spawned Each Week During 1974 as Used in the ETM Analyses[a]

Year	Week	Proportion
1974	4/22 - 4/28	0.0577
	4/29 - 5/5	0.1692
	5/6 - 5/12	0.0826
	5/13 - 5/19	0.0722
	5/20 - 5/26	0.1687
	5/27 - 6/2	0.3862
	6/3 - 6/9	0.0552
	6/10 - 6/16	0.0080
	6/17 - 6/23	0.0002

[a]from Table 21 in Boreman (1979)

Table IV-6. Proportion of Bay Anchovy Eggs Spawned Each Week During 1974 and 1975 as Used in the ETM Analyses[a]

Year	Week	Proportion
1974	6/3 - 6/9	0.0078
	6/10 - 6/16	0.5254
	6/17 - 6/23	0.1486
	6/24 - 6/30	0.0047
	7/1 - 7/7	0.0035
	7/8 - 7/14	0.0569
	7/15 - 7/21	0.1279
	7/22 - 7/28	0.0627
	7/29 - 8/4	0.0326
	8/5 - 8/11	0.0118
	8/12 - 8/18	0.0181
1975	6/1 - 6/7	0.2784
	6/8 - 6/14	0.0463
	6/15 - 6/21	0.0096
	6/22 - 6/28	0
	6/29 - 7/5	0.3012
	7/6 - 7/12	0.2838
	7/13 - 7/19	0.0689
	7/20 - 7/26	0.0098
	7/27 - 8/2	0.0020

[a] from Tables 27 and 28 in Boreman (1979)

estimated weekly standing crop of Atlantic tomcod yolksac larvae occurred during the first week of sampling in 1975 (Table 26, Boreman 1979), which supports the validity of this assumption. The entrainment periods of the six fish populations selected for ETM analyses are listed in Table IV-7.

4. REFERENCES CITED

Boreman, J. 1979. Life histories of seven fish populations that inhabit the Hudson River estuary. 94 pp. Exhibit EPA-198.

Table IV-7. Entrainment Period Durations for Selected Fish Populations Inhabiting the Hudson River During 1974 and 1975 as Used in the ETM Analyses

Population	Year	Entrainment interval (days)	Spawning period (days)	Entrainment period (dates)[a]
Striped bass	1974	65.5	63	4/29 - 8/29
	1975	63.5	49	5/11 - 8/25
White perch	1974	63	63	5/6 - 9/2
	1975	69.5	63	5/4 - 9/7
Alosa spp.[b]	1974	63	49	4/29 - 8/12
	1975	63	63	4/21 - 8/18
American shad	1974	60	63	4/22 - 8/16
Atlantic tomcod	1975	91	-[c]	3/9 - 6/8
Bay anchovy	1974	74	77	6/3 - 10/25
	1975	74	63	6/1 - 10/9

[a] beginning of entrainment periods are based on dates when eggs (or tomcod yolksac larvae) were first sampled in the TI Long River surveys, from Boreman (1979)

[b] blueback herring and alewife

[c] single cohort used due to lack of data on the temporal distribution of Atlantic tomcod egg deposition

CHAPTER V

W-FACTORS FOR HUDSON RIVER ICHTHYOPLANKTON ENTRAINED AT BOWLINE, LOVETT, INDIAN POINT, ROSETON, AND DANSKAMMER

TESTIMONY OF

LAWRENCE W. BARNTHOUSE, Ph.D.

K. DEVA KUMAR, Ph.D.

AND

BERNADETTE L. KIRK

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

PREPARED FOR THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II

APRIL, 1979

SUMMARY

This chapter contains estimates of W-factors developed from ichthyoplankton data collected at the Bowline, Lovett, Indian Point, Roseton, and Danskammer generating stations. Two sets of W-factors were developed for each of five populations: striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa (alewife and blueback herring). The chapter consists of five parts:

1. An introductory discussion of several methodological problems associated with all estimates of W-factors and of our approach to dealing with these problems: the calculation of two sets of parameters, using two independent methods of computation.
2. A description of the two methods, the Modified Utility (MU) and Gear Bias Cancelling (GBC) method, used to compute W-factors.
3. Separate sets of W-factors for striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa computed using the MU and GBC methods.
4. A point by point discussion of our disagreements with the data and methods used by LMS in Exhibit UT-3 to compute w-ratios.
5. A comparison between W-factors for each population calculated using the MU and GBC methods.

1. INTRODUCTION

Entrainment models employed by consultants for both the utilities and EPA to estimate conditional entrainment mortality rates include a parameter, known as the w-ratio (utilities) or W-factor (EPA). This parameter is intended as a measure of the abundance of organisms in power plant intake water relative to their average abundance in an idealized cross-section of the river in front of a power plant. The W-factor is included in entrainment models primarily to account for the effects of non-uniform distribution of organisms in the river on the number entrained.

If, for example, larvae are concentrated in the center of the river while power plants draw cooling water from near shore, then the density of larvae in the intake water is likely to be less than the average density of larvae in the cross-section of the river in front of the intake. The same result can occur if organisms are concentrated near the bottom of the river while cooling water is withdrawn primarily from the surface. In either case, the number entrained would be less than would be predicted by a model that assumes that the density of organisms in power plant cooling water is equal to the cross-sectional average density of organism in the river.

There are also distributions that can result in the abundance of organisms in the intake water being greater than their average cross-sectional abundance in the river: if, for example, they congregate in shallow water near the shore (all Hudson River power plants have shoreline intakes).

In the past it has been argued that, for entrainable life-stages of striped bass, the distribution of organisms in the river is such that in general they are less abundant in the river strata from which cooling water is drawn than in the entire river cross-section, and therefore W-factors should on the average be less than 1.0. Barnthouse et al. (1977) have summarized the positions of both the NRC staff and utility consultants at the time the Final Environmental Statement for Indian Point Unit 3 was prepared. Results derived from ORNL's striped

bass young-of-the-year model (developed for NRC) indicated that striped bass ichthyoplankton are concentrated near the river bottom or the shores, where they are less susceptible to downstream transport (Barnthouse et al. 1977, p. 5-58). Moreover, a comparison of plant intake and river transect data collected at Bowline, Lovett, Roseton, and Danskammer in 1973 showed that the measured densities of striped bass life-stages were generally lower in samples collected at power plant intakes than in samples collected at the river transect stations (Barnthouse et al. 1977, p. 5-53). The NRC staff concluded that W-factors (then called f_I) for striped bass life stages were generally less than 1.0 but greater than 0.5 (Barnthouse et al. 1977, p. 5-60). Similarly, in Exhibit UT-3 both TI and LMS employ W-factors that are generally less than 1.0. TI assumed (Exhibit UT-3, Sections 2-VI and 2-VII) that W-factors for all life-stages of all species for which entrainment impacts were estimated (striped bass, white perch, Atlantic tomcod, and American shad) are equal to 0.5. LMS concluded (Exhibit UT-3, p. 3-IV-54), based on plant and year specific intake and river transect data, that both upper layer and lower layer w-ratios are generally less than 1.0. Most of the W-factors developed in this testimony are smaller than 1.0. However, a substantial percentage are larger than 1.0, and the majority are larger than the value of 0.5 assumed by TI.

Many of the w-ratios calculated by LMS (Exhibit UT-3, Table 3-IV-27) are based on data that, in our opinion, should not be used for that purpose. More important, we believe that, because of biases inherent in the methods used to calculate w-ratios, and because of the extraordinarily low precision of all estimates of ichthyoplankton abundance, neither LMS' estimates nor any other single set of W-factors can by itself be assumed to be accurate.

In Section 1.1 we discuss two seemingly insurmountable methodological problems associated with the estimation of W-factors. In Section 1.2 we propose our solution to these problems: the use of two, rather than one, independently derived methods of estimating W-factors. The first, referred to as the Modified Utility (MU) method,

is only slightly different from the method used by LMS in Section 3-IV of Exhibit UT-3. The second, referred to as the Gear Bias Cancelling (GBC) method, was developed in an attempt to eliminate biases introduced into estimates of W-factors by differences in the types and methods of deployment of the gear used in collecting plant and river ichthyoplankton samples. Sections 2 and 3 contain, respectively, descriptions of the MU and GBC methods and the results obtained when the two methods are applied to data collected at Bowline, Lovett, Indian Point, Roseton, and Danskammer (the specific data sets used are described in Appendix B of this exhibit). In Section 4 we discuss our objections to the LMS w-ratios. For the most part these are objections to the data used by LMS rather than to the analytical treatment of the data. A general discussion of the W-factors is presented in Section 5.

1.1 METHODOLOGICAL PROBLEMS ENCOUNTERED IN ICHTHYOPLANKTON SAMPLING AND THEIR CONSEQUENCES WITH RESPECT TO THE ESTIMATION OF W-FACTORS

In summarizing and criticizing the data and methods used by both the utilities and the NRC staff to estimate f_I (now called the W-factor) for striped bass, Barnthouse et al. (1977; Section 5.4.3) pointed out two basic problems that severely limit the accuracy and precision of those estimates. The first of these is insufficient quantity of data, caused by insufficient plant and river sampling effort during periods of high abundance of striped bass ichthyoplankton, and by the inability of the gear to effectively sample older larvae and juveniles. The second is that the methods used to collect ichthyoplankton from the river invariably have been substantially different from those used to collect ichthyoplankton at power plant intakes.

Although two additional years of data are now available for most plants, these two sources of error still plague all attempts to obtain accurate empirical estimates of W-factors for striped bass and other Hudson River fish populations. In this section we briefly discuss the problems caused by small sample size and lack of gear comparability and argue that no sampling program can completely eliminate them.

The collection efficiency of ichthyoplankton sampling gear, defined as the fraction of organisms in the path of the gear that are captured and counted, is strongly influenced by the design of the gear and the manner in which it is deployed. Therefore, ichthyoplankton densities computed from data collected with different gears can differ substantially, even though the actual densities of organisms in the paths of the gears are identical. Since the methods used to collect ichthyoplankton at power plant intakes on the Hudson River are invariably different from those used at the river transect stations, W-factors computed as simple ratios of plant and river concentrations are subject to potentially severe biases.

Carpenter (1979) has identified three major sources of such bias: gear avoidance, clogging of nets with detritus, and extrusion. According to Carpenter, the ability of larval and juvenile fish to detect the presence of towed plankton nets (the gear used to collect the data used to compute W-factors) and to subsequently evade capture is a function of the size of the net, the speed at which it is towed, and the presence or absence of turbulence-creating structures (such as bridles) in front of the net. All other factors being equal, the probability that an organism in the path of a net will be able to swim out of that path before it is captured decreases as the diameter of the net opening increases. Similarly, the probability of escape decreases with increasing net speed because, once the net has been detected, less time is available for the organism to react and swim out of the path of the net. The presence of bridles, towlines, or other structures in front of the net mouth is thought to increase the probability of escape by enabling organisms to detect the gear at a greater distance.

Clogging of a net with plankton or detritus reduces its filtration efficiency, i.e., the fraction of the <u>water</u> (as distinct from the fraction of organisms) in the path of the net that enters the net mouth and is filtered. According to Smith et al. (1968), clogging increases the incidence of gear avoidance by creating turbulence in front of the net. In addition to increased avoidance, clogging can lead to underestimates of the true density of organisms in the water sampled by

causing overestimation of the volume of water filtered. At Bowline, Lovett, and Indian Point, intake sample volumes have been estimated indirectly from measurements of intake velocity rather than directly measured by placing flowmeters in the nets.

It is possible for eggs and small larvae to burst in a net or to be pushed through the mesh pores and lost. The magnitude of this bias, referred to by Carpenter (1979) as extrusion, increases as the tow speed of the net increases because the rate of filtration per unit net area (and therefore the pressure with which organisms are pushed against the net) increases.

In general, the nets used at Hudson River power plant intakes have smaller mouth openings than do the nets used to collect river transect samples (Carpenter 1979). Moreover, the velocity of sampling is invariably much higher in the river than at power plant intakes. At the plants, nets are simply lowered into the intake flow. Intake velocities at Bowline, Indian Point, and Roseton are on the average less than 30 cm/sec (Carpenter 1979). In contrast, the river transect samples are collected by towing nets at a velocity of 60-150 cm/sec (Carpenter 1979, Table 3). If the effects of net size and sampling velocity were the only biases present, then ichthyoplankton densities measured at power plant intakes would be less than those measured at the river transect stations, even in the absence of real differences in ichthyoplankton abundance. However, because of the higher sampling velocity in the river, it is possible for life stages susceptible to extrusion to be sampled less efficiently in the river than at power plant intake stations. In addition, the nets used to collect river samples have bridles and towlines while the nets used to collect plant samples do not (Carpenter 1979). Increased gear avoidance due to the presence of bridles probably offsets to some degree the biases caused by the greater size and sampling velocity of the gear used to collect the river samples.

Carpenter (1979) concluded that the overall effect of the various biases is an underestimation of ichthyoplankton densities measured at the Roseton, Bowline, and Indian Point intakes relative to densities

measured at the corresponding river transect stations. However, the possibility exists that for some life-stages of some species at some plants it may be the river concentrations that are underestimated. At present it is not possible to quantify the relative biases, and therefore it is not possible to compute unbiased estimates of W-factors using simple ratios of plant and river concentrations.

Even if there were no gear biases, precise estimates of W-factors based on plant and river ichthyoplankton data would still be impossible to obtain. The reason for this unfortunate fact is the extremely "patchy" nature of ichthyoplankton distributions. By patchy we mean that the variation among the numbers of organisms collected in different samples is greater than would be expected if organisms were randomly distributed throughout the river.

According to Cassie (1963), the proper technical term for this type of distribution is "overdispersion." Based on his review of the literature, Cassie concluded that planktonic organisms are nearly always overdispersed. In the Final Environmental Statement for Indian Point Unit 3 (U. S. Nuclear Regulatory Commission 1975), the NRC staff examined ichthyoplankton densities observed in individual samples collected at Bowline, Lovett, Roseton, and Danskammer in 1973. The staff concluded that the distribution of these densities was "strongly skewed toward zero." In other words, many samples contained no organisms while a few contained many organisms. This is a characteristic of overdispersed distributions.

The major consequence of overdispersion, as far as the computation of W-factors is concerned, is that estimates of the mean concentration of ichthyoplankton present at a power plant intake or in the river will have high standard errors, even if large numbers of samples are collected. We will illustrate this problem by examining several sets of abundance data for striped bass post yolk-sac larvae. These data were collected in 1975 at the Roseton intake, the Roseton/Danskammer river transect stations, and the Indian Point intake and discharge.

The sampling program at Roseton is typical of those conducted at most Hudson River power plants. In Table V-1 we have tabulated mean densities, numbers of samples, standard errors, and 95% confidence intervals for striped bass post yolk-sac larvae collected at the Roseton intake and at the Roseton/Danskammer river stations on sampling dates between May 29 and June 19, 1975. Results are presented separately for day and night. The most precise results were obtained at night at the Roseton intake on June 2. As measured by the ratio of the upper and lower 95% confidence bounds, the actual density of striped bass post yolk-sac larvae (neglecting gear bias) is known only to within a factor of two. On all other nights the precision of estimates of the mean density of post yolk-sac larvae at the Roseton intake is much lower. Even though a mean density of 100 larvae/1000 m^3 was observed on the night of June 5, the precision of this estimate is so low that it is not significantly different from zero. The daytime estimates at the Roseton intake are even less precise than the nighttime estimates. Only two of the five means are significantly different from zero, and the most precise (June 2) is known only to within a factor of 4.6. The precision of the estimates of the abundance of post yolk-sac larvae at the Roseton/Danskammer river stations is lower still. None of the daytime means is significantly different from zero. The upper and lower 95% confidence bounds around the two nighttime means that are significantly different from zero differ by greater than a factor of 6.

The sampling program conducted at the Indian Point intakes and discharge canal is the most intensive conducted at any Hudson River power plant. Therefore, the precision of the abundance estimates obtained at Indian Point should be higher than that obtainable at any other plant. However, the intensive sampling effort at Indian Point appears to have produced estimates of the abundance of striped bass post yolk-sac larvae that are only marginally more precise than those obtained at Roseton. During the period from May 27-June 24, 1975, which spans the period of peak abundance of striped bass post yolk-sac larvae in the Indian Point vicinity, between 36 and 69 samples were

Table V-1. The precision of estimates of the density of striped bass post yolk-sac larvae at the Roseton intake and river transect stations, 1975[a]

Date	N[b]	Density[c] Mean	Minimum	Maximum	Standard error of mean	95% confidence bounds	Ratio of upper and lower bounds
				ROSETON INTAKE (DAY)			
May 29	6	1.0	0	12.0	1.6	0-5.4	--
June 2	18	149.7	0	622.0	45.9	53.3-246.1	4.6
June 5	12	502.7	0	1762.3	165.6	138.4-867.0	6.3
June 9	6	231.8	0	582.5	99.2	0-489.7	--
June 12	5	3.3	0	16.6	3.3	0-12.5	--
June 19	6	2.5	0	14.8	2.5	0-9.0	--
				ROSETON INTAKE (NIGHT)			
May 29	5	2.8	0	7.7	1.7	0-10.4	--
June 2	8	473.4	66.7	612.2	63.9	320.0-626.8	2.0
June 5	3	100.2	0	157.1	50.3	0-316.5	--
June 9	3	406.0	312.5	467.7	47.6	201.3-610.7	3.0
June 19	2	29.1	27.9	30.3	1.2	13.9-44.3	3.2
				ROSETON INTAKE (DAY)[d]			
May 29	7	20.0	3.5	66.9	9.4	0-43.5	--
June 2	7	57.6	0	187.2	27.4	0-126.1	--
June 5	7	147.5	0	565.9	77.2	0-340.5	--
June 9	7	118.0	0	364.2	57.8	0-262.5	--
June 19	7	2.9	0	12.7	1.8	0-7.4	--
				ROSETON INTAKE (NIGHT)[d]			
May 29	7	113.2	0	652.7	90.8	0-340.2	--
June 2	7	551.9	100.6	1340.5	163.2	143.9-959.9	6.7
June 5	7	465.8	153.7	1207.5	136.9	123.6-808.1	6.5
June 9	7	466.4	49.0	1907.2	248.7	0-1088.2	--
June 19	7	3.6	0	12.6	1.9	0-8.4	--

[a]Source of data is described in Appendix B.

[b]Total number of samples collected (depths and stations combined).

[c]Number of organisms per 100 m^3.

[d]All transect stations combined.

collected every night from the Indian Point Unit 2 intake and between 18 and 71 were collected from the discharge canal (Table V-2). Even with this level of effort, the standard errors associated with estimates of mean abundance on each date are large. On the dates on which the most precise estimates were obtained (June 17 at the intake and June 3 at the discharge canal), the mean abundance of striped bass post yolk-sac larvae is known only to within a factor of 2. On the date on which the highest abundance was observed (June 10), the mean densities (neglecting gear bias) are known only to within a factor of 3.5 at the intake and 4.5 at the discharge. Although we have not performed the above analysis for all life-stages of all species collected at all plants during all years for which data are available, there is no a priori reason to expect other ichthyoplankton abundance estimates to be more precise than are those that we have examined.

All estimates of W-factors obtained from this data, both ours and those of the utilities, are low in precision. Even large numerical deviations from 1.0 may be attributable to sampling error, as can between-year differences in the calculated W-factors for the same population and life stage. No single analytical method can completely overcome the inherent limitations on accuracy and precision caused by non-comparable sampling methods and the patchy nature of ichthyoplankton distributions.

1.2 WHY TWO ESTIMATORS ARE BETTER THAN ONE

In a well-known and frequently cited paper, Levins (1966) discussed the dilemma faced by a biologist attempting to model the evolution of a hypothetical plant or animal population (e.g., the Hudson River striped bass stock). Such populations, composed of individual organisms of different ages and genetic constitutions, interact with a heterogeneous, fluctuating environment and with other populations (e.g., their competitors, predators, and prey) that are themselves evolving. Levins concluded that biological systems are so complex and poorly understood that it is not practical to attempt to build a single model that faithfully reflects all of the bewildering complexity that characterizes

Table V-2. The precision of estimates of the density of striped bass post yolk-sac larvae at the Indian Point intake and discharge stations, 1975[a]

Date	N[b]	Density[c] Mean	Minimum	Maximum	Standard error of mean	95% confidence bounds	Ratio of upper and lower bounds
			INDIAN POINT INTAKE (NIGHT)[d]				
May 27	48	30.6	0	856.6	18.8	0-68.2	--
June 3	36	571.1	0	2325.2	112.0	347.1-795.1	2.3
June 10	36	2899.7	0	11870.7	578.9	1141.9-4057.5	3.6
June 17	48	619.5	0	2447.6	93.3	432.9-806.1	1.9
June 24	69	5.3	0	244.8	3.9	0-13.1	--
			INDIAN POINT DISCHARGE (NIGHT)[e]				
May 27	24	12.9	0	308.4	12.9	0-40.0	--
June 3	36	602.0	0	2745.9	104.7	392.6-811.4	2.1
June 10	18	2542.9	0	12856.8	804.6	853.2-4232.6	5.0
June 17	48	228.1	0	1630.5	50.7	126.7-329.5	2.6
June 24	71	6.6	0	260.1	4.7	0-16.0	--

[a]Source of data is described in Appendix B.

[b]Total number of samples collected (depths and stations combined).

[c]Number of organisms per 100 m^3.

[d]Stations Z2 and Z5.

[e]Stations D1 and D2.

the interaction of an evolving population with its environment. As a solution to the dilemma, he proposed the use of clusters of models: alternative models of the same phenomenon, each constructed using a different set of simplifying assumptions. If only one such model were used, it would not be possible to determine whether results derived from the model were realistic or whether they were artifacts introduced by the simplifying assumptions. Suppose, however, that two or more independent models, each simplified in a different way, lead to similar results. In this case it is possible to have some confidence that the realistic aspects of the models, rather than the simplifications, are responsible for those results. Truth, Levins suggested, can be found at the "intersection of independent lies."

Although proposed for a different problem than the one considered here, Levins' solution is as valid an approach for estimating W-factors as it is for studying the evolution of populations. The method used by LMS to compute w-ratios is simplified, in that the sampling gear used to collect ichthyoplankton from the river and from power plant intakes and discharges are assumed to be equally efficient at collecting organisms, regardless of differences in size, structure, and means of deployment. Since the gears undoubtedly differ in efficiency in ways that have not been (and perhaps cannot be) accurately measured, the w-ratios derived using LMS' method are influenced by biases that cannot be quantified. Such biases could cause results obtained from the Real Time Life Cycle model to be seriously in error.

In order to ensure that results obtained from the Empirical Transport Model (and especially resource management decisions based on those results) are not overly influenced by errors in the estimation of W-factors, we developed not one, but two sets of W-factors. The two sets were obtained using independent methods, each of which employs different simplifying assumptions. Our first method, the Modified Utility (MU) method, is conceptually identical to the approach taken by LMS in that the collection efficiencies of all sampling gears are assumed to be equal. There are no major differences between the two

other than the fact that one is used to compute w-ratios for a 2-layered model of the river and the other to compute depth-averaged W-factors for a single-layered model.

Our second method, the Gear Bias Cancelling (GBC) method, is entirely different in concept. The efficiencies of the gears used to collect ichthyoplankton from the river and from power plants are assumed to be different, and the computational procedure is designed specifically to cancel out biases caused by these differences. Simplifying assumptions about the distribution of organisms in the river and about the flow of water into a power plant intake are employed as part of the GBC method, and these assumptions may introduce biases into the results. However, such biases are likely to differ in magnitude and/or direction from the biases associated with W-factors calculated using the MU method. Similarly, W-factors computed using these two methods are influenced in different ways by sampling errors (the sensitivities of the MU and GBC W-factors to biases and sampling errors are discussed in Section 5). If conditional entrainment mortality rates obtained from the Empirical Transport Model are similar, regardless of which set of W-factors is used, then we have some confidence that the ETM results are not seriously compromised by errors in our estimates of this parameter.

2. METHODS USED TO COMPUTE W-FACTORS FOR HUDSON RIVER POWER PLANTS

In this Section we describe the two methods used to compute W-factors for Hudson River ichthyoplankton entrained at the Bowline, Lovett, Indian Point, Roseton, and Danskammer power plants. Our two methods are similar to the utilities' method in several respects. First, separate W-factors are computed for each life-stage (eggs, yolk-sac larvae, post yolk-sac larvae, and, for some species, juveniles) of each population. Second, W-factors are computed separately for day and night, with day and night having the definitions set forth by the utilities on p. 3-IV-32 of Exhibit UT-3. Third, in general only paired sets of plant and river data collected on the same dates were used. Unlike the utilities' w-ratios, which are computed separately for upper and lower layers of the river and the power plant intake bays, our W-factors are averaged over all depths. Moreover, unlike the utilities, we included data collected on all dates on which organisms were caught in either the plant or the river, regardless of how low the densities might have been (this procedure expands the data base slightly and should, in theory, slightly increase the precision of the resulting W-factor estimates).

2.1 MODIFIED UTILITY (MU) METHOD

Three steps are involved in the computation of a W-factor for a given species and life-stage using the MU method:

(1) calculation of average plant and river densities for each sampling date on which the life-stage was collected,
(2) calculation of mean seasonal plant and river densities, i.e., the average densities over all the sampling dates on which the life-stage was collected, and
(3) calculation of the W-factor as a ratio of the seasonal plant and river densities.

A number of samples (sometimes a large number) are collected at each location (plant or river) during each time period (day or night). River samples are collected at several stations; samples are collected at three depths both in the river and at the power plants. Several sets of plant samples may be collected during a given day or night. We treat all plant or river samples collected on the same date during the same time period as if they are replicate samples drawn from a common sample population. All of these samples are pooled in order to calculate the average day or night plant or river density of a particular fish population and life-stage. That is, the average density is equal to the sum of the numbers of organisms collected in all of the samples divided by the sum of the sample volumes:

$$D_{ij} = \frac{\sum_{k=1}^{m} n_{ijk}}{\sum_{k=1}^{m} v_{ijk}} = \frac{n_{ij.}}{v_{ij.}} \quad , \qquad \text{(V-1)}$$

where

n_{ijk} = number of organisms caught in the kth sample collected at location i (plant or river) on date j,

v_{ijk} = volume of kth sample collected at location i on date j,

m = number of samples collected at location i on date j during either daytime or nighttime,

$n_{ij.}$ = sum of the n_{ijk}'s over all values of k,

$v_{ij.}$ = sum of the v_{ijk}'s over all values of k.

The above computational procedure is equivalent to weighting each sample according to its volume, on the assumption that the greater the volume of a sample, the more reliable the resulting density estimate. In order to demonstrate this, we define a weighting factor,

$$w_{ijk} = \frac{v_{ijk}}{v_{ij.}}$$

If d_{ijk} ($= n_{ijk}/v_{ijk}$) is the density of organisms in a particular sample, then we can define a weighted average density as

$$D'_{ijk} = \sum_{k=1}^{m} w_{ijk} d_{ijk} \quad . \qquad \text{(V-2)}$$

From the definitions of w_{ijk} and d_{ijk},

$$D'_{ijk} = \sum_{k=1}^{m} (v_{ijk}/v_{ij.})(n_{ijk}/v_{ijk})$$

$$= \sum_{k=1}^{m} n_{ijk}/v_{ij.}$$

$$= j_{ij.}/v_{ij.}$$

$$= D_{ij}$$

Given the plant and river densities for each date, the seasonal plant and river densities ar computed as unweighted averages of the respective D_{ij}'s. Finally, the W-factor is computed as the ratio of the seasonal plant and river densities. Since only paired sets of plant and river data are used to calculate W-factors, the number of sampling dates used to compute the seasonal plant density is always equal to the number used to compute the seasonal river density. Therefore,

$$W = D_{1.}/D_{2.} \quad , \qquad \text{(V-3)}$$

where

$D_{1.}$ = sum of plant densities over all dates,
$D_{2.}$ = sum of river densities over all dates.

The seasonal W-factors are equivalent to weighted averages of W-factors computed separately for each date, with the weighting factor

assigned to each date being a function of the density of organisms in the river on that date. In order to demonstrate this we can rewrite Eq. (V-3) as:

$$W = [\sum_{j=1}^{T} D_{2j}(D_{1j}/D_{2j})]/D_{2.}$$

$$= \sum_{j=1}^{T} (D_{2j}/D_{2.})/(D_{1j}/D_{2j}) \qquad \text{(V-4)}$$

$$= \sum_{j=1}^{T} w_j(D_{1j}/D_{2j}) \quad ,$$

where

T = number of sampling dates on which organisms were collected,

$w_j = D_{2j}/D_{2.}$ = weighting factor for date j.

The quotient (D_{1j}/D_{2j}), the ratio of plant density to river density on date j, is simply an estimate of the W-factor on date j. The weighting factor, w_j, is the ratio of the river density on date j to the sum of river densities over all dates. If the life-stage in question were very abundant on date j relative to its abundance on other dates, the weighting factor would be large. If, on the other hand, the density in the river were relatively low on date j, the weighting factor would be small. Thus, our W-factor estimator gives the greatest weight to dates on which organisms were most abundant in the river. This is a desirable property because these are the dates on which it is most important to know the fraction of organisms in the vicinity of a power plant that are entrained and killed.

The only deviations from the computational procedure described above occurred in the treatment of the intake and discharge data at Indian Point. The sampling conditions at the intake and discharge stations are quite different. Different gears are used, and sampling velocities are several times higher at all of the discharge canal stations than at the Unit 1, 2, and 3 intake stations. Therefore, the

intake and discharge data were not treated as if drawn from a common sample population. Instead, intake and discharge densities on each date were computed separately using Eq. (V-1). Like the utilities (Exhibit UT-3, p. 3-IV-37), we then computed plant densities for each date as unweighted averages of the intake and discharge densities. The W-factors were then computed from [Eq. (V-3)].

2.2 GEAR BIAS CANCELLING (GBC) METHOD

Because of differences in the types and methods of deployment of sampling gear between river and plant, direct comparisons between the calculated plant and river abundances probably do not yield unbiased estimates of W-factors. Although the differences in sampling techniques should generally result in relative underestimates of plant abundance (Carpenter 1979), it is conceivable that in some cases (e.g., because of greater extrusion in river samples) it is the river abundance that is underestimated. Because the magnitude and direction of biases due to differences in sampling technique cannot be quantified, we have attempted to eliminate the problem of gear bias by developing a new method of estimating W-factors. This method, called the Gear Bias Cancelling (GBC) method, is based on a two-layered model of the river cross-section that is essentially identical to that used by LMS as the basis for the w-ratios presented in Section 3-IV of Exhibit UT-3. The upper and lower layers of the river are defined, respectively, as the water masses lying above and below an imaginary boundary exactly midway between the surface and bottom, from shore to shore. The upper and lower layers of an intake bay are defined similarly.

Like the calculation of LMS w-ratios, the calculation of W-factors using the GBC method involves comparing densities of organisms observed in the upper (or lower) layer of an intake bay to corresponding densities observed in the upper (or lower) layer of the river. Thus, as an intermediate step in our procedure, we calculate w-ratios that are identical in concept to those of the utilities. However, rather than applying our w-ratios directly to a two-layered version of the Empirical Transport Model, we use them to compute depth-averaged

W-factors in which the biases caused by unequal plant and river gear efficiencies are cancelled out. In order to demonstrate the bias cancelling principle that is the basis for the GBC method, we define:

$D_{PU}, D_{RU}, D_{PL}, D_{RL}$ = actual densities of organisms in the upper and lower layers of plant and river,

e = efficiency of plant sampling gear,

f = efficiency of river sampling gear,

$eD_{PU}, fD_{RU}, eD_{PL}, fD_{RL}$ = observed densities of organisms in the upper and lower layers of plant and river.

From the definition of a w-ratio (Exhibit UT-3, p. 3-IV-30),

$$w_U = eD_{PU}/fD_{RU} \text{ and } w_L = eD_{PL}/fD_{RL} .$$

The w-ratios, as calculated directly from the observed plant and river densities, are biased estimators of the ratios of actual plant and river upper and lower layer densities. However, if the ratio of w-ratios is calculated, the gear bias terms e and f cancel out:

$$\begin{aligned} w_U/w_L &= (eD_{PU}/fD_{RU})/(eD_{PL}/fD_{RL}) \\ &= eD_{PU}fD_{RL}/eD_{PL}fD_{RU} \\ &= D_{PU}D_{RL}/D_{PL}D_{RU} \end{aligned} \qquad \text{(V-5)}$$

In the GBC method, ratios of upper and lower layer w-ratios are used to compute W-factors that are independent of biases caused by unequal plant and river sampling efficiencies.

The GBC method employs simplifying assumptions about the distribution of organisms in the upper layer of the river and about the flow of water into a power plant intake. For this reason we use it as a complement to, rather than a replacement for, the Modified Utility (MU) method. Moreover, since the Bowline plant draws water from Bowline Pond rather than directly from the river, it is unlikely that

the upper and lower layers of the Bowline intake bay are in any way related to the upper and lower layers of the river. For this reason the GBC method is not used to estimate W-factors for Bowline. For this plant, the Modified Utility method can be used to compute estimates of W-factors that are free from gear bias, using the Bowline Pond ichthyoplankton data instead of intake data.

The assumptions required by the GBC method are discussed in detail in Section 2.2.1; the computational procedure is explained in Section 2.2.2.

2.2.1 Discussion of Assumptions

The GBC method is based on four assumptions:

(1) There are no lateral trends in the abundance of organisms in the upper layer of the river. Such trends may, however, exist in the lower layer.

(2) There is no active avoidance of the intake structure by entrainable ichthyoplankton.

(3) Power plants draw 57% of their cooling water from the upper layer of the river and 43% from the lower layer.

(4) All water in the upper layer of an intake bay is drawn from the upper layer of the river. Water in the lower layer of an intake bay comes from both layers of the river.

The first assumption, that of absence of lateral trends in abundance in the upper layer of the river, is consistent with data on the lateral distribution of ichthyoplankton reported in Exhibits UT-4, UT-6, and UT-7. In Sections 7.4.1.5.1 and 7.4.2.6.1 of Exhibit UT-4, TI reported results obtained from studies of the lateral distribution of striped bass yolk-sac and post yolk-sac larvae in the Cornwall vicinity. The lateral distribution of yolk-sac larvae at the surface and at the bottom was studied on May 22-23 and May 28-29, 1975. On May 22-23, no statistically significant differences in density between east, channel, or west zones or between surface and bottom strata were found (Exhibit UT-4, Fig. 7.4-8). On May 28-29, the surface density of yolk-sac larvae was significantly lower in the channel zone than in the

west zone. The lateral distribution of post yolk-sac larvae was studied on May 28-29 and on June 13-14, 1975. Although statistically significant trends in lateral abundance were noted in the bottom layer on June 13-14, no such trends were found at the surface (Exhibit UT-4, Fig. 7.4-18).

Exhibit UT-6 contains information on the lateral distribution of white perch, striped bass, Atlantic tomcod, Alosa, and bay anchovy eggs and larvae in the Roseton/Danskammer vicinity from 1974 through 1976. No consistent lateral trends in abundance were observed at any depth for white perch or striped bass eggs or larvae (Exhibit UT-6, Tables 9.1-2, 9.1-4, 9.1-8, 9.1-10). There is some evidence for a trend in lateral distribution of Atlantic tomcod larvae in the Roseton/Danskammer vicinity (eggs were collected on too few sampling dates for trends to be observed). Data obtained on five sampling dates are listed in Table 9.1-15 of Exhibit UT-6. Both at the surface and at the bottom, Atlantic tomcod larvae were most abundant at the west station and least abundant at the east station on three of the five dates. Stronger evidence for a trend in lateral abundance exists for Alosa eggs and larvae. Eggs have been consistently most abundant at the west station at all depths (Exhibit UT-6, Table 9.1-16). Larvae have been consistently most abundant at the east station at all depths (Exhibit UT-6, Table 9.1-18). A plausible hypothesis explaining the observed trend in larval distribution is presented on p. 9.1-55 of Exhibit UT-6: the higher abundance of larvae at the east station may be related to its proximity to the mouth of Wappinger's Creek, a possible spawning site for large numbers of alewife and blueback herring. Although the egg distribution data indicate greater Alosa spawning activity on the west side of the river than on the east side, no explanations are proposed in Exhibit UT-6. Data presented in Table 9.1-22 of Exhibit UT-6 indicate no lateral trends in larval bay anchovy abundance at any depth.

Data presented in Tables 9.1-4 and 9.1-8 of Exhibit UT-7 do not reveal any consistent lateral distribution patterns for larval white perch or striped bass in the Bowline vicinity. White perch larvae

were, as noted on p. 9.1-12 of Exhibit UT-7, more abundant at the channel station than at the east or west stations on the dates of peak abundance in 1975 and 1976, but no such pattern was observed in 1973 or 1974. The highest densities of eggs of both species appear to be found at the east and west stations (Tables 9.1-2 and 9.1-7), with lowest densities at the channel stations. Unlike the pattern observed at Roseton/Danskammer, there appears to be no east-west trend in abundance of Atlantic tomcod (Table 9.1-11) or Alosa (Table 9.1-14) larvae in the Bowline vicinity. Few Atlantic tomcod or Alosa eggs have been collected at Bowline, and thus there is no lateral distribution data for this life-stage of either species. Although no lateral trends in abundance of bay anchovy eggs have been observed in the Bowline vicinity (Exhibit UT-7, Table 9.1-17), such a trend does exist for larval bay anchovy (Exhibit UT-7, Table 9.1-18). Densities of larvae are usually lower at the channel station than at the shallower east and west stations.

In summary, our first assumption is generally supported by results presented in Exhibits UT-4, UT-6, and UT-7. These results indicate that consistent lateral trends in abundance of eggs and larvae of the Hudson River fish species considered in this testimony are the exception rather than the rule.

There is no direct evidence with which to test our second assumption, that of the absence of active intake avoidance by ichthyoplankton. Active intake avoidance is, or course, impossible for eggs and probably impossible for yolk-sac larvae. It is at least theoretically possible for post yolk-sac larvae and early juveniles to detect alterations in current patterns caused by the intake flow and to react to these alterations. Whether detection actually does occur, and whether any of these organisms escape the intake flow once it is detected, are unknown.

Our third assumption, that power plants draw 57% of their cooling water from the upper layer of the river and 43% from the lower layer, is derived from the LaSalle hydraulic model study, described on p. 3-IV-62 of Exhibit UT-3. Although the LaSalle study was designed to

predict patterns of water withdrawal for the Indian Point plant, LMS has argued (Exhibit UT-3, p. 3-IV-62) that the results are also applicable at other Hudson River power plants. In the absence of hydraulic model studies for Lovett, Roseton, and Danskammer, we, like LMS, have applied the Indian Point results to all other plants.

Our fourth assumption, that all of the water in the upper layer of an intake bay is drawn from the upper layer of the river, while water in the lower layer of an intake bay is drawn from both layers of the river, is not testable with any existing data. It is employed because it is the simplest assumption that is consistent with the vertical velocity profiles observed at power plant intakes. If 57% of power plant cooling water is drawn from the upper layer of the river and 43% is drawn from the lower layer, then it must be true that either 57% of the total flow enters the plant through the upper half of the intake bay, or else water from the upper layer of the river enters the lower half of the intake bay. If 57% of the total flow is drawn through the upper half of the intake bay, then the mean velocity of water in the upper half should be 1.33 (0.57/0.43) times as high as the mean velocity in the lower half. Table 9.1A-4 of Exhibit UT-7A shows that at Bowline the ratio of velocities of water entering the upper and lower halves of the intake bay is much too small to result in 57% of the total flow being drawn in through the upper half. The greatest difference in velocities is observed at low tide when all six pumps are operating. In this case the ratio of surface to bottom velocities is 1.17 (0.83/0.71). However, the average velocities in the upper and lower layers are probably better estimated, respectively, by the mean of the surface and middepth velocities and the mean of the middepth and bottom velocities. If these latter measures of velocity are compared, then the mean velocity in the upper layer of the intake bay is only 1.08 (0.785/0.725) times as high as that in the lower layer.

Texas Instruments measured velocity profiles at Indian Point unit 2 travelling screens in 1974 (Exhibit EPA-92B). In 10 out of 16 experiments, no statistically significant differences between the velocities measured at different depths were detected. Approach

velocities measured on the upper halves of intake screens were substantially higher than those measured on the lower halves only in four cases in which screens were fitted with experimental fish collection baskets (Exhibit EPA-92B, Table III-6). No consistent vertical trends in velocity were observed in experiments conducted at unbasketed screens (Exhibit EPA-92B, Table III-7).

Thus, vertical velocity profiles observed at Bowline and Indian Point indicate that when differences between velocities in the upper layer and the lower layer of an intake bay exist, the velocity in the upper layer is usually higher than in the lower layer. However, such differences are not found consistently and are not large enough to result in 57% of the intake flow being drawn in through the upper half of the intake bay. Therefore, we feel safe in assuming that some water from the upper layer of the river is present in the lower layer of an intake bay.

Given that some water from the upper layer of the river enters the lower half of an intake bay, the simplest possible way to apportion the water coming from the upper and lower layers of the river is to assume that:

(1) 50% of the total cooling water flow enters the upper half of the intake bay and 50% enters the lower half.

(2) The 43% of the cooling water flow that is drawn from the lower layer of the river all enters the lower half of the intake bay.

Given these two assumptions, the remaining water entering the plant through the lower half of the intake bay, representing 7% of the total flow, is drawn from the upper layer of the river. Therefore 86% (43/50) of the water in the lower layer of the intake bay is drawn from the lower layer of the river and 14% is drawn from the upper layer. The remaining 50% of the total flow, all drawn from the upper layer of the river, enters the upper half of the intake bay.

2.2.2 Description of Computational Procedure

The first step in the procedure for calculating a W-factor for a particular fish population and life-stage at a particular plant is the estimation of seasonal upper and lower layer w-ratios. Like LMS (Exhibit UT-3, Section 3-IV), we use the surface and middepth samples from plant or river to estimate the density of organisms in the upper layer and the middepth and bottom samples to estimate the density in the lower layer. The plant and river upper-and lower-layer densities for each date are computed using the procedure described in Section 2.1 for the Modified Utility (MU) method: all of the samples collected on a given date from a given layer during a given time period (day or night) are pooled [Eq. (V-1)].

In order to compute valid upper- and lower-layer w-ratios under the assumptions described in Section 2.2.1, the estimated densities of organisms in the upper and lower layers of an intake bay should be estimates, respectively, of the densities of organisms in cooling water drawn from the upper and lower layers of the river. However, the lower layer of an intake bay contains water drawn from the upper layer of the river. Since the upper and lower layers of the river may contain different densities of organisms, the observed density of organisms in the lower layer of an intake bay must be adjusted to account for the presence of water drawn from the upper layer of the river. We define:

d_{PU} = observed density of organisms in water drawn from the upper layer of the river,

d'_{PL} = observed density of organisms in the lower layer of the intake bay, reflecting the mixing of water drawn from both layers of the river,

d_{PL} = adjusted density of organisms in water drawn from the lower layer of the river.

Since 86% of the water in the lower layer of the intake bay is drawn from the lower layer of the river and 14% is drawn from the upper layer (Section 2.2.1), we express the relationship between the adjusted

density in the lower layer of the intake bay and the observed upper- and lower-layer densities using the following equation:

$$d'_{PL} = 0.14d_{PU} + 0.86d_{PL} \qquad \text{(V-6)}$$

Rearranging, the adjusted density of organisms in water drawn from the lower layer of the river is given by:

$$d_{PL} = (d'_{PL} - 0.14d_{PU})/0.86 \qquad \text{(V-7)}$$

Equation (V-7) is used to adjust the density estimates for the lower layer of the intake bay as computed from the raw data, to account for the presence of water drawn from the upper layer of the river. Occasionally, the observed density in the lower layer of the intake bay is less than 14% of the observed density in the upper layer. In these cases the adjusted density in the lower layer is set equal to 0.

After the computation and adjustment of density estimates for each date, seasonal plant and river upper and lower layer densities are calculated as unweighted averages over all dates (i.e., the same procedure used in the MU method). Next, w-ratios are obtained by computing the ratio of the seasonal plant upper layer density to the seasonal river upper layer density and of the plant lower layer density to the river lower layer density:

$$w_U = D_{PU}/D_{RU} \qquad \text{(V-8)}$$

$$w_L = D_{PL}/D_{RL} \qquad \text{(V-9)}$$

We next use the gear bias cancelling principle to compute an estimate of w_L which if free from gear bias. First, we form a ratio of w-ratios that can be used to express the observed value of w_L as a function of the observed value of w_U:

$$(w_U - w_L)/(w_U + w_L) = A \quad . \qquad \text{(V-10)}$$

This particular ratio, rather than other possible ratios (e.g., w_U/w_L), is employed because the distribution of possible values of A is symmetrical around 0 and bounded by 1.0 and -1.0. If the distribution were asymmetrical, then sampling error could cause estimates of A to be severely biased. It is easy to verify that gear bias terms cancel out of Eq. (V-10) so that the factor A is free of gear bias. Using the definitions of w_U and w_L presented on p. V-18, Eq. (V-10) can be rewritten as:

$$\begin{aligned} A &= (eD_{PU}/fD_{RU} - eD_{PL}/fD_{RL})/(eD_{PU}/fD_{RU} + eD_{PL}/fD_{RL}) \\ &= (e/f)(D_{PU}/D_{RU} - D_{PL}/D_{RL})/(e/f)(D_{PU}/D_{RU} + D_{PL}/D_{RL}) \\ &= (D_{PU}/D_{RU} - D_{PL}/D_{RL})/(D_{PU}/D_{RU} + D_{PL}/D_{RL}) \quad , \end{aligned}$$

where D_{PU}, D_{RU}, D_{PL}, and D_{RL} are the actual densities of organisms in the upper and lower layers of the river and intake bay. Next, we express w_L as a function of w_U and A:

$$\begin{aligned} w_U - w_L &= Aw_U + Aw_L \\ w_L &= w_U(1 - A)/(1 + A) \end{aligned} \qquad \text{(V-11)}$$

As discussed in Section 2.2.1, we assume that there are no lateral trends in ichthyoplankton abundance in the upper layer of the river, and no active avoidance of the intake structure by entrainable organisms. Given those assumptions, and given that all water in the upper layer of an intake bay is drawn from the upper layer of the river, the density of organisms in the upper layer of an intake bay should be equal to the density in the upper layer of the river. Therefore, the actual value of w_U, which we will denote as w_U^*, should be equal to 1.0 (observed deviations from 1.0 are assumed to be attributable to sampling error or to unequal plant and river gear efficiencies). Assuming that the value of w_U^* is 1.0, our estimate of the true value of w_L is given by:

$$w_L^* = (1 - A)/(1 + A) \quad . \qquad \text{(V-12)}$$

Values of A are computed from the seasonal estimates of upper and lower layer w-ratios [Eqs. (V-8 and (V-9)]. Wherever possible, we have chosen to combine estimates of A obtained at the same plant during different years before computing w_L^*. We do this for two reasons:

(1) If the observed value of w_U is 0.0, as occasionally occurs for some species and life-stages, then unless the observed value of w_L is also 0.0, A is equal to -1.0 and w_L^* (= 2/0) cannot be computed. Combining values of A across years eliminates this problem. If so few organisms are collected at a given plant that observed values of w_U are equal to 0.0 for more than one year, the GBC method is not used to calculate a W-factor.

(2) Combining values of A across years allows W-factors to be computed for years in which the plant data are not usable (e.g., Roseton in 1974), provided that sufficient river data exist for that year and that sufficient plant data exist for other years.

Thus, estimates of A that apply across years at any given plant are computed as unweighted means of the values computed for each individual year (3 years at Indian Point, 2 years for all other plants). After the across-years estimate of A is obtained, w_L^* is calculated using Eq. (V-12).

Finally, the computed value of w_L^* and the fractional distribution of organisms in the upper and lower layers of the river are used to compute the W-factor. If power plants withdrew water equally from all depths and there were no vertical stratification of organisms in the river, then the number of organisms entrained per unit time could be estimated from the following equation:

$$E = QWN/V \quad , \qquad \text{(V-13)}$$

where

E = number of organisms entrained per unit time,

Q = water withdrawal rate,

W = depth-averaged W-factor,

N = number of organisms in the river segment from which the plant withdraws water,

V = volume of the river segment from which water is withdrawn.

Since we have assumed that the river consists of two distinct layers and that power plants draw water differentially from these two layers, Eq. (V-13) must be modified to account for these assumptions:

$$E = Q_U w_U^* N_U / V_U + Q_L w_L^* N_L / V_L \quad , \qquad \text{(V-14)}$$

where

Q_U, Q_L = water withdrawal rates from the upper and lower layers of the river,

w_U^*, w_L^* = upper and lower layer w-ratios,

N_U, N_L = numbers of organisms in the upper and lower layers of the segment from which water is withdrawn,

V_U, V_L = volumes of upper and lower layers of the river segment from which water is withdrawn.

Because we have defined the upper and lower layers of the river with respect to a boundary that is equidistant between surface and bottom from shore to shore, V_U is equal to V_L. Given that 57% of the cooling water is drawn from the upper layer of the river and 43% from the lower layer, and that w_U^* is equal to 1.0, Eq. (V-14) can be rewritten as:

$$E = 0.57QN_U/0.5V + 0.43Qw_L^*N_L/0.5V \qquad \text{(V-15)}$$

If we define f_U as the fraction of organisms in the river segment that are contained in the upper layer of the river and f_L as the fraction contained in the lower layer, then:

$$E = 1.14Qf_UN/V + 0.86Qw_L^*f_LN/V$$
$$= Q(1.14f_U + 0.86w_L^*f_L)N/V \quad . \tag{V-16}$$

If Eqs. (V-13) and (V-16) are compared, it can be seen that the expression in parentheses in Eq. (V-16) is equivalent to the depth-averaged W-factor in Eq. (V-13). Therefore,

$$W = 1.14f_U + 0.86w_L^*f_L \quad . \tag{V-17}$$

Since we have defined the upper and lower layers of the river so that their volumes are equal, only the densities of organisms in the upper and lower layers, rather than absolute standing crops, are required in order to estimate f_U and f_L. These values are obtained from the same data bases used to compute the w-ratios and the MU W-factors. Seasonal upper and lower layer densities are computed by the same method used in computing the w-ratios [Eqs. (V-2) and (V-3)]. However, data obtained on all river sampling dates are used, regardless of whether or not simultaneous collections were made at the plant. Given the seasonal mean densities D_{RU} and D_{RL}, the fractional distribution of organisms in the upper and lower layers of the river is calculated from the following equations:

$$f_U = D_{RU}/(D_{RL} + D_{RU}) \tag{V-18}$$

$$f_L = D_{RL}/(D_{RL} + D_{RU}) \tag{V-19}$$

Unlike the values of A, f_U and f_L are computed separately for each year. Thus, each GBC W-factor is computed from a value of A that applies across years and values of f_U and f_L that are year-specific.

3. RESULTS

The results obtained when the MU and GBC methods were applied to plant and river ichthyoplankton data collected at the Bowline, Lovett, Indian Point, Roseton, and Danskammer power plants are presented in Tables V-3 - V-12. The populations for which W-factors could be computed are striped bass (Tables V-3 and V-4), white perch (Tables V-5 and V-6), Atlantic tomcod (Tables V-7 and V-8), bay anchovy (Tables V-9 and V-10), and Alosa spp. (Tables V-11 and V-12). Appendix B contains descriptions of the data bases used to compute W-factors for each plant and year. Separate day and night W-factors were computed for each of four life-stages (eggs, yolk-sac larvae, post yolk-sac larvae, and juveniles) for the years 1974 through 1976.

It was not possible to compute W-factors for all populations, life-stages, plants, and years. In some cases no data were available. No 1974 data for any population were available for Lovett and Danskammer. Although 1974 ichthyoplankton abundance data were available for all species for Bowline and Roseton, only the striped bass data were broken down by life-stage. For all other populations yolk-sac larvae, post yolk-sac larvae, and juveniles were pooled. W-factors could not be computed for those populations and life-stages. For bay anchovy, 1976 Lovett intake data were not available.

In other cases W-factors were not computed because the available data were deemed unsuitable (see Section 4) or because too few organisms were caught. The 1974 striped bass data collected at the Roseton intake were excluded because of insufficient sampling effort (see discussion in Section 4). Therefore, no MU W-factors could be calculated. Since sufficient Roseton/Danskammer river transect data were available for 1974, GBC W-factors could still be calculated. As mentioned in Section 2.2, GBC W-factors were not calculated for any population at Bowline because this plant does not draw water directly from the river. MU W-factors for Bowline were calculated using the Bowline Pond data rather than the intake data to estimate the density of organisms at the plant. Unlike the intake samples, the pond samples are collected using

Table V-3. W-factors for striped bass computed using the Modified Utility (MU) method[a,b]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Bowline	Eggs	--	--	0.03	0.09	0.28	0.00
	YSL	0.36	0.08	0.32	0.11	0.10	0.17
	PYSL	0.49	0.40	0.24	0.98	0.10	0.60
	Juveniles	--	--	--	--	--	--
Lovett	Eggs	--	--	--	0.98	0.16	0.28
	YSL	--	--	4.16	0.43	0.14	0.55
	PYSL	--	--	1.42	3.31	0.04	0.64
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	1.37	1.61	0.64	1.94	0.49	0.85
	YSL	0.98	0.61	0.41	0.28	0.48	0.49
	PYSL	0.45	0.65	0.69	1.40	1.07	0.39
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	--	--	1.95	--	2.01	3.31
	YSL	--	--	1.66	1.03	1.05	0.76
	PYSL	--	--	2.20	0.61	0.91	0.29
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	0.39	--	1.56	6.82
	YSL	--	--	0.61	0.48	2.58	0.78
	PYSL	--	--	1.23	0.16	2.34	1.03
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

Table V-4. W-factors for striped bass computed using the Gear Bias Cancelling (GBC) method[a,b,c]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Lovett	Eggs	--	--	--	0.32	0.59	0.32
	YSL	--	--	1.15	1.16	1.15	1.16
	PYSL	--	--	3.37	1.45	3.29	1.55
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	1.22	0.16	1.20	0.34	1.20	0.24
	YSL	0.82	0.80	0.77	0.80	0.79	0.86
	PYSL	0.98	0.97	0.98	0.91	0.97	0.91
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	0.66	0.37	0.37	--	0.41	0.24
	YSL	0.98	0.78	0.95	0.78	0.94	0.76
	PYSL	0.55	0.84	0.64	0.88	0.62	0.86
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	1.18	--	1.17	0.94
	YSL	--	--	0.55	0.88	0.52	0.86
	PYSL	--	--	0.69	0.99	0.68	0.99
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

[c]GBC W-factors are not calculated for Bowline.

Table V-5. W-factors for white perch computed using the Modified Utility (MU) method[a,b]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Bowline	Eggs	--	--	21.51	--	2.04	--
	YSL	--	--	0.78	0.49	--	--
	PYSL	--	--	0.09	0.74	0.24	0.78
	Juveniles	--	--	--	--	--	--
Lovett	Eggs	--	--	--	--	0.67	0.37
	YSL	--	--	--	--	0.21	0.14
	PYSL	--	--	1.12	1.17	0.03	0.13
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	2.36	--	2.59	--	2.19	6.21
	YSL	1.30	0.19	0.81	0.16	1.30	0.14
	PYSL	1.01	0.99	0.60	0.50	1.28	1.10
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	--	--	4.38	3.23	9.56	4.93
	YSL	--	--	0.85	1.34	0.22	0.56
	PYSL	--	--	0.84	0.88	1.98	0.40
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	16.68	11.14	18.67	16.68
	YSL	--	--	0.51	0.00	0.21	0.32
	PYSL	--	--	1.85	1.04	0.45	0.83
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

Table V-6. W-factors for white perch computed using the Gear Bias Cancelling (GBC) method[a,b,c]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Lovett	Eggs	--	--	--	--	0.45	1.12
	YSL	--	--	--	--	0.75	0.73
	PYSL	--	--	1.12	0.98	1.13	0.98
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	1.18	1.36	1.18	1.43	1.18	1.73
	YSL	0.90	0.56	0.89	0.53	0.93	0.69
	PYSL	0.92	0.77	0.90	0.76	0.93	0.80
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	--	--	0.43	0.56	0.50	0.64
	YSL	--	--	0.28	1.46	0.64	1.33
	PYSL	--	--	1.05	0.99	1.05	0.99
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	0.35	0.44	0.43	0.53
	YSL	--	--	0.69	1.06	0.88	1.09
	PYSL	--	--	0.82	1.01	0.80	1.02
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

[c]GBC W-factors are not calculated for Bowline.

Table V-7. W-factors for Atlantic tomcod computed using the Modified Utility (MU) method[a,b]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Bowline	Eggs	--	--	--	--	--	--
	YSL	--	--	0.40	0.50	1.09	0.51
	PYSL	--	--	0.41	1.09	0.28	0.55
	Juveniles	--	--	0.00	0.00	0.00	0.01
Lovett	Eggs	--	--	--	--	--	--
	YSL	--	--	0.42	0.71	4.12	1.19
	PYSL	--	--	1.27	1.70	0.27	0.11
	Juveniles	--	--	0.00	0.04	0.21	0.04
Indian Point	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	0.00	1.71	0.70	10.34	1.07	--
Roseton	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	0.37	3.37
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	1.50	1.71
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

Table V-8. W-factors for Atlantic tomcod computed using the Gear Bias Cancelling (GBC) method[a,b,c]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Lovett	Eggs	--	--	--	--	--	--
	YSL	--	--	1.32	1.03	1.28	1.00
	PYSL	--	--	1.08	0.66	1.08	0.53
	Juveniles	--	--	0.08	0.10	0.08	0.08
Indian Point	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	0.32	0.57	0.42	0.55	0.32	--
Roseton	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	1.03	0.75
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	--	--	--	--	2.04	0.54

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

[c]GBC W-factors are not calculated for Bowline.

Table V-9. W-factors for bay anchovy computed using the Modified Utility (MU) method[a,b]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Bowline	Eggs	--	--	0.11	0.31	0.01	0.57
	YSL	--	--	0.15	--	--	--
	PYSL	--	--	0.95	0.98	0.24	0.51
	Juveniles	--	--	--	0.78	--	1.77
Lovett	Eggs	--	--	7.11	4.31	--	--
	YSL	--	--	44.35	225.35	--	--
	PYSL	--	--	1.97	3.65	--	--
	Juveniles	--	--	--	0.17	--	--
Indian Point	Eggs	0.45	0.81	1.26	0.90	2.24	9.19
	YSL	1.65	--	1.39	0.12	0.67	0.41
	PYSL	1.45	0.63	0.97	1.60	2.03	0.20
	Juveniles	1.27	36.32	1.61	10.53	--	1.05
Roseton	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

Table V-10. W-factors for bay anchovy computed using the Gear Bias Cancelling (GBC) method[a,b,c]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Lovett	Eggs	--	--	0.38	0.19	--	--
	YSL	--	--	0.06	156.94	--	--
	PYSL	--	--	1.34	1.06	--	--
	Juveniles	--	--	7.83	1.20	--	--
Indian Point	Eggs	0.53	0.33	0.53	0.19	0.60	0.16
	YSL	1.43	--	1.35	0.30	1.40	0.27
	PYSL	1.01	0.58	0.96	0.63	0.98	0.60
	Juveniles	0.31	0.74	0.68	0.85	--	0.86
Roseton	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	--	--	--	--	--	--
Danskammer	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	--	--	--	--
	Juveniles	--	--	--	--	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

[c]GBC W-factors are not calculated for Bowline.

Table V-11. W-factors for *Alosa* spp. computed using the Modified Utility (MU) method[a,b]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Bowline	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	0.44	5.33	0.53	0.59
	Juveniles	--	--	--	--	--	--
Lovett	Eggs	--	--	--	--	--	--
	YSL	--	--	0.00	--	--	29.77
	PYSL	--	--	2.26	1.65	0.29	0.57
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	--	--	--	--	--	--
	YSL	1.00	0.88	0.79	0.50	1.28	1.49
	PYSL	1.16	1.07	1.36	1.47	1.05	1.82
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	--	--	12.19	1.53	10.07	5.82
	YSL	--	--	1.18	0.91	0.63	0.96
	PYSL	--	--	0.55	0.40	0.34	0.66
	Juveniles	--	--	1.33	0.43	--	1.97
Danskammer	Eggs	--	--	62.24	22.23	17.77	52.67
	YSL	--	--	2.07	1.32	0.46	0.76
	PYSL	--	--	1.12	0.40	0.53	0.69
	Juveniles	--	--	0.71	0.17	--	0.38

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

Table V-12. W-factors for Alosa spp. computed using the Gear Bias Cancelling (GBC) method[a,b,c]

Plant	Life-stage	1974 Day	1974 Night	1975 Day	1975 Night	1976 Day	1976 Night
Lovett	Eggs	--	--	--	--	--	--
	YSL	--	--	--	--	--	--
	PYSL	--	--	1.21	0.85	1.21	0.80
	Juveniles	--	--	--	--	--	--
Indian Point	Eggs	--	--	--	--	--	--
	YSL	0.86	0.69	0.89	0.59	0.92	0.69
	PYSL	1.02	0.91	1.06	0.90	1.05	0.89
	Juveniles	--	--	--	--	--	--
Roseton	Eggs	--	--	0.48	0.77	0.51	0.96
	YSL	--	--	0.78	0.84	0.87	0.78
	PYSL	--	--	0.92	0.88	0.93	0.88
	Juveniles	--	--	0.53	0.85	--	--
Danskammer	Eggs	--	--	0.47	0.89	0.50	1.02
	YSL	--	--	0.57	0.74	0.70	0.66
	PYSL	--	--	1.16	0.98	1.16	0.97
	Juveniles	--	--	0.92	1.23	--	--

[a]Sources of data described in Appendix B.

[b]The available data were not sufficient to calculate W-factors for all life-stages at all plants during all years.

[c]GBC W-factors are not calculated for Bowline.

the same gear and deployment technique used to collect the river samples. Therefore, MU W-factors computed from the pond data should be free from gear bias.

W-factors computed using any method will be highly unreliable if they are based on ichthyoplankton collections containing only a few organisms. Unrealistically high or low W-factors (particularly values of 0 or infinity) are more likely to be produced under these circumstances. Therefore, we used an exclusion criterion to eliminate W-factors based on insufficient numbers of organisms. In order to calculate a W-factor for a given population, life-stage, and period (day or night) at a given plant, we require that at least 10 organisms have been collected in either the plant samples or the river samples used to compute that W-factor. Many data sets failed to meet the 10-organisms exclusion criterion. In particular, in only a few cases, primarily for bay anchovy and Alosa, was it possible to compute W-factors for entrainable juveniles. So few data sets for juvenile striped bass and white perch satisfied the 10-organism criterion that we decided not to compute any MU or GBC W-factors for juveniles of these species.

When near-field data collected at power plant intakes and river transects were unavailable or unusable (Section 4), W-factors were computed from riverwide abundance data using the method described in Chapter V-6.

4. DISAGREEMENTS WITH DATA AND METHODS USED BY LMS IN EXHIBIT UT-3 TO COMPUTE W-RATIOS

Ideally, plant river samples used to compute w-ratios or W-factors should be collected using identical gear deployed in an identical manner (Carpenter 1979). Moreover, large numbers of samples should be collected at each location in order to obtain estimates of plant and river abundance that are as precise as possible given the limitations imposed by the patchy distribution of ichthyoplankton. Judged by these criteria, none of the Hudson River sampling programs has every been ideal for obtaining data suitable for estimating W-factors. For the most part we have used the available data in spite of their limitations. However, some of the data have been collected under conditions that deviate so far from the ideal that we believe they should not be used to compute W-factors. In this section we identify these data and explain our reasons for excluding them. We also discuss two methodological problems that we believe have led LMS to underestimate the numbers of organisms entrained at Hudson River power plants. One of these is the overestimation of sample volumes at the Indian Point intake and discharge staions. The other is LMS' assumption that if no organisms are collected in either the plant or the river samples, the w-ratio is equal to zero.

4.1 NINETY MINUTE SAMPLE DURATIONS AT THE BOWLINE INTAKE

According to page 9.1A-15 of Exhibit UT-7A, during the entire 1974 entrainment sampling season and prior to June 10, 1975, the sampling duration at the Bowline intake was 90 minutes. Ecological Analysts (1976a) conducted studies at Bowline and Lovett between May and July 1975 in order to determine whether nets left in the water for such extended periods of time could become clogged with detritus. It was found that such clogging could indeed occur, and could result in substantial reductions in the filtration efficiency of the nets. Sample volumes at Bowline are not measured directly from flowmeter readings, but are estimated indirectly using the matrix of intake

velocities presented in Table 9.1A-4 of Exhibit UT-7A. Therefore, in addition to possible increased gear avoidance, reductions in filtration efficiency due to clogging would cause sample volumes at the Bowline intake to be overestimated. If intake sample volumes used in computations are erroneously high, then the densities of organisms in the intake samples (and therefore the w-ratios) would be erroneously low.

According to EA's 1975 Annual Interpretive Report for Bowline (Ecological Analysts 1976a, p. B-2), significant reductions in net filtration efficiency due to clogging were observed in experiments conducted on May 7, May 14, June 2, June 25, and July 10, 1975. Clogging was most frequently observed in nets placed at the bottom of the intake bay. In some of these experiments, clogging began to be observed after only about 40 m^3 of water had been filtered; in all experiments in which significant clogging was observed, it was observed before 80 m^3 had been filtered. The importance of this finding can be seen from Table V-13, which contains information pertaining to the volumes of samples collected at the Bowline intake during the period between June 5 and July 12, 1974 (no intake samples collected prior to June 5 were used to compute w-ratios). The volumes of intake samples collected during this period, as estimated using Table 9.1A-4 of Exhibit UT-7A, are far higher than the 40 to 80 m^3 range in which EA began to observe clogging. The mean sample volumes on the four dates listed in Table V-13 ranged from 132 to 148 m^3. The volumes of the smallest samples collected during this period were larger than 130 m^3. Based on EA's observations of clogging at sample volumes of 80 m^3 and less, such clogging could have occurred frequently at the Bowline intake in 1974. According to the testimony of Dr. Gerald Lauer of EA the clogging of nets observed at Bowline in 1975 was an unusual occurrence related to "an extraordinary increase in the volume of detritus collected in the nets" (Transcript pp. 8119). Under cross-examination he claimed that this conclusion was included in EA's report. Dr. Lauer stated (Transcript pp. 8119-20): "as I recall from the report itself, in general the report concluded that based upon these perceptions of

Table V-13. Mean, minimum, and maximum volumes of samples collected at the Bowline intake on selected sampling dates during 1974[a,b]

Date	Volume (m^3)		
	Mean (number of samples)	Minimum	Maximum
June 5 (day)	142.5 (12)	131.4	163.8
June 5 (night)	132.3 (12)	131.4	134.1
June 12 (day)	136.1 (9)	131.4	163.8
June 12 (night)	142.5 (6)	131.4	163.8
June 19 (day)	145.9 (18)	131.4	163.8
June 19 (night)	137.4 (12)	131.4	163.8
June 26 (day)	142.5 (18)	131.4	163.8
June 26 (night)	147.6 (12)	131.4	163.8
July 2 (day)	142.5 (12)	131.4	163.8
July 2 (night)	140.6 (11)	131.4	163.8

[a]Source of data described in Appendix B.

[b]Data collected on these dates were used by LMS to compute w-ratios for striped bass life-stages.

volume of detritus that you see in the nets ordinarily, this was an extraordinary occurrence that you would not expect to see most of the time in most years." Despite a thorough search, I found no such conclusions anywhere in EA's report on the clogging experiments (Ecological Analysts 1976a, pp. B-1 - B-9). Moreover, Ecological Analysts did not conduct the entrainment sampling at Bowline in 1974 (it was done by LMS), so that neither Dr. Lauer nor any other EA personnel could have observed whether detritus loads at the Bowline plant were lower in 1974 than in 1975.

In any case, Dr. Lauer's suggestion that the occurrence of clogging can be determined from the amount of visible detritus collected in the nets is at variance with the conclusion of Smith, Counts and Clutter (1968; p. 245) that:

> We found that indirect means of judging whether clogging will take place, such as taking a Secchi disc reading, was not a suitable substitute for monitoring filtration efficiency. Inspection of the net after a tow was not reliable for determining whether it had clogged. After heavy clogging at San Pedro, the net was discolored but no indication of clogging appeared at the Catalina Island site, even when the net had been accepting less than half of the water presented to it at the end of the tow.

According these authors, clogging can be detected only by comparing velocity readings taken from flowmeters placed inside and outside a plankton net.

Since there is no scientifically valid evidence that the amount of detritus present at the Bowline plant was higher in 1975 than in 1974, and since subjective impressions about the amount of detritus collected in a plankton sample are not alone sufficient to determine whether or not significant clogging has occurred, we conclude that clogging may well have occurred during the 1974 sampling program and gone undetected. Therefore we believe that all of the data collected at the Bowline intake during 1974 and up to June 10, 1975 should have been excluded when LMS' w-ratios were calculated. We have not used any of this data to compute W-factors. The sampling program conducted at Lovett in 1975

was identical to that at Bowline in that the duration of sampling at the intake was 90 minutes on all sampling dates prior to June 10, 1975 (Ecological Analysts 1976b). We have excluded this data from our estimates of W-factors for all species except Atlantic tomcod. This exception was made because Lovett and Bowline are the only plants at which enough simultaneous plant/river sampling is conducted during the early spring for W-factors to be calculated for yolk-sac larvae of this species. We felt that the advantage of having the additional data for this life-stage outweighed the disadvantage of the potential bias.

4.2 BOWLINE POND VS BOWLINE INTAKE

When the Bowline plant is operating, Bowline Pond functions as a very large intake bay: water is pulled into the pond by the pumps, entrained through the plant, and discharged back out into Haverstraw Bay. Organisms drawn in with the cooling water can leave the pond in only two ways: by being entrained through the plant or by swimming back out of the pond against the current caused by the intake flow. In order to avoid being entrained, an organism must first locate the pond inlet, a "keyhole" only 240 feet wide and about 15 feet deep (Exhibit UT-7, Fig. 3.1-6). Judging from Fig. 3.1-7 of Exhibit UT-7, the pond itself is roughly 1500 to 2000 feet across and 30 to 40 feet deep. Having reached the inlet, the organism must then swim out against the flow being drawn into the pond.

It does not seem likely that very many larvae could achieve this feat before being entrained (escape is, of course, out of the question for eggs). If all, or nearly all, the ichthyoplankton drawn into Bowline Pond is destined to be entrained through the plant, it seems reasonable to us to use the data collected in Bowline Pond, rather than data collected at the intake, to calculate W-factors. As we mentioned in Section 2.2 and again in Section 3, the pond samples are collected with the same gear used to collect the river samples, and thus no gear biases should be introduced when w-ratios are calculated using pond data rather than intake data. LMS did calculate w-ratios using pond

data, but only when no intake data was available. We believe that the pond data are clearly superior to the intake data and that they should have been used to calculate all of the w-ratios for Bowline.

4.3 INSUFFICIENT SAMPLING EFFORT AT THE ROSETON PLANT, 1974

The sampling program conducted at Roseton in 1974 was of especially poor design for estimating W-factors. Only 12 samples were collected at the intake on each sampling date. Of these, six were collected at dawn or dusk. However, LMS did not use dawn or dusk data to compute w-ratios. Thus, half of the samples collected at the Roseton intake were automatically excluded from LMS' analysis. Of the remaining six samples per date, many failed to meet LMS' outlier criteria (Exhibit UT-3, p. 3-IV-49) and were therefore excluded. The remaining sampling effort, measured either as the number of samples collected or as the total volume sampled, was extraordinarily small. Table V-14 contains the total number of day and night samples collected (minus outliers) and the total day and night sample volumes for five sampling dates between May 9 and July 2, 1974. Data collected on these five dates were used by LMS to compute all 1974 w-ratios for Roseton (Exhibit UT-3, p. 3-IV-51). After excluding outliers, dawn and dusk samples, and samples collected on days when no river samples were collected, only 17 samples remain for the entire striped bass entrainment season. Only eight samples were available for computing daytime w-ratios and only nine for nighttime w-ratios. On three of the five dates the total volume sampled during the day was less than 20 m^3; on two dates less than 20 m^3 was sampled at night. The highest volume sampled, on the night of July 2, was less than 120 m^3. By comparison, the smallest individual sample collected at Bowline between June 5 and July 12, 1974 had a volume greater than 130 m^3 (Table V-13).

Tables V-14 through V-16 contain similar analyses of the sampling effort at Roseton in 1975 and at Bowline and Indian Point in both 1974 and 1975. The data used by LMS to compute w-ratios for Bowline and Indian Point in 1974, and for all three plants in 1975, were obtained

Table V-14. Numbers of samples and total volumes sampled at the Roseton intake on selected sampling dates during 1974 and 1975[a,b]

Date	Volume[c] (number of samples) Day	Night
	1974	
May 9	10.0 (1)	8.5 (1)
May 21	69.7 (3)	46.7 (2)
June 4	0 (0)	15.6 (1)
June 19	63.5 (3)	71.4 (2)
July 2	18.8 (1)	117.9 (3)
	1975	
May 15	420.9 (6)	259.7 (3)
May 22	406.6 (6)	205.5 (3)
May 29	748.6 (8)	410.6 (5)
June 2	251.9 (18)	126.9 (8)
June 9	272.0 (6)	125.7 (3)
June 19	292.8 (6)	128.6 (3)
June 23	261.5 (6)	147.5 (3)

[a]Source of data described in Appendix B.

[b]Data collected on these dates were used by LMS to compute w-ratios for striped bass life-stages.

[c]Sum of volumes of all samples collected during the day or night, after excluding outliers.

Table V-15. Numbers of samples and total volumes sampled at the Indian Point intake and discharge stations on selected sampling dates during 1974 and 1975[a,b,c]

1974		1975	
Date	Volume (number of samples)	Date	Volume (number of samples)
May 7	279.9 (23)	May 13	179.8 (22)
May 28	258.5 (18)	May 20	545.5 (92)
June 4	519.6 (36	May 27	470.0 (72)
June 13	425.0 (27)	June 3	448.1 (72)
June 25	473.2 (34)	June 10	379.5 (54)
July 2	663.6 (43)	June 17	608.6 (96)
July 9	476.0 (33)	June 24	869.1 (140)
		July 1	555.8 (88)

[a]Source of data described in Appendix B.

[b]Data collected on these dates were used by LMS to compute w-ratios for striped bass life-stages.

[c]All intake and discharge stations combined.

[d]Sum of volumes of all samples and total number of samples collected during nighttime at all intake and discharge stations (no plant samples are collected during daytime), after excluding outliers.

Table V-16. Numbers of samples and total volumes sampled at the Bowline intake and in Bowline Pond on selected sampling dates during 1974 and 1975[a,b]

	Volume (number of samples)[c]			
	Bowline intake		Bowline pond	
Date	Day	Night	Day	Night
1974				
May 8	0 (0)	0 (0)	1425.5 (6)	1572.7 (10)
May 22	0 (0)	0 (0)	1225.8 (8)	2048.7 (10)
June 5	1710.0 (12)	1587.6 (12)	1185.1 (7)	2261.9 (10)
June 19	2626.2 (18)	1648.8 (12)	1285.3 (8)	1758.8 (10)
June 26	2565.0 (18)	1771.2 (12)	217.9 (4)	0 (0)
July 2	1710.0 (12)	1546.2 (11)	1946.2 (10)	752.8 (3)
1975				
May 20	0 (0)	0 (0)	510.1 (2)	558.4 (2)
May 27	0 (0)	0 (0)	575.0 (2)	602.0 (2)
June 3	333.9 (3)	683.1 (6)	570.2 (2)	529.0 (2)
June 10	50.3 (8)	92.7 (15)	586.7 (2)	612.7 (2)
June 17	92.7 (15)	37.1 (6)	618.5 (2)	563.2 (2)
June 18	30.9 (5)	117.4 (19)	0 (0)	0 (0)

[a]Source of data described in Appendix B.

[b]Data collected on these dates were used by LMS to compute w-ratios for striped bass life-stages.

[c]Sum of volumes of all samples and total number of samples collected during the day or night, after excluding outliers.

from sampling programs that were far more intensive than that conducted at Roseton in 1974. Eighty-four intake samples were used to compute the 1975 w-ratios for Roseton (Table V-14). The smallest volume sampled at Roseton during the day or night on any date in 1975 (125.7 m^3 on the night of June 9) was greater than the largest volume sampled during any similar period in 1974.

On each night during both years more samples were collected at the Indian Point intake and discharge stations than were used by LMS to compute 1974 w-ratios for Roseton (Table V-15). On most of these nights the total volume sampled exceeded the total volume (422 m^3) of the 1974 Roseton intake samples. Only at the Bowline intake on June 10, June 17, and June 18, 1975 were total day or night sample volumes as low as the volumes sampled throughout the 1974 entrainment season at Roseton (Table V-16).

In Section 1.1 we discussed the fact that ichthyoplankton distributions in the Hudson River are patchy, or overdispersed. As a consequence of this over-dispersion, the probability that any particular intake sample will contain zero organisms, even when organisms are in fact being entrained, is much higher than it would be if organisms were randomly distributed throughout the intake water. Therefore, given the low sampling effort, it is not surprising that very few striped bass were collected at the Roseton intake in 1974. We have determined from LMS' data tapes (Appendix B) that the 17 samples used to compute the w-ratios for 1974 contained a total of three striped bass yolk-sac larvae, all caught in the single sample available for June 4, and two post yolk-sac larvae, both caught at night on July 2. In our opinion no meaningful estimates of the abundance of striped bass ichthyoplankton in water entrained by the Roseton plant can be obtained from the data collected at the Roseton intake in 1974. No faith can be placed in the w-ratios calculated from these data. We have not used them to compute any W-factors.

4.4 USE OF SAMPLES COLLECTED AT INDIAN POINT RIVER STATIONS F AND G

NYU collected ichthyoplankton samples at seven river stations in 1974 and 1975 (Exhibit UT-3, Fig. 3-IV-8). LMS used data from all seven stations to compute the densities of striped bass life-stages in the vicinity of the Indian Point plant. These river densities were then used to compute the w-ratios. In addition, data collected at three of the seven stations, stations B, D, and G, were used as substitutes for intake and discharge stations when the daytime w-ratios were calculated (no plant samples are collected during the daytime at Indian Point).

According to Table 1-5 of NYU's Progress Report for 1975 (New York University 1977), Stations A through E are all located between river miles 41 and 43 (the plant itself is located at RM 42). Stations F and G, however, are located at RM 39, three miles downriver from the plant. We believe that stations F and G are too far from the Indian Point plant to be considered "near-field" stations and therefore we have not used data collected at these stations to compute W-factors.

According to p. 3-IV-20 of Exhibit UT-3, the hydraulic model studies performed at LaSalle Hydraulic Laboratory show that "water comes to the Indian Point intakes from a band about 200 to 350 ft (61 to 107 m) wide along the east shore of the river during the ebb and flood stages." At slack tide, water is drawn from "a radius of approximately 1600 ft (488 m) from the intake." It is for this reason that we chose stations D and E rather than stations C and D as substitutes for intake and discharge stations. Although station C is directly opposite the Indian Point intakes (Exhibit UT-3, Fig. 3-IV-8), it is more than 1600 feet from those intakes, according to Dr. O'Connor of NYU (Transcript p. 8527). Since station E is closer to the shoreline than station C (Exhibit UT-3, Fig. 3-IV-8), in theory it should be more representative of the water actually entrained by the plant. We say "in theory" because in practice no consistent differences have been observed among the densities of entrainable striped-bass life stages at any of river stations A through E. According to Table 7-5 of NYU's Progress Report

for 1974 (New York University 1976), in 1974 significantly lower densities of striped bass larvae (= post yolk-sac larvae) were observed at station G than at station B. Otherwise, no significant differences among stations were observed. According to Table 7-6 of NYU's 1975 Progress Report (New York University 1977), in 1975 no significant differences in abundance among stations were observed for any striped bass life-stage. These results appear to indicate that, at least for striped bass, it does not make a great deal of difference which river stations are chosen to represent the plant.

4.5 INTAKE AND DISCHARGE SAMPLE VOLUMES AT INDIAN POINT

In 1974 and 1975, the volumes of samples collected at the Indian Point intake and discharge stations were not measured with flowmeters. Instead, volumes were estimated indirectly, as they are at Bowline and Lovett. However, unlike LMS, NYU did not use actual measurements of intake or discharge canal velocities to estimate the volumes sampled. The volumes were calculated assuming that at full flow the intake velocity at both Indian Point Units 1 and 2 is 1.0 feet per second, and that the velocity at all discharge stations is 4.5 feet per second (Exhibit EPA-141). These velocities were multiplied by a flow factor equal to the fraction of the maximum possible flow observed on each sampling date (Exhibit EPA-141). The velocities used to compute sample volumes are incorrect; NYU's applicaton of the flow factors is also incorrect. According to Table 1-2 of NYU's Progress Report for 1975 (New York University 1977), the maximum design velocities at the Indian Point Unit 1 and 2 intakes are, respectively, only 0.7 feet per second and 0.9 feet per second. The design velocity at discharge station D-1 is 4.4 feet per second, only slightly smaller than the assumed value. However, the design velocity at discharge station D-2 is substantially smaller, only 3.4 feet per second. The velocities presented in Table 1-2 of NYU's 1975 Progress Report are those expected at mean low water in the Hudson. According to the heading of Table 1-2, velocities are expected to be 10% lower than the stated values at high slack tide and 5% lower at low slack tide.

On Transcript pp. 8244-45 Dr. O'Connor of NYU confirmed that the design velocities are the velocities that should have been used:

> MR. KURENT: If it were a full flow situation- that is, 100 percent operation- would you use the one foot per second at the intake and the 4.5 feet per second at the discharge?
>
> DR. O'CONNOR: No.
>
> According to the design values we had at the time, we would have used .9 feet per second for the Unit 2 intake and .7 feet per second for the Unit 1 intake.

On Transcript pp. 8254-55, Dr. O'Connor stated that, instead of the design velocities contained in NYU's 1975 Progress Report, the velocities contained in Exhibit EPA-141 were used in the preparation of the utilities' testimony for these hearings:

> MR. KURENT: Although Table 72 does reflect less than full flow was considered, did you still assume as stated in Exhibit 141 that full flow velocity was one foot per second?
>
> DR. O'CONNOR: Yes, we did at the time of the preparation of this report. That value, however, was corrected earlier this spring when the data -- when the plant operating data were being reevaluated in preparation for submission of the Federal Energy Regulatory Commission report on Cornwall.
>
> MR. KURENT: Are you saying that you used the one-foot per second velocity for the preparation of the testimony that was submitted on July 11, 1977 for this hearing?
>
> DR. O'CONNOR: Add (sic) corrected by the percentage flow, yes.

The errors introduced by NYU's assumption of erroneously high intake velocities are partially offset by an erroneous application of flow factors to correct for cooling water flows of less than 100% of capacity. When any particular circulator pump is operating, that pump is operating at 100% of capacity, regardless of whether other pumps are operating or not. Since each pump at Indian Point Units 1 and 2 is located in a separate forebay, the intake velocity within a forebay containing an operating pump should always be 100% of the design flow.

Since an intake sample can be collected only from a forebay containing an operating pump, no flow factors need to be applied in order to estimate the volumes of the intake samples. There is no such offsetting error in the computation of the discharge sample volumes. When the actual cooling water flow is less than 100% of capacity, the design velocities presented in NYU's 1975 Progress Report for discharge Stations D-1 and D-2 must be adjusted downward using the flow factors.

Primarily because of the erroneously high values used for sampling velocities at the Unit 1 intake and at discharge Station D-2, the nighttime densities (and the w-ratios as well) of striped bass life stages computed by LMS for the Indian Point plant in 1974 and 1975 are erroneously low. As no plant samples are used to compute daytime w-ratios, these are not affected by the errors discussed in this secton.

4.6 COMPARISON OF SURFACE AND MIDDEPTH SAMPLES COLLECTED IN BOWLINE POND TO SURFACE, MIDDEPTH, AND BOTTOM SAMPLES COLLECTED IN THE RIVER

During May of both 1974 and 1975, pairs of river and plant data sets collected on the same day were not available for Bowline. Since paired sets of river and Bowline Pond data were available, LMS calculated w-ratios using the pond data as a substitute for data collected at the plant itself. We agree that it is valid to use data collected in Bowline Pond to calculate W-factors. In fact, as is stated in Section 4.2, we believe that these data are <u>superior</u> to data collected at the Bowline intake and that they should be used to compute all W-factors for Bowline. We disagree, however, with the method used by LMS to compute w-ratios using the pond data.

Two stations in Bowline Pond, referred to as Bowline Pond Long (BPL) and Bowline Pond Short (BPS), were sampled in 1974 (Exhibit UT-7A, p. 9.1A-7). Only Bowline Pond Long was sampled in 1975 (Exhibit UT-7A, p. 9.1A-7). Surface, mid-depth, and bottom samples were collected at station BPS, but, due to obstructions on the bottom of the pond, only surface and mid-depth samples were collected at station BPL. LMS computed pond lower layer densities for 1974 using bottom

samples collected at BPS and mid-depth samples collected at both BPS and BPL. Similar lower layer densities for 1975 were computed using only the mid-depth samples collected at Bowling Pond Long. The corresponding lower layer densities for the river were computed using both mid-depth and bottom samples.

The highest densities of striped bass eggs and larvae in the river are generally found near the bottom, especially during the daytime (Exhibit UT-4, Sections 7.3.6, 7.4.1.6, and 7.4.2.7). If the pattern of distribution of these life-stages in Bowline Pond is similar to that found in the river, then the lower layer w-ratios computed by LMS using the 1975 pond data may be biased. If eggs and larvae in Bowline Pond are more abundant at the bottom than at mid-depth, and if bottom samples had been collected at station BPL, then higher lower layer densities, and therefore higher lower layer w-ratios, would have been computed.

In the absence of bottom samples, it is not possible to show whether the vertical stratification of ichthyoplankton in Bowline Pond is similar to or different from that found in the River. However, there is no reason to believe that these organisms behave any differently in the pond than they do in the river. Eggs will still tend to sink unless resuspended by turbulence. Larvae will still migrate toward the bottom during the day and disperse throughout the water column at night. This fact was acknowledged by Dr. O'Connor of NYU on Transcript p. 8548:

> DR. O'CONNOR: As pointed out by Dr. Englert, the larvae probably undergo the same sorts of diurnal migration in the pond, those that might occur there as they undergo in the river.

However, Dr. O'Connor claimed that the turnover rate of Bowline Pond (i.e., the rate at which water in the pond is entrained through the Bowline plant and replaced by water drawn from the river) is so high that eggs and larvae would not have time to accumulate at the bottom (Transcript pp. 8539-41):

MR. KURENT: Would you expect the concentration of striped bass eggs to be highest near the bottom given the conditions prevailing in that pond?

DR. O'CONNOR: I would not expect that.

First of all, there is no evidence that striped bass spawn in Bowline pond. Therefore, to have large numbers of eggs in the pond is unlikely.

The entrance to the Bowline pond, I believe, has a depth only of five feet. Therefore, any striped bass eggs emerging the pond are going to be those from about the top five feet of water in the river and the turnover of water in the pond is sufficiently rapid; I would believe that there would be insufficient time for the eggs to sink to the bottom.

MR. KURENT: Larvae that would be present in the pond would be more likely to remain at or near the bottom amongst the objects near the bottom; wouldn't they?

DR. O'CONNOR: I honestly couldn't say.

First of all, there are no samples from the very bottom strata.

Larvae which entered the pond, again, will be those which are capable of coming over that sill at the entrance to the pond. And since most of the data, to my recollection, indicate that yolk sack larvae and the younger of the post yolk sack larvae tend to remain in the bottom and middle depths of the river, that the numbers coming over the sill would be relatively small.

And, again, turnover in the pond would probably be sufficiently rapid to prevent them from forming any great accumulation in the bottom.

Since there is no information available on the sinking rate of striped bass eggs in Bowline Pond, there is no way to verify or disprove Dr. O'Connor's claim with respect to this life-stage. However, it seems likely that there is in fact sufficient time for the actively migrating larvae to move to the bottom. Diurnal migration occurs over a period of only a few (at most 12) hours: larvae present in the upper strata during the night are capable of moving to the bottom strata by the next afternoon. Therefore, unless the average residence time of larvae present in the pond is less than 12 hours, they will be able to migrate to the bottom before being entrained.

We believe that given the tendency of organisms to distribute themselves within the pond in the same way they are distributed in the river, and given the lack of data on the actual vertical distribution of organisms in the pond, it is better to assume that the pond and river distributions are the same. Therefore, in our calculation of W-factors for Bowline we have compared data collected at the surface and at mid-depth in Bowline Pond to data collected at the same depths in the river. We have excluded all of the data collected at the river bottom. For consistency we have also excluded the bottom samples collected at station BPS in 1974.

4.7 ZERO DIVIDED BY ZERO EQUALS ZERO

At Bowline in 1974 no striped bass eggs were caught during the daytime at either the river or the Bowline Pond stations assigned to the lower layer (Exhibit UT-3, Table 3-IV-22). Similarly, at Roseton, both in 1974 and in 1975, no eggs were collected at night in either the river samples or the plant samples assigned to the upper layer (Exhibit UT-3, Tables 3-IV-25 and 3-IV-26).

In all cases in which the seasonal plant and river densities are identical and non-zero, the w-ratio is equal to one. Therefore, it seems logical to us that whenever these densities are both equal to zero, the value of the w-ratio should be set equal to one. However, in all three of the above cases at Bowline and Roseton, LMS assumed a w-ratio of zero, implying no entrainment by the plants regardless of whether or not there actually were eggs present in the river. Dr. Englert of LMS offered two justifications for the assumption that zero divided by zero equals zero. First, he argued that it is valid to assume that w is equal to zero because the finding of no organisms in the intake samples indicates that none were being entrained (Transcript pp. 8383-85, emphasis added):

> MR. KURENT: Since the river and the plant concentrations are identical, that is, in your ratio the numerator and the denominator for the equation are the same, shouldn't the w ratio logically be 1?

DR. ENGLERT: A zero divided by zero is an undefined quantity mathematically.

MR. KURENT: Undefined, but you define the w ratio as zero as a result of that calculation.

MR. FRIEDLANDER: He had a remainder of an answer to give, his mouth was open.

DR. ENGLERT: As we indicated, the w ratio is an estimate of the number of organisms entering the plant divided by the number of organisms out in the river.

And keep in mind, of course, that we are using this w ratio in the computation of power plant impact.

So that it would seem ridiculous to assume a value of 1 for the w ratio which is going to be used to estimate this impact when, in fact, no organisms entered the plant.

MR. KURENT: Isn't it equally as ridiculous to determine this equation to result in a zero?

DR. ENGLERT: No, it is not ridiculous for the very reason that I just explained.

MR. KURENT: Shouldn't the mean concentrations actually be excluded if you don't choose to make the conservative assumption and call it a 1?

Since it is mathematically a like numerator and a like denominator, shouldn't you either consider it a 1 or exclude this data in determining w ratios?

DR. ENGLERT: No.

As I indicated in one of my previous answers, what we are trying to do here is to estimate power plant impact, and there is no reason to assume a w ratio of 1 when in fact we didn't find any organisms of that life stage at that plant in either the intake or discharge samples.

MR. KURENT: How can you assume any w ratio on the basis of no organisms?

Isn't the w ratio some measure of withdrawal or comparison of concentrations in the river and the plant?

If you have no organisms, how can you use those zeros to give us a withdrawal ratio of zero? It is like making something from nothing; isn't it?

DR. ENGLERT: The purpose of the w ratios as I have indicated several times is to aid us in estimating power plant impact.

Now, as I have said repeatedly, now if we are trying to estimate the number of organisms entering the plant based on this w ratio, I see no basis for assuming a value of 1 when in fact we did not find any organisms in either the intake or the discharge of the plant.

The fact that we didn't find any organisms means that there were none entering.

Later, Dr. Englert offered a second justification: since Roseton and Bowline are at the extreme ends of the spawning range of striped bass, no eggs were present in the river in the vicinity of these plants. We quote from Transcript pp. 8386-89 (emphasis added):

MR. KURENT: Didn't you state earlier that the purpose of establishing criterion of wanting ten organisms per thousand cubic meters was to show that you were sampling at a time when in fact organisms were present in the river in significant concentrations?

The fact that you have a zero concentration in the river and at the plant runs contrary to the stated purpose of computing the w ratio using the criteria that you established.

DR. ENGLERT: As I recall, I said criterion were established to allow us to look at the period of appreciable abundance in either the plant or the river and to limit ourselves to those samples.

But, in fact, what happened in these cases is that we note that there were eggs and/or larvae in the Hudson River during the sampling periods because these samples covered the entire period of abundance of those organisms.

The fact that we didn't find them at the plant or the river simply means that they weren't in that particular plant region and in that particular plant.

So I don't see any problem with assuming a value of zero in this case.

MR. KURENT: Does the fact that you didn't find them in the river mean they weren't in the river?

DR. ENGLERT: It means in terms of the data, it means that we didn't find them in our samples.

MR. KURENT: Does the fact that you didn't find them in the river mean that they weren't in the river?

DR. ENGLERT: We know that during that same period there were organisms of that life stage of striped bass in the Hudson River.

MR. KURENT: Does the fact that you didn't find them at the intake mean that they weren't entrained into the intake?

DR. ENGLERT: It means that we did not capture any in our samples at the intakes.

MR. KURENT: And you are not able to judge whether they were entrained into the intake; are you?

DR. ENGLERT: I am not able to judge that based on the sampling program that was in effect during that time.

MR. KURENT: You can assume, even though you found zero in the river, that there were still organisms present in the river; why can't you assume that even though you didn't find them at the intake that there were still organisms present going through the intake?

DR. ENGLERT: Because I -- because for the plants that we are looking at, the Bowline and Roseton plants which are on the extreme of the spawning regime of the striped bass, it is not unexpected to believe that there were no organisms in that plant region.

I said that there were organisms of that life stage in the Hudson River as a whole.

I say that based on our sampling program, we believe that those organisms were not present in the Bowline or Roseton area at that time, or that year.

We find both of Dr. Englert's rationalizations to be exceedingly unconvincing. First, the fact that no eggs were captured in the plant samples does not imply that no eggs were entrained (as Dr. Englert claimed in the emphasized quote on p. V-61). It simply means that none were collected in the tiny fraction of the intake water sampled by LMS (as Dr. Englert admitted in the emphasized quote on p. V-62). It clearly is possible that eggs were present but simply not collected.

Given the pitifully inadequate sampling effort expended at the Roseton intake in 1974 (Section 4.3 of this testimony), it would have been surprising if any eggs had been collected. We noted in Section 4.3 that the total volume of all the samples collected at the Roseton intake on dates used to compute 1974 w-ratios for striped bass was only about 400 m^3. On the two dates used by LMS to compute 1974 w-ratios for eggs, May 9 and May 22 (Exhibit UT-3, p. 3-IV-51), only seven samples were collected at the plant and only 135 m^3 of intake water were filtered (Table V-14). This total volume is approximately equal to the volume of a single river sample.

Dr. Englert's second argument is flatly contradicted by the facts. Striped bass eggs were collected in the Bowline and Roseton regions in 1974 and 1975 by both LMS and TI. TI collected striped bass eggs in the Croton Haverstraw (CH) region, where the Bowline plant is located, and in the Poughkeepsie (PK) region, where the Roseton plant is located, both in 1974 and in 1975 (Exhibit UT-4, Tables 6.2-1 and 6.2-5). During both years eggs were collected in every river region except Yonkers (YK). If striped bass eggs were in fact present throughout the river, both above and below the Bowline and Roseton plants, then they must have been present in the vicinity of each plant. LMS' data shows that eggs were present at both locations, although they were not caught at all depths at all times of day. For example, at Roseton in 1974 and 1975 eggs were found in river samples collected at night in the lower layer and during the day in both upper and lower layers. Can it be that during the day eggs were present throughout the water column but at night they migrated to the bottom? Considering both TI's and LMS' data, the only reasonable conclusion that can be drawn is that even though during some time periods at some depths no eggs were collected in the vicinity of the Bowline and Roseton plants, eggs were in fact present in the vicinity of the plants at those depths during those time-periods.

Is the fact that eggs were probably present in the river, even though none were caught, further evidence that it is justifiable to assume that the w-ratio is equal to zero? Dr. Englert thinks so, as evidenced by Transcript pp. 8417-23:

MR. KURENT: Since your sampling reflected the presence of no striped bass eggs in the river in the upper layer at night, can we then infer that if eggs were in fact present in the river in the vicinity of the plant, even though LMS' sampling program missed them, that it wouldn't be valid to assume then that zero over zero equals zero?

DR. ENGLERT: No.

In the context of the answer that I just gave a few questions ago, that would in fact support the idea of a zero w ratio because, as I explained, any number divided by zero is in fact zero.

So that if there were eggs there and we were able to measure that river concentration, if we divided that by the zero catch in the plant, we would get again zero.

MR. KURENT: Let me restate the question and see if you can interpret it differently.

I said, then can we infer that if eggs were in fact present in the river in the vicinity of the plant, even though your sampling program missed them, that it would not be valid to assume zero over zero to equal to zero; is that the question as you understand it?

DR. ENGLERT: Yes, that's the question I just answered.

MR KURENT: If it can be shown that striped bass were present in the river in significant numbers but you missed them, which you apparently did, wouldn't it be equally logical to assume that they were present in the vicinity of the intake and you missed them there as well?

MR. FRIEDLANDER: Objection.

You asked that same question yesterday. This is on page 8388.

I will read the question and we will see the parallels between what was asked yesterday.

MR. KURENT: I am asking a new question.

MR. FRIEDLANDER: You are not. You are asking the same questions as you asked yesterday. It's on page 8388, lines 11 to 16.

I would appreciate your distinguishing the difference between that question and the question you just asked.

Talk about a waste of time.

MR. KURENT: Mr. Friedlander is correct that I asked that question yesterday, but I looked at the answer in the record that Dr. Englert gave, and the answer he just gave is different than the answer he gave yesterday and I would like him to explain the difference.

If I may read his answer from 8388. He said in response to the question yesterday:

"Because for the plant that we are looking at, the Bowline and Roseton plants, which are on the extreme of the spawning regime of the striped bass, it's not unexpected to believe that there were no organisms in the plant region."

MR. FRIEDLANDER: And the answer continues.

MR. KURENT: "I said that there were organisms of that life stage in the Hudson River as a whole. I say that based on our sampling program. We believe that those organisms were not present in the Bowline or Roseton area at that time or that year."

I appreciate the reference, Mr. Friedlander.

Now, that seems to differ with the answers you have given me this morning. So I am asking you again, if in fact there were organisms in the river contrary to your assumption in yesterday's answer --

DR. ENGLERT: First of all, I see no inconsistency in the answer. You are asking me now to work on a hypothetical, as I understand it.

MR. KURENT: The hypothetical being?

DR. ENGLERT: That there were organisms in the river which we did not capture.

MR. KURENT: Perhaps I could assist you in that. Perhaps you could look at Exhibit 4, Table 6.2-5.

Do you have a copy of that?

DR. ENGLERT: I am sorry, I don't.

JUDGE YOST: I have provided the witness with a copy of the exhibit.

MR. KURENT: Thank you, your Honor.

That table, Dr. Englert, sets forth the regional densities of striped bass eggs during 1974 in the Hudson River estuary.

Now, isn't the Roseton plant in the river section delineated by Poughkeepsie, PK?

MR. FRIEDLANDER: Your Honor, I object to this line of questioning. These materials are on abundance and distribution, which was examined by Mr. Strong for two weeks.

Dr. Englert is not particularly prepared to respond on these materials.

We were told that we would be questioned on w ratios today.

JUDGE YOST: I will overrule your objection. I know what you are saying, but on the other hand I don't think it's improper to refer a witness to an exhibit in the testimony that speaks for itself.

He doesn't have to know about it to read the numbers.

MR. KURENT: Dr Englert, if you look at the data presented under the column marked "Poughkeepsie," which is the Roseton plant vicinity, isn't it apparent that there were striped bass eggs recovered in various quantities throughout the sampling period around the Roseton plant during 1974?

DR. ENGLERT: The figures that you are showing -- this table, 6.2-5, shows regional densities for the Poughkeepsie region, which extends seven or eight miles, as I recall.

It's rather large region and according to that table, there were some eggs collected within that region.

MR. KURENT: How do you square this with the fact that you have assumed that there were no striped bass eggs in the Roseton plant region?

DR. ENGLERT: I didn't assume that there were no eggs in the Roseton region. I computed a w ratio and I computed concentrations in the river in the immediate vicinity of the plant based on transsect sampling that was done by our company in the river immediately adjacent to the Roseton power plant.

And those results are presented in Table B-21.

MR. KURENT: Dr. Englert, if you would also look at the chart, isn't it apparent that in regions on either side of Poughkeepsie there were eggs present in various densities as well?

DR. ENGLERT: Yes, that's true.

MR. KURENT: Considering the fact that they appear to exist in both regions on either side of Roseton and in the region in which Roseton is located, isn't it logical to assume that they existed in all these contiguous regions and therefore in front of the Roseton plant?

DR. ENGLERT: As I am trying to explain, the sampling that we were basing the w ratios on is the transect sampling and the sampling at the plant that was performed during 1974.

Now, it wouldn't bother me at all if in fact we had found eggs in the river or if in fact there were eggs in the river during 1974 because the important point is that we didn't find any in the plant.

And in fact, it would simplify our discussions if there were some eggs in the river because it would mean that we have a non-zero number to divide into the zero that we found in the plant and it would still give us the result, which is a zero w ratio.

Dr. Englert's argument is fallacious. If eggs were present in the river but not collected, then eggs may just as well have been present at the plant but not collected there either. In fact, since the sampling effort at power plant intakes is nearly always substantially less than that at the corresponding river stations, it is much more likely that no eggs would be collected at a power plant intake, even though eggs were being entrained, than it is that no eggs would be collected in the river, even though eggs were present there.

No eggs were collected at the Roseton intake in 1974. We have previously noted that only 135 m^3 of water were filtered at the Roseton intake on the two sampling dates in 1974 that met LMS' criteria for w-ratio analysis for striped bass eggs. In Table V-17 we present the volume (m^3) of the river samples collected on these dates, and the number of these samples that contained striped bass eggs. Even though the average volume of each sample collected from the river on these two dates was greater than the total volume sampled at the

Table V-17. Numbers of samples collected at Roseton/Danskammer river transect stations on May 9 and May 21, 1974[a] that contained striped bass eggs

Date	N[b]	Average sample volume (m^3)	Number of eggs collected	Number of samples containing eggs
May 9	36	199.1	11	1
May 21	37	202.6	39	3

[a]Data collected on these dates were used by LMS to calculate w-ratios for striped bass eggs.

[b]Total number of samples collected at all stations and depths during daytime and nighttime.

intake on both dates combined, only 1 out of 36 (3%) river samples collected on May 9 and only 3 out of 37 (8%) collected on May 21 actually contained eggs. Clearly, even if the density of eggs in water entrained by the Roseton plant on these dates was in reality equal to the density of eggs in the river, the probability that any would be collected in the 19 m^3 of water sampled on May 9 or the 116 m^3 sampled on May 21 (Table V-14) is negligible.

We believe that LMS' assumption that zero divided by zero is equal to zero is unjustifiable. W-factors are not measures of the numbers of organisms entrained by power plants, but measures of the density of organisms in power plant cooling water relative to their density in the river in the vicinity of the plant. If no organisms are collected at either location, the most reasonable assumption is that the plant and river densities are equal. Therefore W-factors should be set equal to one.

Since we do not compute a W-factor unless at least ten organisms were collected in either the plant or the river samples, we do not encounter this problem when calculating W-factors using the MU method. A similar problem does occasionally occur in the application of the GBC method: if the computed values of the upper and lower layer w-ratios are both zero, then the value of the factor A computed from Eq. (V-10) (Section 2.2.2), i.e., $(w_U - w_L)/(w_U + w_L)$, is equal to zero divided by zero. Interestingly, in this case we assume that A is equal to zero, for the same reason we set forth above when arguing that LMS' w-ratios should be set equal to one. If w_U and w_L are equal and nonzero, then A is equal to zero. Thus, zero divided by zero is equal to one, but zero minus zero divided by zero is equal to zero.

5. DISCUSSION

Even a casual inspection of Tables V-3 through V-12 reveals that many of the GBC and MU W-factors computed for the same population, life-stage, year, and time of day differ substantially from each other. This is not unexpected, given the differences in assumptions and computational procedures between the two methods. The MU method assumes that the gears used to collect plant and river ichthyoplankton samples have equal collection efficiencies. All differences between observed plant and river densities are attributed to real differences between the abundance of organisms in a power plant intake and their abundance in the river cross-section in front of the plant. The same is not true of the GBC method. The GBC method attributes all differences between the abundance of organisms in the upper layer of an intake bay and their abundance in the upper layer of the river to the effects of gear bias. It is the relative magnitudes of upper and lower layer w-ratios and the vertical stratification of organisms in the river that determine the value of a W-factor calculated using the GBC method.

Because of the differences between the two methods, violations of assumptions that affect one will not affect the other. If, for some population and life-stage, the efficiency of the gear used to collect samples at a particular plant is markedly different from the efficiency of the gear used to collect the corresponding river samples, a bias will be introduced into the MU W-factor but not into the GBC W-factor. Conversely, if there is a lateral trend in the distribution of organisms belonging to a given species and life-stage in the upper layer of the river (e.g., they are more abundant near the east or west shore than in the channel), the GBC W-factor will be affected but the MU W-factor will not. Equally important, and for exactly the same reasons, the two methods are affected differently by sampling errors. If, by chance alone, the observed density of organisms of a particular population and life-stage in the river samples is lower than the observed density in the plant samples, although the true plant and

river densities are the same, then the MU W-factor will be erroneously high. The GBC W-factor computed from the same data may be erroneously high, erroneously low, or unaffected, depending on how the relative magnitudes of w_U and w_L, and the fractional distribution of organisms in the upper and lower layers of the river are affected by the sampling error.

Since each run of the Empirical Transport Model employs 20 W-factors (five plants x four life-stages), the differences observed within individual GBC/MU pairs are unimportant as long as neither method produces consistently larger or smaller W-factors than does the other. Table V-18 presents a comparison of the GBC and MU W-factors for striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa. For each population we tabulated the number of times the GBC W-factors were larger than the corresponding MU W-factors. We then used the sign test (Siegel 1956) to determine whether W-factors for any of these species calculated using the GBC method are on the average larger or smaller than similar W-factors calculated using the MU method.

The MU W-factors for bay anchovy are consistently larger than the GBC W-factors. This result indicates that for this species one (or both) method(s) is subject to some kind of systematic bias. Unfortunately, we cannot determine the nature of this bias, and therefore we have no way of knowing which set of W-factors corresponds most closely to reality. The practical effects of the systematic difference between the two sets are an increase in the range of conditional entrainment mortality rates obtained from the Empirical Transport Model, and a concomitant increase in the uncertainty of conclusions drawn about the impact of entrainment on the Hudson River bay anchovy population.

For the other four species, the sign test revealed no significant difference between the number of GBC W-factors that are larger than the corresponding MU W-factors and the number that are smaller. Thus, for striped bass, white perch, Atlantic tomcod, and Alosa there is little overall difference between the two sets of W-factors. Similar

Table V-18. Statistical significance of differences between the MU and GBC W-factors for each species, as determined from the sign test[a]

Species	Number of pairs[b]	n_+^c	pd
Striped bass	50	25	1.00 (NS)
White perch	48	22	0.67 (NS)
Atlantic tomcod	21	10	1.00 (NS)
Bay anchovy	30	6	0.01[e]
Alosa spp.	43	16	0.13 (NS)

[a]Method described by Siegel (1956).

[b]Number of pairs of MU and GBC W-factors calculated for the same species, life-stage, plant, year and time of day, excluding ties.

[c]Number of pairs in which GBC W-factor is larger than MU W-factor.

[d]Two-tailed test.

[e]Significant at 1% level.

conditional entrainment mortality rates should be obtained from the Empirical Transport Model regardless of which method supplies the input parameters.

For four out of five species, independent methods of solving the same problem (i.e., how to estimate a W-factor), each involving different simplifying assumptions and subject to different sorts of biases, have led to similar results. Because the conditional entrainment mortality rates for striped bass, white perch, Atlantic tomcod, and Alosa produced by the ETM are relatively independent of the method used to generate W-factors, they should be, in Levins' (1966) terminology, "robust" with respect to these parameters. For these species conclusions drawn from the ETM results, and management decisions based on those conclusions, should be relatively free from the effects of the various types of errors that can affect estimates of W-factors and w-ratios.

6. REFERENCES CITED

Barnthouse, L. W., J. B. Cannon, S. W. Christensen, A. H. Eraslan, J. L. Harris, K. H. Kim, M. E. LaVerne, H. A. McLain, B. D. Murphy, R. J. Raridon, T. H. Row, R. D. Sharp, and W. Van Winkle. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point Generating Station. ORNL/TM-5877. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Carpenter, E. J. 1979. Sampling ichthyoplankton. Exhibit EPA-196.

Cassie, R. M. 1963. Microdistribution of plankton. Oceanogr. Mar. Biol. Ann. Rev. 1:223-52.

Ecological Analysts. 1976a. Bowline Generating Station entrainment survival and abundance studies. 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts. 1976b. Lovett Generating Station entrainment survival and abundance studies. 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Exhibit UT-3. Consolidated Edison. 1977b. Supplement I to 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.

Exhibit UT-4. Consolidated Edison. 1977a. 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.

Exhibit UT-6. Central Hudson. 1977. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Exhibit UT-7. Orange and Rockland. 1977a. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Exhibit UT-7A. Orange and Rockland. 1977b. Appendixes-Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Levins, R. 1966. The strategy of model building in population biology. Am. Sci. 54(4):421-31.

New York University. 1976. Effects of entrainment by the Indian Point power plant on biota in the Hudson River estuary. Progress Report for 1974. Prepared for Consolidated Edison Co. of New York, Inc.

New York University. 1977. Effects of entrainment by the Indian Point power plant on biota in the Hudson River estuary. Progress Report for 1975. Prepared for Consolidated Edison Co. of New York, Inc.

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. McCraw-Hill, New York. 312 pp.

Smith, P. E., R. C. Counts, and R. I. Clutter. 1968. Changes in filtering efficiency of plankton nets due to clogging under two. J. Cons. Perm. Int. Explor. Mer 32(2):232-42.

Texas Instruments. 1975. Indian Point impingement study report for the period 1 January 1974 through 31 December 1974. Prepared for Consolidated Edison Company of New York, Inc. Exhibit EPA-92B.

CHAPTER VI
ESTIMATING RATIOS OF POWER PLANT INTAKE ORGANISM DENSITIES TO RIVER DENSITIES USING THE RIVER DATA METHODOLOGY

Testimony of
John Boreman, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

The W-factor, as used in the Empirical Transport Model (ETM), is the ratio of the average intake to average regional density of an entrainable life stage of a given fish population. Chapter V of this exhibit presents W-factors for entrainable life stages of six fish populations inhabiting the Hudson River estuary. The values in Chapter V are based on two estimation techniques: the Gear Bias Cancelling method (GBC) and Modified Utility (MU) method. However, due to lack of sufficient data, GBC and MU W-factors could not be calculated for all entrainable life stages of the six populations at all plants; missing values are denoted in Table VI-1. Consequently, alternative approaches to estimation of the missing values were used.

This chapter presents a methodology for estimating W-factors when river-wide life stage density data summarized by depth strata are available. The approach is used to supply the missing W-factors (Table VI-1) for entrainable juvenile striped bass, white perch, Atlantic tomcod, and American shad, as well as values for earlier life stages of Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy.

2. RIVER DATA METHODOLOGY

When average river-wide densities by depth strata for an entrainable life stage of a fish population are available, the River Data Methodology (RDM) can be used to estimate W-factors. Use of this approach for entrainable life stages of Hudson River fish populations relies on three assumptions: (1) the depth distributions of the life stages are the same throughout the river; (2) the life stages have uniform lateral distributions; and (3) the depth distributions of the life stages do not vary among years. The first assumption is necessary because the data used in this methodology represent average river-wide densities by depth strata over the entire period a life stage was present in the water body.

Table VI-1. Missing[a] GBC and/or MU W-Factors for Entrainable Life Stages of Six Hudson River Fish Populations

Plant	Life Stage	Population					
		Striped bass	White perch	Alosa spp.[b]	American shad	Atlantic tomcod	Bay anchovy
Roseton	Eggs				X		X
	Yolksac larvae				X	X	X
	Post yolksac larvae				X		X
	Entrainable juveniles	X	X		X	X	X
Indian Point	Eggs			X	X		
	Yolksac larvae				X	X	
	Post yolksac larvae				X	X	
	Entrainable juveniles	X	X		X		
Bowline	Eggs			X	X		
	Yolksac larvae			X	X		
	Post yolksac larvae				X		
	Entrainable juveniles	X	X	X	X		
Lovett	Eggs			X	X		
	Yolksac larvae			X	X		
	Post yolksac larvae				X		
	Entrainable juveniles	X	X	X	X		X
Danskammer	Eggs				X		X
	Yolksac larvae				X	X	X
	Post yolksac larvae				X		X
	Entrainable juveniles	X	X		X	X	X

[a] for 1974, 1975, and 1976 data bases, based on Chapter V
[b] blueback herring and alewife
X denotes missing GBC and/or MU W-factor

As documented in Chapter V of this exhibit, the second assumption (uniform lateral distribution) is supported by data collected on entrainable life stages of striped bass and white perch in the Bowline and Roseton regions and Atlantic tomcod in the Bowline region of the Hudson River. Atlantic tomcod larvae were more abundant on the west side of the river in the vicinity of Roseton and Danskammer. Entrainable life stages of Alosa spp. (blueback herring and alewife) in the Roseton and Danskammer region, as well as entrainable life stages of bay anchovies in the Bowline region, also exhibited some lateral preferences. The extent of these lateral preferences, as well as their effects on the assumption of uniform lateral distribution, are discussed in section 2.2.1 of Chapter V.

For a pelagic species such as the American shad, the assumption of uniform lateral distributions of its post yolksac larval and early juvenile life stages is supported by data presented in the 1974 Year-Class Report (Table V-11, TI 1977). These data showed no significant differences in concentrations of American shad post yolksac larvae and early juveniles between the east and west shoal strata of the Hudson River in 1974; eggs and yolksac larvae were not included in the analysis.

The third assumption of the RDM (depth distribution of a life stage does not vary among years) is necessary because river density data by depth strata were not available for all years of data collection for entrainable life stages of the six fish populations. Therefore, values based on one or two year's data had to be used for other years.

Violations of the above assumptions may reduce the accuracy of the RDM estimates, but do not invalidate them. The W-factors are as likely to be underestimated as they are likely to be overestimated. For example, if all the organisms are concentrated in the shorezones, the W-factors will be underestimated; whereas, if all the organisms are concentrated in the middle of the river, the W-factors will be overestimated.

2.1. MATHEMATICAL BASIS OF THE RDM

Based on the assumptions in the previous section, the following equation is the mathematical formulation of the RDM:

$$W_\ell = \frac{0.57U_\ell + 0.43B_\ell}{(U_\ell + B_\ell)/2} \qquad \text{(VI-1)}$$

where W_ℓ = W-factor for life stage ℓ,

U_ℓ = average concentration of life stage ℓ individuals in upper half of the water column (equals average of surface and mid-water values), and

B_ℓ = average concentration of life stage ℓ individuals in the bottom half of the water column (equals average of mid-water and bottom values).

The coefficients of 0.57 and 0.43 in equation VI-1 were derived from Indian Point intake modeling studies conducted by LaSalle (LaSalle 1976) that indicated the plant withdraws an average 57 percent of its water from the upper half of the water column, and the remaining 43 percent from the lower half (Figure VI-1). The utilities considered these values appropriate for Indian Point, Roseton, and Bowline (p.3-IV-62, Exhibit UT-3). I also used the LaSalle values for those plants, as well as for Lovett and Danskammer due to a lack of other evidence.

2.2. INPUT DATA AND RESULTS

Data used in equation VI-1 (RDM) for estimating W-factors in order to fill in the missing values in Table VI-1 were obtained from all available data sources. W-factors were calculated for the entrainable juvenile life stages of striped bass and white perch using river-wide average densities by depth strata summarized in the 1974 Year-Class Report (Tables V-6 and V-8, respectively, TI 1977). The estimates presented in the TI report were combined day/night average densities in surface, mid-water, and bottom strata sampled with the epibenthic sled

and Tucker trawl from late April through mid-August, 1974. These estimates and the W-factors based on the estimates and equation VI-1 are listed in Table VI-2.

Tables 9.1-16 and 9.1-18 in Exhibit UT-6 list mean densities of Alosa spp. (blueback herring, alewife, and American shad) eggs and larvae by depth strata in the Roseton vicinity for selected dates. These densities are listed in Table VI-3 along with the corresponding W-factors as calculated using equation VI-1. The densities were averaged across river transect stations RDW, RDCH, and RDE. As discussed in the testimony on life histories (Boreman 1979), Alosa spp. collections in the Hudson River were principally composed of blueback herring. The W-factors listed in Table VI-3 are used for alewife, as well as for blueback herring, due to a lack of alternative data sources.

Since an alternative data source exists for entrainable life stages of American shad, W-factors were computed separately for this species. W-factors for American shad egg, yolksac, and post yolksac larvae were obtained from data summarized in Table VII-11 of TI (1977). The data and resultant W-factors are listed in Table VI-4.

Table VI-5 lists W-factors, based on the RDM, for entrainable life stages of Atlantic tomcod. Data used in calculating W-factors for yolksac and post yolksac life stages of Atlantic tomcod were obtained from Raytheon (1971) by averaging sample densities of yolksac and post yolksac larvae across all three sample stations (Roa Hook, Indian Point, and Stony Point) during the respective weeks of their maximum densities. Data were also obtained from Tables 7A-185 and 7A-187 of NYU (1973), averaging across all sample stations (Stations A-H).

W-factors for the egg stage of the bay anchovy population (Table VI-6) were derived from data presented in Tables 9.1-17 of Exhibit UT-7 in the same manner described for Alosa spp. Bay anchovy larvae W-factor values (Table VI-6) were also derived in the same manner from data

Table VI-2. Estimated W-Factors for the Entrainable Juvenile Life Stages of Striped Bass and White Perch Based on the River Data Methodology

Population	Ave. density[a]			W_ℓ[b]
	Surface	Mid-water	Bottom	
Striped bass	0.07	0.13	1.09	0.90
White perch	0.06	0.33	0.82	0.93

[a] number per 1000 m^3 from Tables V-6 and V-8 in TI (1977)

[b] see equation VI-1 for derivation

Table VI-3. Estimated W-Factors for Eggs and Larvae of Alosa spp. (Blueback Herring and Alewives) Based on the River Data Methodology

Date	Ave. density[a] Surface	Mid-water	Bottom	W_ℓ[b]
Eggs:[c]				
5/7/74	0	0	9.81	0.86
6/18/74	0	0	0.63	0.86
4/28/75	287.57	119.61	1393.08	0.92
5/5,8/75	22.53	0.71	112.81	0.91
5/15/75	51.32	37.26	344.09	0.91
5/29/75	39.35	35.38	89.69	0.96
5/20/76	129.45	0	78.01	1.03
6/1,3/76	15.77	0.92	33.25	0.95
6/10/76	0.60	0	74.68	0.86
Geometric average				0.92
Larvae:[d]				
5/21/74	866.74	506.12	491.04	1.02
6/4/74	1111.68	1597.42	714.35	1.01
6/18/74	336.71	746.36	221.50	1.01
5/29/75	1090.90	2552.50	593.09	1.01
6/2/75	1345.62	1081.79	1256.65	1.00
6/9/75	495.79	593.67	596.00	0.99
5/24/76	797.97	2680.44	1475.87	0.99
5/27/76	2559.51	1041.70	2189.84	1.01
6/24/76	1293.57	1197.43	1108.16	1.01
Geometric average				1.01

[a] number per 1000 m^3, averaged across river transect stations (RDE, RDCH, and RDW)

[b] see equation VI-1 for derivation

[c] from Table 9.1-16, exhibit UT-6

[d] from Table 9.1-18, exhibit UT-6

Table VI-4. Estimated W-Factors for Entrainable Life Stages of American Shad Based on the River Data Methodology

Life stage	Ave. density[a]			W_ℓ[b]
	Surface	Mid-water	Bottom	
Eggs	5.95	7.63	30.07	0.93
Yolksac larvae	0.53	2.20	2.69	0.96
Post yolksac larva.	19.66	6.10	9.80	1.03
Entrainable juveniles	0.55	2.32	2.21	0.97

[a] number per 1000 m^3, from Table VI-11 in TI (1977)

[b] see equation VI-1 for derivation

Table VI-5. Estimated W-Factors for Entrainable Life Stages of Atlantic Tomcod Based on the River Data Methodology

Life stage	Ave. density[a] Surface	Mid-water	Bottom	W_ℓ[b]
Yolksac larvae				
Raytheon (1971)[c]	281.67	708.33	1007.67	0.96
NYU (1973)[d]	7.99	19.30	52.30	0.94
Geometric average				0.95
Post yolksac larvae				
Raytheon (1971)[c]	79.00	130.00	560.00	0.93
NYU (1973)[d]	67.50	303.63	604.28	0.94
Geometric average				0.93
Entrainable juveniles				
TI (1977)[e]	0.32	22.74	117.26	0.90

[a] number per 1000 m^3

[b] see equation VI-1 for derivation

[c] data from Raytheon (1971), digitized (Tektronix 4956 Graphics Tablet) from Figures 6-7 to 6-9, choosing the date of maximum sample densities (3/29/70 for yolksac larvae and 4/26/70 for post yolksac larvae), and averaging across all three sample stations (Roa Hook, Indian Point, and Stony Point)

[d] data from NYU (1973), Tables 7A-185 and 7A-187, averaging across all sample stations (A-H), day samples only

[e] data from Table V-10 in TI (1977)

Table VI-6. Estimated W-Factors for Entrainable Life Stages of Bay Anchovy Based on the River Data Methodology

Date	Ave. density[a] Surface	Mid-water	Bottom	W_ℓ[b]
Eggs:[c]				
7/1/75	4.22	0	1351.08	0.86
7/8/75	7.04	2407.40	6668.01	0.92
7/15/75	0	96.40	985.35	0.88
7/20/76	0	0	2746.30	0.86
7/27/76	56.15	684.57	2993.28	0.91
8/4/76	0	31.83	127.92	0.91
Geometric average				0.89
Larvae:[d]				
8/13/74	24.47	23.54	23.09	1.00
8/27/74	15.64	20.80	14.34	1.00
7/17/75	7.34	34.78	9.54	1.00
7/30/75	13.23	62.96	5.71	1.01
8/14/75	9.81	19.12	13.20	0.99
8/27/75	4.11	0	8.87	0.95
9/11/75	11.51	0	2.49	1.09
9/13/75	9.03	0	2.06	1.09
7/15/76	0	1.84	1.36	0.96
7/29/76	8.64	0	9.69	0.99
8/12/76	0.61	0	0.54	1.01
8/26/76	7.41	0	12.28	0.97
9/16/76	1.25	3.43	9.89	0.93
Geometric average				1.00

[a] number per 1000 m^3

[b] see equation VI-1 for derivation

[c] data from Table 9.1-17 in exhibit UT-7, averaged across river transect stations

[d] data from Table 9.1-22 in exhibit UT-6, averaged across river transect stations

presented in Table 9.1-22 of exhibit UT-6.

Since no depth distribution data was presented in the utility exhibits or available reports for the entrainable juvenile life stages of Alosa spp. or bay anchovies in the Hudson River, a W-factor of 1.0 is used. This value is supported by the pelagic characteristics of the juvenile life stages of these species, as well as the average RDM W-factors of the larval life stage of each species. The average RDM W-factor for Alosa spp. larvae is 1.01 (Table VI-3) and the average RDM W-factor for bay anchovy larvae is 0.98 (Table VI-6).

3. ADJUSTMENT FOR RECIRCULATION

Because the W-factors derived by the River Data Methodology are not based on simultaneous sampling at the power plant intakes and in the river, recirculation of organisms present in the power plant discharge water has to be taken into account. Therefore, W-factors derived by the RDM were adjusted to account for recirculation of discharge water through the intake at each plant. A recirculation value of 0.07 was chosen for Indian Point, 0.13 for Roseton, and 0.13 for Bowline. These values are based on estimates used by the utilities (Table 3-IV-28, exhibit UT-3). Values of 0.11 and 0.10 were used for Lovett and Danskammer, respectively, to account for the estimated recirculation rate of discharge water at these plants, as provided to EPA by the utilities (Marcellus 1978).

The entrainable life stage W-factors for the six populations, adjusted for recirculation, are presented in Table VI-7. This method of adjustment assumes all live and dead organisms in the power plant discharge water are recirculated at the same rate as the discharge water is recirculated. Settling of dead organisms and sounding (movement towards the river bottom) by live organisms are two reasons why the adjustment for recirculation introduces a bias into the W-factors that tends to underestimate the true values. The adjusted RDM W-factors are used in the ETM analyses whenever GBC or MU values for a given life stage at a given plant are

Table VI-7. RDM W-Factors for Entrainable Life Stages of Six Hudson River Fish Populations Adjusted for Recirculation of Power Plant Discharge Water

Plant	Population	Life stage[a]	W_ℓ (unadjusted)	W_ℓ (adjusted)[b]
Roseton (0.13)	Striped bass	juv	0.90	0.78
	White perch	juv	0.93	0.81
	American shad	egg	0.93	0.81
		ysl	0.96	0.84
		pysl	1.03	0.90
		juv	0.97	0.84
	Atlantic tomcod	ysl	0.95	0.83
		juv	0.90	0.78
	Bay anchovy	egg	0.89	0.77
		ysl	1.00	0.87
		pysl	1.00	0.87
		juv	1.00	0.87
Indian Point (0.07)	Striped bass	juv	0.90	0.84
	White perch	juv	0.93	0.86
	Alosa spp.[c]	egg	0.92	0.86
	American shad	egg	0.93	0.86
		ysl	0.96	0.89
		pysl	1.03	0.96
		juv	0.97	0.90
	Atlantic tomcod	ysl	0.95	0.88
		pysl	0.93	0.86
Bowline (0.13)	Striped bass	juv	0.90	0.78
	White perch	juv	0.93	0.81
	Alosa spp.[c]	egg	0.92	0.80
		ysl	1.01	0.88
		juv	1.00	0.87
	American shad	egg	0.93	0.81
		ysl	0.96	0.84
		pysl	1.03	0.90
		juv	0.97	0.84
Lovett (0.10)	Striped bass	juv	0.90	0.80
	White perch	juv	0.93	0.83
	Alosa spp.[c]	egg	0.92	0.83
		ysl	1.01	0.90
		juv	1.00	0.89
	American shad	egg	0.93	0.83
		ysl	0.96	0.85
		psyl	1.03	0.92
		juv	0.97	0.86
	Bay Anchovy	juv	1.00	0.89

Table VI-7 (cont.).

Plant	Population	Life stage[a]	W_ℓ (unadjusted)	W_ℓ (adjusted)[b]
Danskammer (0.10)	Striped bass	juv	0.90	0.81
	White perch	juv	0.93	0.84
	American shad	egg	0.93	0.84
		ysl	0.96	0.86
		pysl	1.03	0.93
		juv	0.97	0.87
	Atlantic tomcod	ysl	0.95	0.85
		juv	0.90	0.81
	Bay anchovy	egg	0.89	0.80
		ysl	1.00	0.90
		pysl	1.00	0.90
		juv	1.00	0.9

[a]ysl = yolksac larvae; pysl = post yolksac larvae;
juv = entrainable juveniles

[b]adjusted W = unadjusted W X (1 - recirculation value)

[c]blueback herring and alewife

Numbers in parentheses are plant recirculation values.

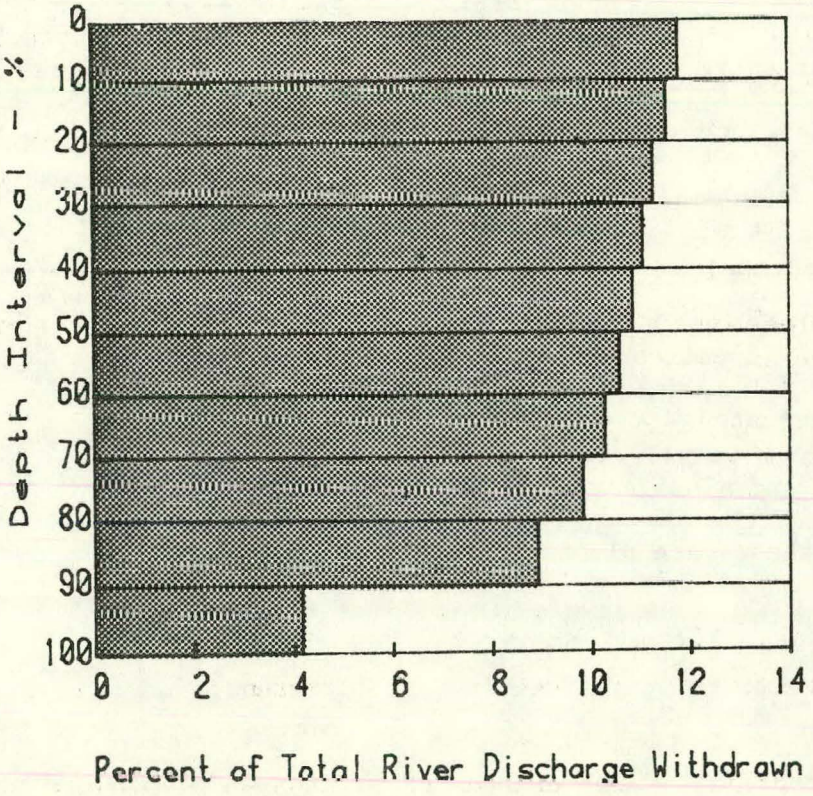

Figure VI-1. Estimated percentages of Hudson River discharge water withdrawn per 10 percent depth stratum by the Indian Point power plant (reproduced from Figure 30, LaSalle 1976).

missing for 1974, 1975, and 1976 (Table VI-1).

4. COMPARISON TO UTILITY ESTIMATES

The utilities use a W-factor of 0.5 for all entrainable life stages of striped bass, white perch, Atlantic tomcod, and American shad in their empirical analyses of the direct impact due to entrainment by Hudson River power plants (Tables 2-VI-1, and 2-VII-1 to 2-VII-3, Exhibit UT-3). To examine the implications of this value under the assumption of a uniform lateral distribution, the RDM was applied to a hypothetical set of vertical distributions of organisms. This set contained a density equal to one organism per unit volume in one to all ten depth strata (each depth stratum representing 10 percent of the water column) and zero densities in the remaining depth strata. Using a modified version of equation VI-1, a W-factor was then calculated for each case in the set. The modified version of equation VI-1 used in this hypothetical analysis is as follows:

$$W_h = \frac{0.118(D_1) + 0.115(D_2) + \ldots + 0.041(D_{10})}{\left(\sum_{i=1}^{10} D_i\right)/10} \qquad \text{(VI-2)}$$

where W_h = hypothetical W factor, and
D_i = density of organisms in depth stratum i: always equals 0 or 1.

The coefficients associated with each depth stratum were obtained from Figure 30 of LaSalle (1976), which represents the estimated percentage of water withdrawn from each 10 percent depth stratum by the Indian Point power plant. Since no values accompany this figure, the figure was digitized with a Tektronix 4956 Graphics Tablet. The digitized figure is reproduced in Figure VI-1, and the values derived from the digitizing are listed in Table VI-8.

Results of this analysis (Table VI-9) indicate that, in order to

Table VI-8. Portions of Hudson River Discharge Withdrawn per 10 Percent Depth Stratum by the Indian Point Power Plant

Depth (%)	Portion of River Discharge[a] (%)
0 - 10	11.77
10 - 20	11.52
20 - 30	11.24
30 - 40	11.03
40 - 50	10.81
50 - 60	10.54
60 - 70	10.25
70 - 80	9.81
80 - 90	8.88
90 - 100	4.15

[a]values obtained by digitizing Figure 30 in LaSalle (1976) with a Tektronix 4956 Graphics Tablet

Table VI-9. Estimated W-factors for Various Hypothetical Depth Distributions of Organisms in the Vicinity of the Indian Point Power Plant

% Depth with 0 density[a]	W-factor[b]
none	1
0 - 10	0.98
0 - 20	0.96
0 - 30	0.93
0 - 40	0.91
0 - 50	0.87
0 - 60	0.83
0 - 70	0.76
0 - 80	0.65
0 - 90	0.41

[a] remaining % depth has a density of one per unit volume

[b] see equation VI-2

achieve a W-factor of 0.5 with a uniform lateral distribution of organisms in front of the Indian Point power plant, organisms have to be absent from all but the lowest 10-20 percent of the water column. The presence of entrainable life stages of all six populations discussed in this chapter in surface and mid-water samples (Tables VI-2 to VI-6) attest to the likelihood of a W-factor greater than 0.5 under the assumption of a uniform lateral distribution.

5. REFERENCES CITED

Boreman, J. 1979. Life histories of seven fish species that inhabit the Hudson River estuary. 94 pp. Exhibit EPA-198.

Exhibit UT-3. Supplement I to influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden and J. P. Lawler. Submitted to Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-6. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-7. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

LaSalle Hydraulic Company, Ltd. 1976. Indian Point Generating Plant hydraulic model study of Hudson River flows around cooling water intakes. Prepared for Consolidated Edison Company of New York, Inc.

Marcellus, K. L. 1978 (pers. comm.). Letter to Henry Gluckstern (EPA) dated November 17, 1978.

New York University Medical Center (NYU). 1973. Hudson River ecosystem studies. Effects of entrainment by the Indian Point Power Plant on biota in the Hudson River estuary. Progress Report for 1971 and 1972 for Consolidated Edison Company of New York, Inc.

Raytheon. 1971. Final report. Ecology of thermal additions. Lower Hudson River Cooperative Fishery Study. Vicinity of Indian Point, Buchanan, New York. June 1969-October 1971 for Consolidated Edison Company of New York.

Texas Instruments, Inc. (TI) 1977. 1974 year-class report for the multiplant impact study of the Hudson River estuary. Prepared under contract with Consolidated Edison Company of New York, Inc.

CHAPTER VII

ENTRAINMENT MORTALITY FACTORS FOR HUDSON RIVER ICHTHYOPLANKTON AT BOWLINE POINT, LOVETT, INDIAN POINT, ROSETON, AND DANSKAMMER POINT POWER PLANTS

TESTIMONY OF

DOUGLAS S. VAUGHAN, Ph.D.
ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

PREPARED FOR THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II

MAY, 1979

SUMMARY

This chapter describes the calculation of estimates of power plant passage entrainment mortality factors which were used as inputs to the Empirical Transport Model (ETM) (see Chapter VIII in this Exhibit). The power plant passage entrainment mortality factor, denoted as either the f-factor or simply as f, is defined as the probability that an entrained live organism will be killed as a result of its passage through a power plant in the cooling water. An attempt has been made to strive for as much realism in our estimated f-factors as possible. We have tried to avoid making assumptions which incorporate biases that might result in an overestimate of the underlying f-factors.

Section 1 presents several equations (derived in Appendices C.1 and C.2) used in estimating f-factors from field-collected data. Since entrainment mortality may be direct (immediate or latent) or indirect (Appendix P), Oak Ridge National Laboratory (ORNL) has made separate estimates of these components and then combined them into a total f-factor.

Section 2 discusses the availability of data, some principles established to determine which data were to be used, and methods for estimating f-factors when data were insufficient to support necessary calculations. A discussion of the precision of these estimates is also given in this section (and Appendix D).

Section 3 is concerned with the estimation of f-factors for 1974 and 1975. These f-factors were used in runs of the ETM to estimate the fractional reduction in the total young-of-the-year of the various populations considered (striped bass, white perch, clupeids including American shad, bay anchovy, and Atlantic tomcod). These estimates of f-factors were also used in a set of projected runs of the ETM. Some biases in these estimated f-factors are discussed in Section 3.3 (and in Appendix E).

Section 4 describes ORNL's application of a model developed by Ecological Analysts, Inc. (EAI) for estimating the thermal component of the entrainment mortality factor from projected river temperatures and power plant operating conditions. This thermal component is later

combined with a mechanical component of the f-factor in order to estimate the direct mortality due to entrainment by a power plant (Section 4.3). A set of projected runs of the ETM was made based on these estimates. Some biases which result from the non-linear relationship of the thermal mortality component to the variables from which it is estimated (river temperature, transit time from power plant condenser to river discharge, and rise in water temperature through the condenser) are discussed. Historical river temperatures and projected power plant operations (for Bowline Point, Roseton, Indian Point, and Danskammer Point) are used in estimating the river temperature, transit time, and water temperature elevation (Section 4.1). Section 4.2 discusses proper statistical techniques for estimating the regression coefficients based on the non-linear relationship employed (the probit transformation). A comparison of field data with the thermal model predictions shows the thermal model may seriously underestimate the thermal component of the f-factor. The use of a range of estimates in projected ETM runs based on the thermal mortality model were made (Section 4.3 and Appendix F). It is our belief that the underlying f-factors are more likely to lie in the upper half of this range rather than the lower half.

Section 5 discusses differences between our handling of data in the development of the entrainment mortality model and EAI's methodology. The employment of the EAI entrainment mortality model as input to Lawler, Matusky, and Skelly's (LMS) Real Time Life Cycle (RTLC) model as used for prediction of power plant impacts on the Hudson River striped bass population is discussed.

1. INTRODUCTION

This testimony describes the calculation of estimates of the entrainment mortality factor for power plant passage which were used as inputs to the Empirical Transport Model (ETM) runs (see Chapter VIII in this exhibit). The entrainment mortality factor for plant passage, denoted as either the f-factor or simply as f, is defined as the probability that an entrained live organism will be killed as a result of its passage through a power plant in the condenser cooling water. It is estimated by applying the following general formula, the derivation of which is described elsewhere (Appendix C.1):

$$f = 1 - (1-f_{i,D})(1-f_{\ell,D})(1-f_I) \quad . \qquad \text{(VII-1)}$$

The term $(1-f_{i,D})$ represents the probability of an entrained organism surviving direct entrainment mortality based on an initial, or immediate, evaluation of survival. The term $(1-f_{\ell,D})$ represents the probability of surviving the direct effects of entrainment based on evaluating the survival 24 hours later of those organisms alive immediately following entrainment. The term $(1-f_I)$ is the probability of surviving the indirect effects of entrainment as described in Van Winkle et al. (1979). Indirect mortality (f_I) is calculated as a proportion of the direct mortality (f_D), i.e.,

$$f_I = k\, f_D \quad , \qquad \text{(VII-2)}$$

where k is specified as either 0.0, 0.1, or 0.2 for a lower estimate, middle estimate, or upper estimate of the indirect mortality, respectively (Appendix P), and f_D is defined in Eq. (VII-3). While calculations of the f-factor will involve this indirect component, we will not discuss the indirect component further in this exhibit.

This chapter involves the estimation of the terms $f_{i,D}$ and $f_{\ell,D}$ in Eq. (VII-1). From these estimates the direct entrainment mortality factor (f_D) is computed as follows:

$$f_D = 1 - (1-f_{i,D})(1-f_{\ell,D}) \qquad \text{(VII-3)}$$

The initial and latent f-factors are calculated from field data which give (a) the proportion alive initially in the intake ($P_{i,I}$) and discharge ($P_{i,D}$) samples and (b) the proportion still surviving 24 hours after sampling at the intake ($P_{\ell,I}$) and discharge ($P_{\ell,D}$) given that they survived the initial sampling process. It then follows (as shown in Appendix C.1) that the initial and latent f-factors can be estimated from the following relationships:

$$f_{i,D} = 1 - \frac{P_{i,D}}{P_{i,I}} \quad , \qquad \text{(VII-4)}$$

and

$$f_{\ell,D} = 1 - \frac{P_{\ell,D}}{P_{\ell,I}} \quad . \qquad \text{(VII-5)}$$

Some biases or tendencies to systematically understate or overstate the f-factor that are inherent in the development of these formulations are discussed in Appendix E.

The remainder of this testimony is concerned with providing estimates of the initial and latent f-factors that are used as input to the ETM (Chapter VIII). Estimates based on field studies that tallied immediate mortalities were used in one set of ETM runs because larger sample sizes are involved in their estimation, and thus greater confidence can be placed in the precision of $f_{i,D}$. However, the latent mortality for the entrainable life-stages of some or all

populations may be considerable, and for this reason a parallel set of ETM runs includes the latent f-factors.

One set of ETM runs in Chapter VIII of this exhibit (made both with and without latent mortality), denoted "historical" runs, was made for the purpose of estimating the actual entrainment mortality in 1974 and 1975. For these runs, estimates of the f-factors for each population were derived directly from net and larval table data. A second group of runs (also made both with and without latent mortality) is concerned with projecting entrainment mortality in future years, based on projected plant operations. One set of estimates of f-factors in this group of "projected" runs was also based on the net and larval table data. A second set of "projected" runs was made with f-factors obtained by estimating separately the f-factors due to thermal stresses (f_t) and the f-factors due to mechanical stresses (f_m). The techniques used in estimating the latter set of "projected" f-factors are discussed in Section 4.

The next section describes the available data used in estimating the f-factors. Some general principles are also described when dealing with common problems in the data. These principles include such matters as the types of data chosen for use in ORNL's analysis and what was done when data were insufficient to permit the estimation of f-factors for certain entrainable life-stages of particular fish populations.

2. DATA MANAGEMENT

This section includes a discussion of the available data, some principles which were established to determine which data were to be used, and means for estimating f-factors when data were insufficient to support necessary calculations.

Data have been collected by two methodologies. Until the past few years, all data collected for estimating the f-factor had been collected using nets (Marcy 1971, 1973). Estimates of f-factors calculated from nets set at the intake and discharge have been shown to be subject to potentially serious bias when differential velocities exist between intake and discharge stations (O'Connor and Schaffer 1977). The larval table technique involves pumping a water sample through a series of inclined plane screens held in a water table which concentrates biological material more gently and uniformly into a sample collection device (Fig. VII-1). This procedure reduces sampling mortality of the entrained organisms and also significantly reduces or eliminates the effect on survival of differential velocities at the intake and discharge stations (McGroddy and Wyman 1977). As a result of net sampling bias, data collected with larval tables, when available, were always used in ORNL's analysis instead of net data.

Years for which larval table data (supplied on magnetic computer tapes to ORNL by the utilities on November 16, 1977 and April 5, 1978) were used in ORNL's analysis are listed in Table VII-1. No egg data were available from larval table collections, so it was necessary to use net data to estimate f-factors for eggs.

Discharge data collected at the Indian Point plant were inconsistent, necessitating a selective use of larval table results. Survival at the discharge port station (DP) (Fig. VII-2) was almost always higher than survival at the earlier discharge station for Unit 3 (D3). This differential in survival could result from the settling to the bottom or floating to the surface of dead organisms as the condenser cooling water flowed from stations D3 to DP as shown at the Millstone Point plant by Carpenter et al. (1972) . Since the DP station

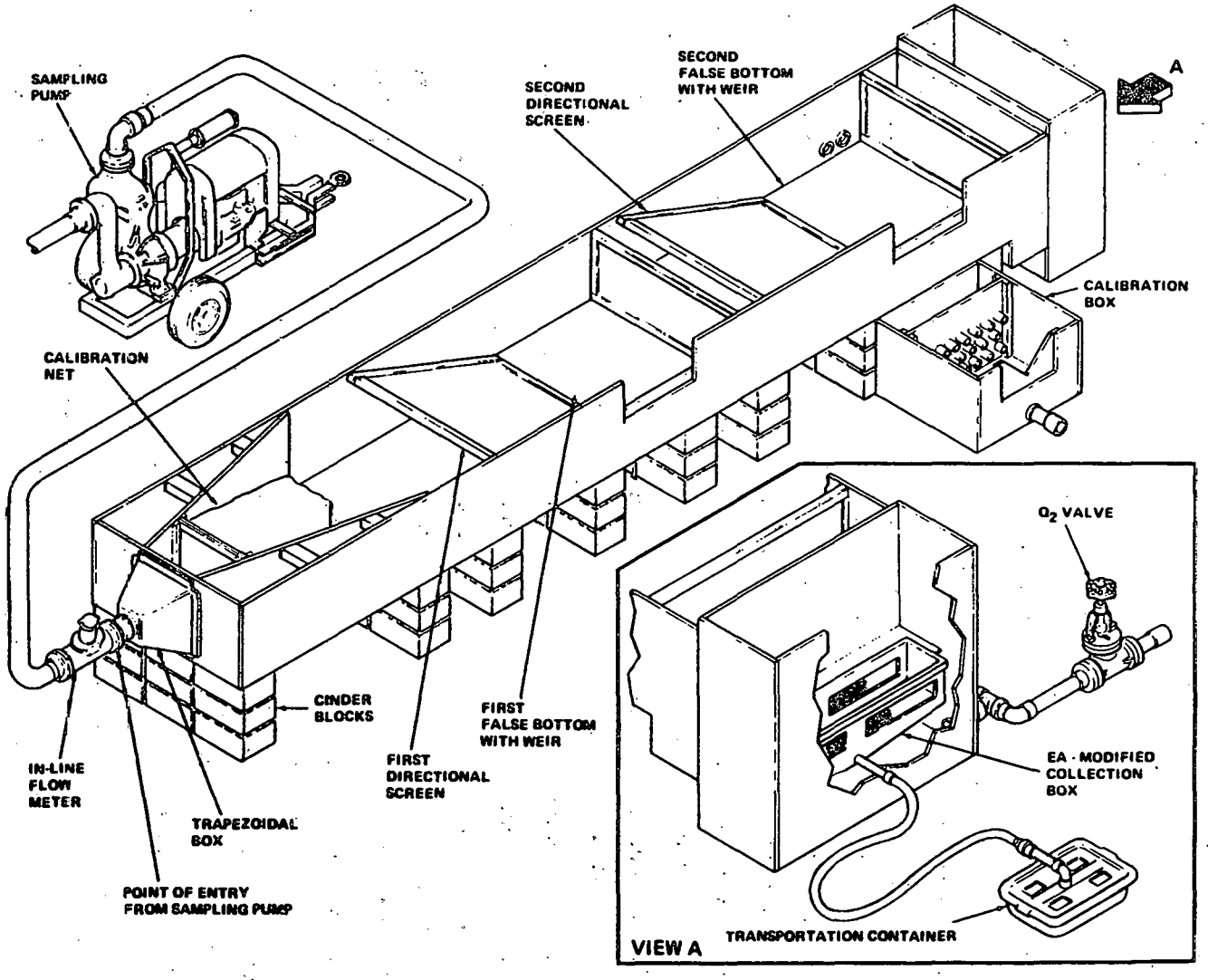

Figure VII-1. Design of the larval collection tables used in the Bowline Point entrainment survival studies beginning in May 1976 (Source: Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report).

Table VII-1. Larval table data by plant and year provided on magnetic tapes to ORNL by the utilities (transmittal of November 16, 1977 from Jay B. Hutchinson to Dr. Webster Van Winkle, and transmittal of April 5, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern)

	Year		
Plant	1975	1976	1977
Bowline Point	X	X	-
Roseton	X	X	-
Indian Point	-	-	X
Danskammer Point	X	-	-
Lovett	-	X	-

Note: X indicates larval data are available on tape, while - indicates data not available on tape.

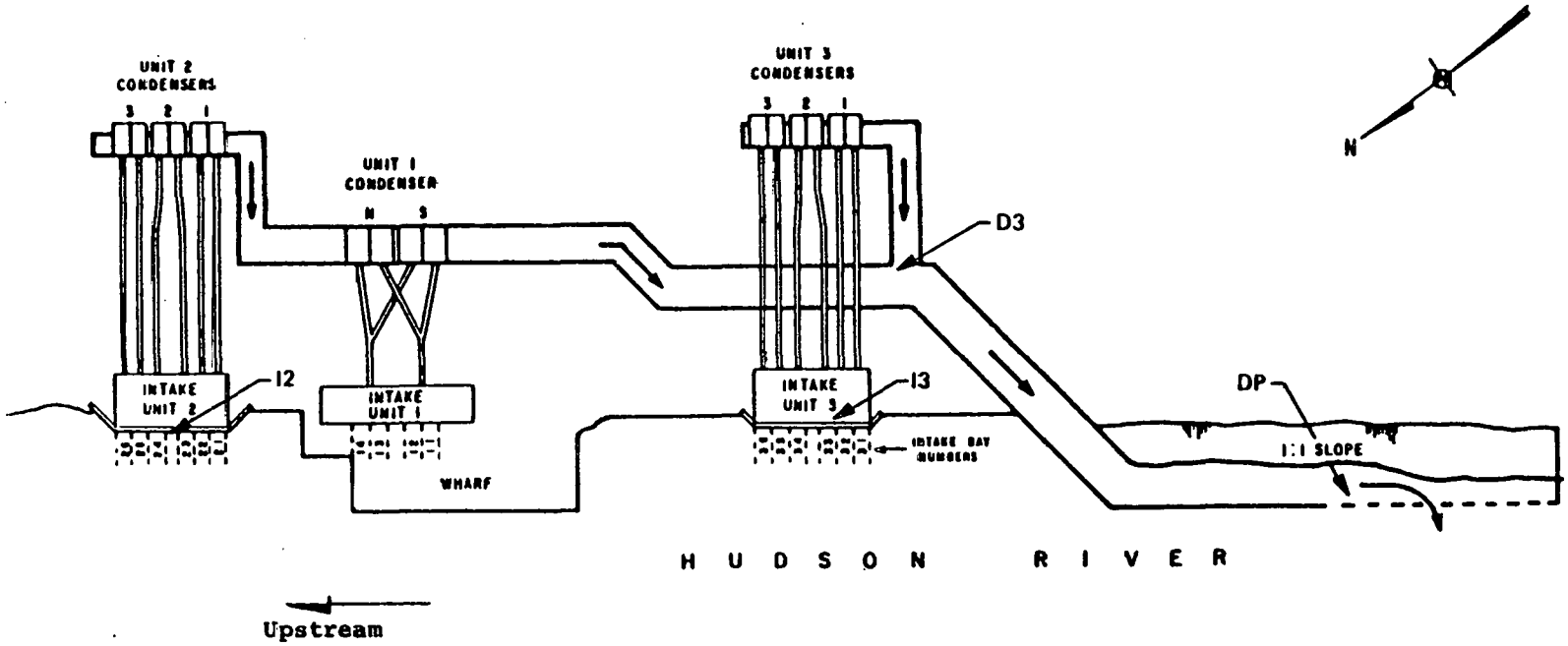

Figure VII-2. Diagram of the Indian Point Generating Station circulating water system showing location of larval table sample stations (Source: Indian Point Generating Station Entrainment Survival and Related Studies, 1977 Annual Report).

represents a mixture of discharge waters from all three units, while the D3 station represents discharge water only from Unit 3 (Transcript p. 8695), it is not unreasonable to expect the sampling survivals at the D3 and DP stations to differ, especially if there is a difference in generating load between the units. Thus, estimates of the f-factor based on Unit 3 data (i.e., samples collected at the Unit 3 intake and at station D3) would be more reliable than using the DP station where the operation of 3 units confuses things greatly. For these reasons all f-factors calculated at Indian Point from larval table data are based on intake and discharge samples for Unit 3. No larval table samples were collected from the cooling water which had only passed through the Unit 2 condensers.

The general strategy used in estimating f-factors with data from the five Hudson River plants (Bowline Point, Roseton, Indian Point, Danskammer Point, and Lovett) was to pool larval table data across plants for the purpose of making estimates (historical and projected) directly from net and larval table data, but to maintain plant-specific calculations for projected estimates that incorporate the thermal model. Pooling data across plants improves the precision of an estimate of total percent losses of eggs and larvae from the river, assuming that there are little or no differences between plants. However, pooled estimates will be weighted toward the plant or plants with the greatest amount of data for a particular life-stage. This pooling was done for each entrainable life-stage of a population for which a single f-factor was calculated.

In order to calculate a f-factor, we required that a minimum of five organisms must have been collected at the intake station and at the discharge station. Although five organisms is not a sample size that allows for a desirably precise estimate, it is the same value that the utilities used (Ecological Analysts, Inc. 1977, Table 4.1.6), and it seemed reasonable to be consistent.

The sample sizes for yolk-sac larvae and entrainable juveniles at each plant were generally too small to support plant-specific estimates of f-factors. The first alternative approach to increase sample size

was to pool data over plants, as was done for the historical estimates. If the pooled sample sizes were still insufficient (fewer than five organisms at the intake or discharge station) to support estimation of an f-factor, the pooled estimate of the post yolk-sac larvae f-factor was used for the life-stage in question (yolk-sac larvae or entrainable juveniles). However, since striped bass and white perch are closely related species (both in the same genus and similar life cycle), rather than using post yolk-sac larvae estimates for yolk-sac larvae within a population, when faced with an insufficient sample size, we used data from the same life-stage from the other population if we thereby met the sample size criterion.

Two sets (historical and projected) of ETM runs were made using f-factors based on immediate entrainment mortality data only. For these runs, no allowance was made for latent mortality. The term $f_{\ell,D}$ in Eq. (VII-1), representing the probability of latent mortality in the first 24 hours after entrainment, was assumed to be zero for these runs.

Latent mortality estimates were confounded by there being considerable mortality being found in both the intake (control) and discharge (experimental) samples over the 24-hour holding period. The strategy employed in working with the latent mortality data involved the pooling among plants of all 24-hour latent data (given initial survival) for a given population and life-stage in order to estimate the latent f-factor. This latent f-factor was then used in Eq. (VII-1) to calculate an overall f-factor. The same rules for sufficient sample size and substitution of estimates that we used for the immediate estimates also were applied in estimating latent f-factors. However, the intake and discharge sample size criterion of five organisms was now applied to the number alive initially in the intake and discharge samples.

Net collections provided the only data for eggs, but even these collections were incomplete. Only striped bass eggs collected at Indian Point in 1973-1975 (Exhibit UT-11, Tables 1.3-11 through 1.3-13) were reported by the utilities. These data were pooled over the three

years, so that a single estimate for striped bass egg mortality was obtained. This estimate of the egg f-factor (0.66) for striped bass was used in the ETM for all populations for both the historical and projected runs. No latent or indirect mortality is included in this estimate.

Occasionally, sampling resulted in an estimate of a negative f-factor. When this happened, f was set at zero, since a negative entrainment mortality is biologically impossible.

In using an estimate of any parameter for predictive purposes, it is important to have an understanding of the precision, or variablity, associated with that estimate. Otherwise, there is a risk of a single, reported value taking on meaning far beyond that which is appropriate from a scientific point of view. Appendix D consists of a discussion of the precision of estimates of the f-factor. That discussion is relevant to both the historical f-factor estimates and the projected f-factor estimates, since the same kind of sampling data forms the basis for both. In general, precision of most f-factor estimates is judged to be poor. However, the precision of the f-factor estimates presented by the utilities are in no case judged to be better and in some cases judged to be worst.

Estimates of component f-factors (i.e., the immediate portion and latent portion of the f-factors) were calculated without regard to their statistical significance. This was necessary because of the poor precision of the component f-factors associated with yolk-sac larvae and entrainable juveniles and, for some populations (clupeids, including American shad, and bay anchovy), because of poor survival in the intake samples (especially for the latent f-factor). The decision to employ a range of estimates in ETM runs using projected thermal model f-factors (see Section 4) was based in part on this poor precision of estimates from the sampling data.

3. ESTIMATES OF THE F-FACTOR FROM NET AND LARVAL TABLE DATA

This section is concerned with the estimation of f-factors for 1974 and 1975. These f-factors were used in runs of the Empirical Transport Model (ETM) to estimate the fractional reduction due to entrainment mortality in the size of the young-of-the-year population for each of the various populations considered (striped bass, white perch, clupeids including American shad, bay anchovy, and Atlantic tomcod). These estimates of f-factors were also used in a set of projected runs of the ETM.

3.1 ESTIMATES FOR EGGS FROM NET DATA

As described in the previous section, a single egg f-factor was calculated from the Indian Point net data (1973-1975) for striped bass. This estimate has a number of problems: (1) net data are generally poor (i.e., biased high or low), (2) population differences are not accounted for, and (3) differing sensitivity of developmental stages of eggs are also not accounted for (Ecological Analysts, Inc. 1978c). However, this pooled estimate was used to estimate the egg f-factor for all populations considered, in the absence of egg data for these other populations. The estimate, which is 0.66, includes no latent effects or indirect effects, and thus some underestimation of the "underlying" f-factor may result.

3.2 ESTIMATES FOR LARVAE AND ENTRAINABLE JUVENILES FROM LARVAL TABLE DATA

In this section a description will be given of the techniques used to obtain estimates of the immediate and latent f-factors from larval table data at five Hudson River plants. These estimates were used in both historical and projected runs of the ETM. Only larval table data supplied on magnetic tape to Oak Ridge National Laboratory (ORNL) by the utilities (see Table VII-1) have been used in estimating the f-factors for larvae (yolk-sac and post yolk-sac) and entrainable juveniles. These pooled estimates are provided in Table VII-2 by

Table VII-2. Estimated larval table f-factors (immediate and latent) pooled across five Hudson River plants (from larval table data provided on magnetic tapes to ORNL by the utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	$f_{i,D}$[b]	f_i[c]	$f_{\ell,D}$[b]	f[d]
Striped bass	Y	0.45	0.47	0.13	0.55
	P	0.27	0.29	0.15	0.40
	J	0.06	0.07	0.11	0.18
White perch	Y	0.45	0.47	0.13	0.55
	P	0.46	0.48	0.0	0.48
	J	0.25	0.26	0.19	0.41
Clupeids	Y	0.55	0.57	0.0	0.57
	P	0.55	0.57	0.0	0.57
	J	0.67	0.69	0.74[e]	0.92
Bay anchovy	Y	1.0	1.0	0.72[e]	1.0
	P	0.88	0.89	0.72[e]	0.97
	J	0.66	0.68	0.77[e]	0.93
Atlantic tomcod	Y	0.04	0.04	0.0	0.04
	P	0.62	0.64	0.0	0.64
	J	0.62	0.64	0.0	0.64

[a] Y = yolk-sac larva, P = post yolk-sac larva, J = entrainable juvenile.

[b] $f_{i,D}$ and $f_{\ell,D}$ are estimates of immediate and latent f-factor components, respectively.

[c] $f_i = 1 - (1-f_{i,D})(1-f_I)$; does not include latent direct mortality.

[d] $f = 1 - (1-f_{i,D})\ (1-f_{\ell,D})(1-f_I)$; includes latent direct mortality.

[e] See Appendix C.2.

life-stage for all five populations considered (striped bass, white perch, clupeids including American shad, bay anchovy, and Atlantic tomcod). The column in Table VII-2 headed by "f_i" incorporates indirect mortality (k = 0.1; see Eq. VII-2) into the immediate f-factor using Eq. (VII-1) without the term $(1 - f_{\ell,D})$ (i.e., without latent direct mortality). The pooled sample sizes for this f-factor estimate are shown in Table VII-3 by life-stage and population. The column headed "Immediate" indicates that the pooled sample size is insufficient (< 5) for estimating the f-factor for:

- white perch yolk-sac larvae
- clupeid yolk-sac larvae
- Atlantic tomcod juveniles

Employing the rules discussed in Section 2, the estimated f-factor for striped bass yolk-sac larvae was used to estimate the f-factor for white perch yolk-sac larvae. Post yolk-sac larvae estimates from clupeids and Atlantic tomcod were used as the basis for estimates for clupeid yolk-sac larvae and Atlantic tomcod juveniles, respectively. The column in Table VII-2 headed "f_i" reflects these substitutions.

The column in Table VII-2 headed "$f_{\ell,D}$" gives the estimated latent f-factor, independent of initial mortality. The sample sizes for the latent estimates (i.e., the number of survivors in the initial samples) are shown in Table VII-3 under the column headed "Latent." This column indicates that the data are insufficient for estimating the latent component of f-factors for

- white perch yolk-sac larvae
- clupeid yolk-sac larvae
- bay anchovy yolk-sac larvae
- Atlantic tomcod juveniles

Again, employing the rules discussed in Section 2, the estimated latent f-factor for striped bass yolk-sac larvae was used for white perch

Table VII-3. Pooled sample sizes by life-stage and population at the intake and discharge sampling stations for use in calculating the immediate and latent components of the f-factor (from larval table data provided on magnetic tapes to ORNL by the utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	Immediate	Latent
INTAKE:			
Striped bass	Y	56	45
	P	991	691
	J	60	54
White perch	Y	2	1
	P	792	447
	J	88	83
Clupeids	Y	0	0
	P	2174	1051
	J	580	367
Bay anchovy	Y	15	1
	P	4516	350
	J	589	337
Tomcod	Y	344	272
	P	64	38
	J	4	4
DISCHARGE:			
Striped bass	Y	52	23
	P	1048	534
	J	66	56
White perch	Y	6	0
	P	813	247
	J	45	32
Clupeids	Y	2	0
	P	2383	519
	J	375	79
Bay anchovy	Y	69	0
	P	4629	41
	J	390	76
Tomcod	Y	210	160
	P	22	5
	J	0	0

[a]Y = yolk-sac larva, P = post yolk-sac larva, J = entrainable juvenile.

yolk-sac larvae, while post yolk-sac larvae f-factor estimates for clupeids, bay anchovy, and Atlantic tomcod were used for clupeid yolk-sac larvae, bay anchovy yolk-sac larvae, and Atlantic tomcod juveniles, respectively.

In a few instances (clupeid entrainable juveniles and bay anchovy post yolk-sac larvae and entrainable juveniles), an estimate of 1.0 was calculated for the latent f-factor ($f_{\ell,D}$) in a situation where (a) the sample size (number initially alive for purposes of estimating latent mortality) at the intake was four to nine times greater than the sample size at the discharge station, (b) only 3 to 4% of those captured alive at the intake survived the 24-hour holding period, and (c) none of those captured alive at the discharge survived the 24-hour holding period. A binomial test (Siegel 1956) was performed in these instances in order to test the likelihood that an estimate of $f_{\ell,D}$ is equal to 1.0 under the null hypothesis that the latent f-factor is zero. In each of these cases, even though the standard normal test (see Exhibit UT-11, p. 1-11) for differences between proportions (one-sided) indicated that the latent f-factor was significantly greater than zero ($P < 0.05$), the binomial test failed to indicate this. Thus, it was felt that a compromise was appropriate. The procedure used is described in Appendix C.2. The output from this procedure was an average f-factor, which was used as our estimate of the latent f-factor. The final column in Table VII-2 headed "f" corresponds to the f-factor estimate defined by Eq. (VII-1); this column gives the estimated f-factor incorporating initial, latent, and indirect mortalities.

3.3 BIASES

Various conditions associated with the sampling techniques can cause a tendency for the true f-factor to be underestimated or overestimated. If this tendency is predominately in one direction (e.g., towards underestimating) for a certain set of conditions, then those conditions are said to result in a biased estimate.

The depth from which samples are collected can result in biased estimates. This depth, together with the geometry of the hoses leading to the larval table, will largely determine the pressure changes (themselves potentially damaging) which an organism will undergo during the collection process. To minimize this source of bias, sampling conditions at the intake and discharge of a particular power plant should be arranged, as much as possible, so that these pressure changes will be the same. While it is not apparent that any effort has been made to assure such similarity, it is also not apparent that hydrostatic changes are consistently either higher or lower at intakes vs discharges, when sampling conditions at the various plants are compared. Therefore, we view this phenomenon as one which increases the variability or uncertainty in individual estimates, but which does not result necessarily in a bias with identifiable direction.

A second sampling condition with the potential for introducing bias relates to the location of the discharge sampling station in relation to the ultimate point of discharge into the river. Elevated temperatures and mechanical stresses in discharge pipes or canals past the point of discharge sampling, or physical conditions in the river relating to plume dilution after discharge, may cause additional mortality. At Bowline Point, Roseton, and Indian Point, a substantial distance must be travelled by the entrained organisms from the discharge sampling station to the actual discharge into the river (see Figs. VII-2, VII-3, and VII-4). For Bowline Point it is roughly 1800 feet from the discharge sampling station for either Unit 1 or Unit 2 to the river discharge (Exhibit UT-7, Table 2.2-1), with two 45° bends for Unit 1 and one 45° bend for Unit 2 (Exhibit UT-7, Fig. 2.2-1). The Roseton discharge sampling station is located in the seal well, with an additional 460 feet to the first diffuser port and 860 feet to the end of the diffuser system (Transcript p. 8724). At Indian Point the distance from D3 (discharge station for Unit 3) is approximately 515 feet from the first discharge port and 765 feet to the last discharge port (Transcript pp. 8726-28). One 45° bend occurs between station D3 and the discharge ports, and the discharge ports are at

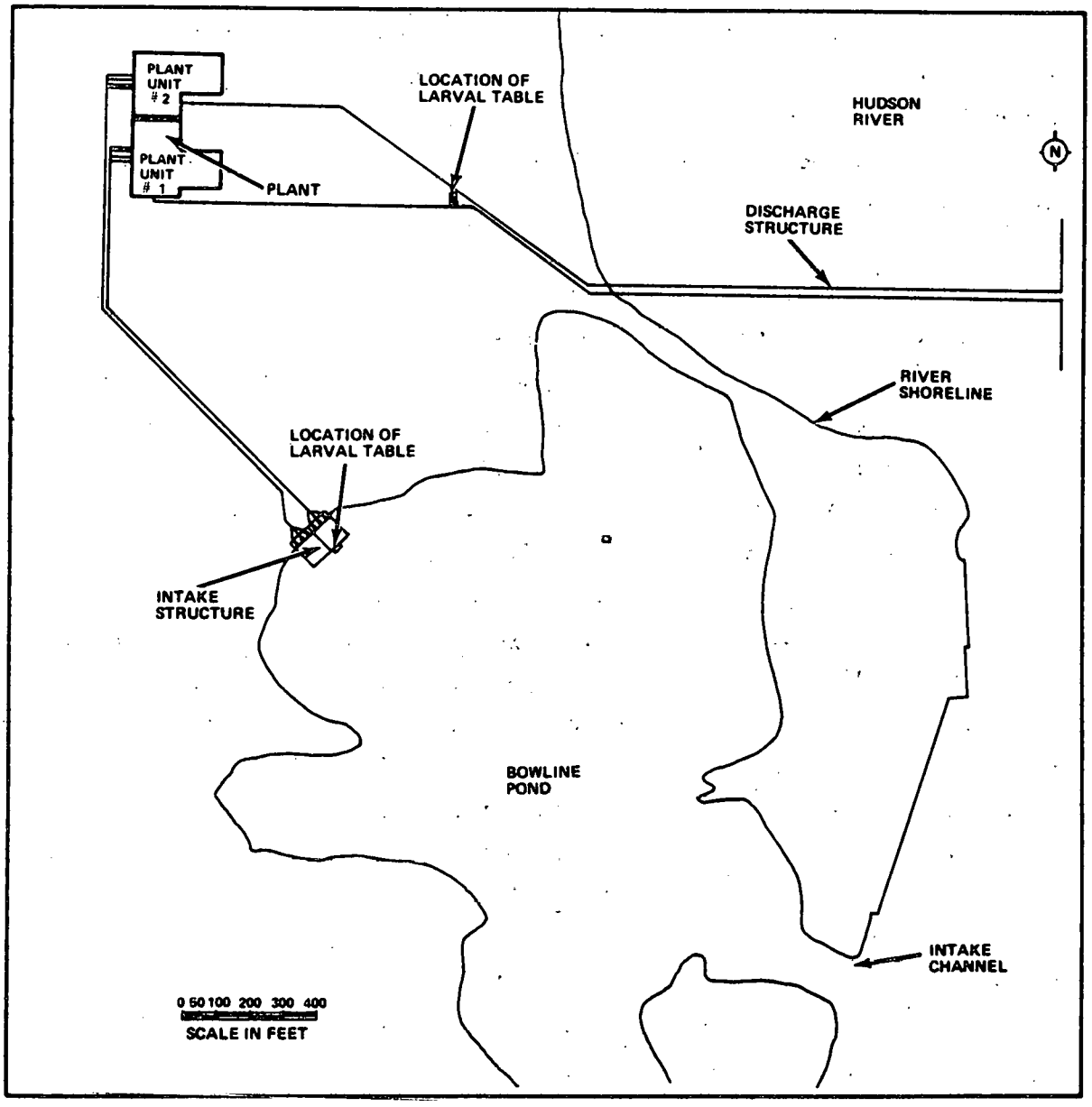

Figure VII-3. Diagram of Bowline Point plant site (Source: Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report).

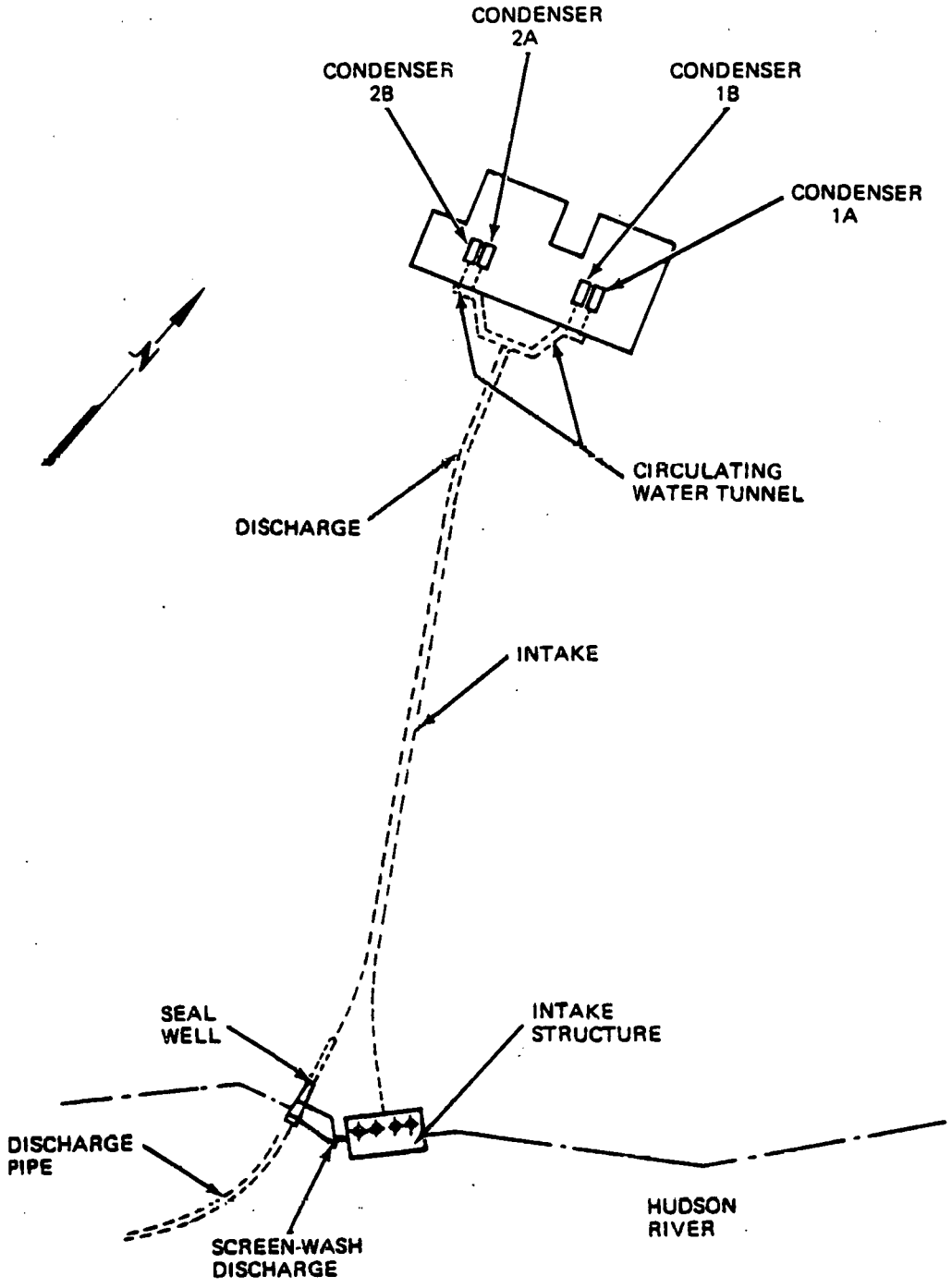

Figure VII-4. General overview of the Roseton Generating Station (Source: Roseton Generating Station Entrainment Survival Studies, 1976 Annual Report).

right angles to the river flow (Transcript pp. 8726-27). The elevated temperatures and mechanical stresses in these pipes and canals after passing the discharge sampling stations may well induce some additional mortality. Also, some additional plant-induced mortality may occur after the entrained organisms are discharged back into the river, due to plume dilution with river water. Finally, as the warmer (less dense) discharge water enters the river, it will tend to rise, carrying eggs and larvae with it; a decrease in hydrostatic pressure is associated with this rise.

Biases associated with discharge sample location may be offset by additional exposure time in the larval table. Since the larval table is operated for 15 minutes and then drained, an average exposure time of at least 7 to 8 extra minutes at the elevated temperatures can be expected. The bias towards understating the f-factor as a result of additional thermal exposure after the discharge sampling station will probably be mostly offset, and in some cases may be more than offset, by the additional thermal exposure experienced in the discharge larval table. [The degree of offset will be less at Indian Point since ambient water was injected into the larval table at the discharge station to reduce the sample water temperature (Ecological Analysts, Inc. 1978b, p. 4-2).] However, additional mortality due to mechanical buffeting and pressure effects is not offset in any manner.

An additional bias, the direction of which is unknown, may occur as a result of failure to evaluate the survival of all organisms that enter the larval table (Transcript p. 8739). In 1975 approximately 40 to 50% of the organisms collected from the larval table were not in the classification live, stunned, or dead (Transcript p. 8743). These "missing" organisms were collected from a net sampling the screened water (and hence the organisms must have passed around or through the screen in the larval table), or they were collected during the wash-down procedure. In either case, the potential for collection damage was deemed high enough to invalidate the use of these organisms for plant survival purposes. After modifications to the design of the larval

table, this loss was reduced to approximately 10% of the organisms collected from 1976 on.

Another general category of sampling conditions having the potential to cause bias in f-factor estimates arises from the possibility that the sampling effort may be concentrated during periods when survival at the plant is unusually high or unusually low. Any toxic chemical additives, such as chlorine, will increase the mortality due to plant passage. Chlorination is used to control biofouling in the cooling water system. The rate of biofouling is enhanced by the pitting of the surface of the condenser tubes (Transcript pp. 8836-8837). Over the lifetime of a plant the necessity for treatment of biofouling may increase, thus leading to higher plant entrainment mortalities (f-factors). Since no chlorination occurred during the use of the larval tables (Transcript p. 8718), this potential bias exists, though it may be extremely small. Sodium hypochlorite is the only chemical added to the cooling water at Bowline Point (Exhibit UT-7, p. 2.4-1), and this occurs only infrequently (though during the striped bass entrainment season) when ambient temperatures exceed 50°F. No chlorination occurred at Roseton in 1975 and 1976 (Exhibit UT-6, p. 2.4-2). The Indian Point Unit 2 cooling water system was chlorinated 16 times in 1974 and 14 times in 1975 (Exhibit UT-9, p. 1-19).

In using the larval table data (that is, discharge samples irrespective of the discharge temperature), the f-factor estimate will be biased if the temperature values for the discharge samples do not reflect the true temperatures experienced in the discharge canal during the entrainment season. Most sampling occurred at night when generating loads (and hence ΔT's) were lower (Exhibit UT-11, p. 3-4). At Indian Point Units 2 and 3, the ΔT would be fairly constant throughout the day. However, the intake temperature (and therefore, the discharge temperature) would probably be lower at night. For instance, at Bowline Point in 1975 only night samples were collected from the initiation of sampling on June 3 up until June 23 (Ecological Analysts,

Inc. 1976, p. 3-1). Since no striped bass larvae or entrainable juveniles were captured after June 23, an estimate of the f-factor based on sampling at Bowline Point in 1975 would underestimate the true f-factor.

In this Section (3.3) we have discussed several general conditions that can result in a biased estimate of the f-factor. Some additional sources of bias are discussed in Appendix E. The direction of some of these biases are unidentifiable, while others lead to underestimates or overestimates of the f-factors. The overall, or net, effect of these biases is not known.

4. PROJECTED THERMAL MODEL ESTIMATES

In order to develop estimates of f-factors for future operating conditions of five Hudson River plants (Bowline Point, Roseton, Indian Point, Danskammer Point, and Lovett) for three fish populations (striped bass, white perch, and clupeids including American shad), Ecological Analysts, Inc. developed an entrainment mortality model (Exhibit UT-11). Their model uses a regression equation to estimate the thermal component of entrainment mortality as a function of the acclimation (or ambient) temperature, exposure duration (or transit time), and exposure temperature. The thermal model results are then combined with a mechanical component of entrainment mortality based on larval table data (presumably taken when there was very little if any thermal mortality) to give a combined estimate of entrainment mortality. The inputs to the thermal component of mortality are developed from an historical data base of river ambient temperature and projected plant operating conditions (plant flows and net generating loads), while the mechanical component is based on larval table data collected during periods when the discharge temperatures are sufficiently low that little or no thermal mortality would be induced.

The regression equation used for the thermal component of entrainment mortality (Exhibit UT-11, p. 2-4), is

$$M_t = b_0 + b_1 T_A + b_2 \cdot \log_{10} t + b_3 \cdot T_E \quad , \qquad \text{(VII-6)}$$

and then

$$f_t = \int_{-\infty}^{M_t - 5} \frac{1}{\sqrt{2\pi}} \exp\left(-\tfrac{1}{2} x^2\right) dx \quad . \qquad \text{(VII-7)}$$

M_t is the probit (defined by Eq. (VII-7)) corresponding to the thermal component of the f-factor (f_t), T_A is the ambient temperature (°C), t is the exposure duration (minutes), T_E is the

exposure temperature (°C), x is the ordinate of the standard normal distribution, and b_0, b_1, b_2, and b_3 are coefficients estimated by probit regression techniques from laboratory experiments (Ecological Analysts, Inc. 1978c). The probit transformation [Eq. (VII-7)] is used to linearize the thermal mortality curve shown in Fig. VII-5 where there is low mortality below a certain temperature, high mortality above a higher temperature, and a rapid increase in mortality over a narrow range between these two temperatures.

The "threshold effect," or rapid change in mortality over a narrow range of exposure temperatures, can cause a significant bias in estimates of entrainment mortality. In Fig. VII-5 only one independent variable, exposure temperature, is considered. As will be discussed later, projected exposure temperatures are a function of ambient temperature, recirculation of plant cooling water, flow rate of plant cooling water, and generation load. Since all of these inputs are subject to error, one might represent the overall temperature error by the normal curve shown in Fig. VII-5. If the mean of a future set of temperatures (e.g., $\overline{T}$ = 35°C) lay just below the threshold (36-40°C), as it in fact tends to do during the summer months, then the estimate of the thermal component of the f-factor based on the mean of the input variable [$f(\overline{T})$] would be considerably less then the mean of the estimates of the thermal component of the f-factor [$\overline{f}(T)$], each calculated over the actual range of the respective variable (Fig. VII-5). For example, if one takes the average of all the exposure temperatures over some period of time (i.e., day or month) and that value falls below the threshold, then one would compute virtually no thermally-induced mortality [i.e., $f(\overline{T}) \simeq 0$]. However, if one takes the individual estimates of exposure temperature, one can calculate the thermal mortality associated with each of these estimates of exposure temperature, and then average these thermal mortalities [i.e., $\overline{f}(T)$]. In general, these two estimates of the thermal mortality factor are different [i.e., $f(\overline{T}) \neq \overline{f}(T)$]. In particular, when exposure temperatures lie below the threshold temperature, the average thermal mortality factor can be considerably greater than the thermal mortality

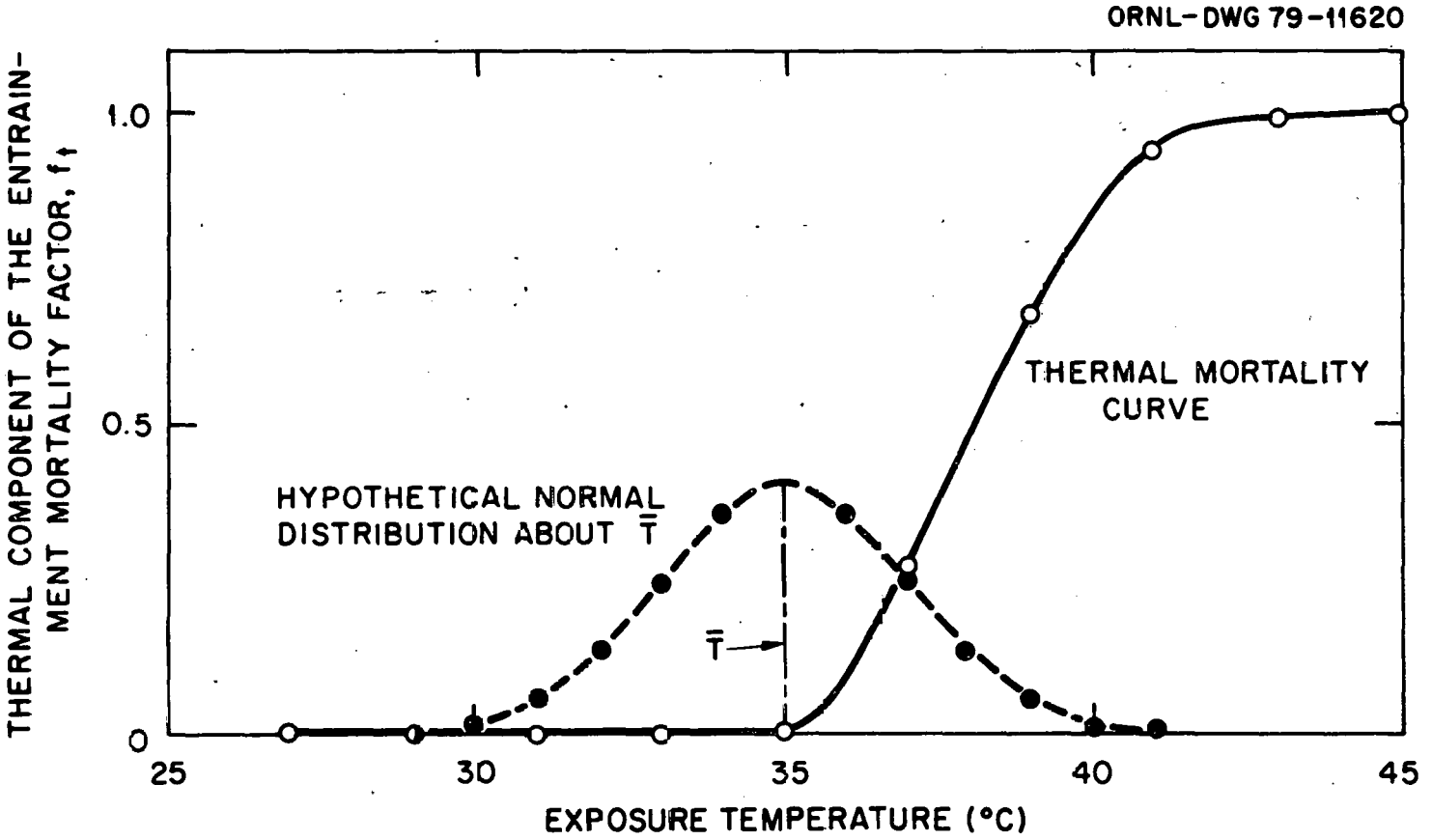

Figure VII-5. Plot of the thermal component of the entrainment mortality factor, f_t, as a function of the exposure temperature, T_E (°C). Superimposed on this plot is the normal probability density function with a mean of 35°C. This plot illustrates the effect of a "threshold" on estimating the average f-factors (see text).

factor based on average conditions. It is the estimated mean of the thermal component of the f-factor which we want to use in our "projected" thermal mortality ETM runs (Chapter VIII). This estimated mean of the thermal component of the f-factor will, in general, be understated by an estimated f-factor based on average exposure or ambient temperatures.

Any averaging performed on the inputs to the thermal mortality regressions can create a source of bias (or an underestimate of the true f-factor). Thus, in assembling inputs to the thermal mortality regression, ORNL has attempted to retain as much of the variability inherent in the data as possible. However, due to the many sources of variability, it was necessary to use averaged inputs in many instances in generating ORNL's estimates of the f-factor, which has resulted in some understatement of the thermal f-factor.

For example, the assumption of uniform transfer of heat from the condensing steam to the cooling water (Transcript p. 9195) and the assumption of uniform pumping rates for the plant cooling water are two assumptions that may lead to underestimates of the true f-factor, especially when the ambient temperatures are high. Slight decreases in flow rate (or increased transit time and ΔT) or areas of the condensers of higher heat transfer will have a greater effect, in terms of increased mortality, than would comparable increases in flow rate (or decreased transit time and ΔT) or areas of lower heat transfer. These effects can become pronounced when exposure temperature is just below the "threshold" exposure temperature. Since these effects are not considered in the thermal component of the entrainment mortality model, a source of bias which leads to an underestimate of the f-factor is present.

Dey (1978) and Exhibit UT-11A (Fig. A.2-19) suggest that there was a bimodal distribution of spawning of striped bass in 1976 on the Hudson River, and that "survival for individuals from the first spawn was extremely low during the transition from yolk-sac to post yolk-sac stage." If this in fact occurred, then the second spawn should be more important in terms of recruitment to adulthood. However, this later

spawn will have a greater entrainment mortality associated with it as a result of higher ambient temperatures occurring later in the striped bass entrainment season. Consequently, f-factors based on the entire spawn would underestimate the actual f-factor applicable to the striped bass population when a bimodal distribution of spawning occurs.

4.1 INPUTS TO MODEL

In this section we discuss the inputs necessary for developing a set of projected thermal model f-factors by plant and life-stage over the entrainment periods of striped bass, white perch, and clupeids including American shad. The model is presently set up to run from April 1 to August 31. The output is averaged by week, on a day (6:00 AM through 8:00 PM) vs night (9:00 PM through 5:00 AM) basis in hourly increments. The first day of the first week is April 1. The final week contains 6 days and is averaged accordingly.

4.1.1 Ambient Temperatures

In order to estimate the ambient temperatures at the various plants [as used in Eq. (VII-6)], a twenty-six year temperature data base (1951-1976) from the Poughkeepsie water supply station (provided on magnetic tape to ORNL by utilities in a transmittal dated November 17, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern) was used. The daily 90th percentiles (i.e., for each day ten percent of the observed values are greater than or equal to these values) were obtained from these data and used as the base ambient temperature for the model runs (Table VII-4). Since the mean ambient temperature (i.e., daily 50th percentiles) would result in an underestimate of the true f-factor, the 90th percentile was used in order to offset this bias. The daily temperature range over the twenty-six-year data base is typically about ten degrees Fahrenheit (5.6°C), so the difference between the mean and 90th percentile is a matter of about 3°F (2°C). It is believed that the increase in thermal entrainment mortality estimates that will occur during periods of high ambient temperature will lead to a more accurate, rather than conservative, estimate of the true f-factor than would the

Table VII-4. Ninetieth percentile of mean daily water temperature (°F) at Poughkeepsie (based on 26-year record for 1951-1976) from April 1 through August 31 (transmittal of November 17, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern)

Day	Apr.	May	June	July	Aug.
1	44	55	67	75	78
2	45	54	68	75	78
3	45	55	68	75	78
4	45	56	68	75	78
5	45	55	68	77	78
6	45	56	68	76	79
7	45	56	67	76	78
8	45	57	69	76	78
9	46	57	69	76	78
10	46	57	69	76	78
11	46	59	69	76	78
12	46	57	70	77	78
13	48	59	70	77	78
14	47	59	70	77	78
15	48	59	70	77	78
16	49	60	70	78	78
17	49	59	71	78	78
18	49	60	71	78	78
19	48	60	72	78	78
20	48	61	72	78	78
21	50	61	72	78	78
22	51	62	72	78	78
23	51	63	72	78	78
24	52	62	72	78	78
25	52	64	73	78	78
26	54	64	73	78	78
27	53	65	73	78	78
28	53	66	74	78	78
29	54	66	74	78	78
30	54	67	74	78	77
31		64		79	77

use of the mean ambient temperature, as a result of the bias inherent in a threshold-type model.

In order to estimate intake temperatures for Bowline Point, Roseton, and Danskammer Point, linear regressions between plant intake temperatures and corresponding Poughkeepsie temperatures were performed for Bowline Point (Unit 2) and Danskammer Point from data provided on the same magnetic tape (transmittal of November 17, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern) as the Poughkeepsie temperature data. For Indian Point the equation given as Eq. 3 IV-61 in Exhibit UT-3 was used. The following linear regressions were used in developing ORNL's estimates of intake temperatures:

Danskammer Point:	$T = 1.07\ PT - 4.52$	(VII-8)
Bowline Point (Unit 2):	$T = PT + 2.38$	(VII-9)
Indian Point (Unit 2):	$T = 0.96\ PT + 3.34$	(VII-10)

where T = the intake temperature (°F) and PT the temperature (°F) at Poughkeepsie. The regression for Danskammer Point has been used also for Roseton (about 0.6 miles downstream of Danskammer Point). A weighted average of the Bowline Point and Indian Point regressions could have been be used for Lovett. Lovett is located about 2 miles downstream of Indian Point and about 3.5 miles upstream from Bowline Point (Exhibit UT-9, Fig. 1-1).

The regression for Danskammer Point used minimum daily temperatures at the intake, a temperature that includes very little recirculation (which would otherwise cause an overestimate of the ambient temperature). The Bowline Point and Indian Point intake measurements, however, do include the effect of recirculation in the "ambient" temperatures. In order to estimate the actual ambient temperature experienced by the entrainable organisms prior to entering the influence of the recirculated water near the intakes (T_A), it was

necessary to subtract from the intake temperature (T) obtained from the regression some value corresponding to the incremental temperature due to the recirculating water. The model, as employed by ORNL, introduces a factor (R_1) to be subtracted from the intake temperature to obtain the ambient temperature, T_A. This factor is

$$R_1 = \Delta T \cdot R \quad , \qquad \text{(VII-11)}$$

where ΔT is a function of plant generating load and flow, and R is the plant specific recirculation estimate (Table VII-5). This factor (R_1) is set to zero for Roseton and Danskammer Point, since the regression for intake temperature is based on minimum daily temperature at Danskammer Point, which reflects essentially no recirculation. Since the regressions for Bowline Point and Indian Point are based on average daily intake temperatures, which include the effects of recirculation, the R values shown in Table VII-5 are used for these plants.

The ambient temperature at Lovett was calculated by averaging two regression equations (both of which include the effects of recirculation). Since the value of R_1 for Lovett is a function of the calculated ΔT at both Indian Point and Bowline Point, it was decided that only larval table estimates of the total f-factor (with and without latent mortality) would be used for the different fish populations and life-stages at Lovett (i.e., the same results used in the historical estimates for yolk-sac larvae and entrainable juveniles, but post yolk-sac larvae f-factor estimates were plant specific whenever possible).

4.1.2 Exposure Duration

The exposure duration, or time of passage of an entrainable organism from the condenser to the discharge ports, is a function of the rate of plant flow. The number of pumps operating and, for some plants, the mode of pump operation directly affect this flow rate.

Table VII-5. Recirculation values for five Hudson River plants as used in generating EPA's estimates of the f-factor

Plant	Recirculation (R)
Bowline Point[a]	13%
Roseton[a]	13%
Indian Point[a]	7%
Danskammer Point[b]	10.4%
Lovett[b]	11.2%

[a]From Table 3-IV-28, Exhibit UT-3.

[b]From transmittal of November 17, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern.

Flow data for once-through cooling in Appendix A to Exhibit UT-3 were used as the basis for projected flow estimates at Bowline Point Units 1 and 2, Roseton, and Indian Point Units 2 and 3. Since some of the projected flows given in this appendix include an allowance for downtime due to planned maintenance, and since estimates of the f-factor should reflect the actual flows at the plants when operating, the plant flows used in generating ORNL's estimates of the f-factor have had the effect of downtime removed. The projected flows for Bowline Point Unit 2 (Exhibit UT-3, Table A-4), which contain no downtime, were used for Bowline Point Unit 1 (Exhibit UT-3, Table A-5). A flow rate of 840,000 gpm was used for April through August for both Units 2 and 3 at Indian Point (Exhibit UT-3, footnote to Table A-2). At Roseton the minimum plant flow with both units operating is 418,000 gpm (two pumps). The projected plant flow for a given month (April through August) at Roseton was calculated as the arithmetic average for the years 1977 through 2015 when the plant flow given in Table A-1 of Exhibit UT-3 exceeded 418,000 gpm. Any flow less than 418,000 gpm implied that one unit was down at Roseton. Since no projected plant flows for Danskammer Point (or Lovett) were available (transmittal of March 8, 1979 from Dr. Kenneth Marcellus to Dr. Douglas Vaughan), monthly averaged flow rates from historical data were used for Danskammer Point Units 3 and 4 (transmittal of October 31, 1977 from Thomas Huggins to Henry Gluckstern). Table VII-6 summarizes the projected flow rates used in estimates of exposure duration for five Hudson River plants.

As a power curve would more accurately represent the relationship between exposure duration and plant flow than does the linear relationship used by EAI (Con Ed Response of December 5, 1977 to EPA October 12, 1977 Motion, Attachment E; and Eqs. 3-IV-55 and 3-IV-57 in Exhibit UT-3), a power curve was used, i.e.,

$$t = a(QP)^b \quad , \qquad \text{(VII-12)}$$

Table VII-6. Projected flows by month and unit for five Hudson River plants (x 1000 gallons per minute)

Plant	Unit	April	May	June	July	August
Bowline Point[a]	1	257.0	257.0	350.0	384.0	384.0
	2	257.0	257.0	350.0	384.0	384.0
Roseton[a]	1&2	418.0	512.0	557.0	641.0	641.0
Indian Point[a]	2	840.0	840.0	840.0	840.0	840.0
	3	840.0	840.0	840.0	840.0	840.0
Danskammer Point[b]	3	48.2	82.0	81.0	82.0	82.0
	4	112.5	150.0	150.0	150.0	150.0
Lovett[c]	4	104.3	104.3	104.3	104.3	104.3
	5	120.0	120.0	120.0	120.0	120.0

[a]Derived from data given in Appendix A to Exhibit UT-3.

[b]Derived from data (Unit 3 from 1975 and Unit 4 from 1976) given in the transmittal of October 31, 1977 from Thomas Huggins to Henry Gluckstern.

[c]From transmittal of January 10, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle.

where t = exposure duration in minutes, QP = plant flow in 1000 gpm, and a, b are parameters estimated by regression techniques. In general, b is approximately equal to minus one, which implies an inverse relationship of cooling water (or plant) flow with transit time (or exposure duration) (Exhibit UT-11, pp. 3-6). The equations developed from the data in Table VII-7 are:

Bowline Point:	$t = 2017.977(QP)^{-1.0}$	($r^2 = 1.00$)	(VII-13)
Roseton:	$t = 1435.69(QP)^{-0.931}$	($r^2 = 0.997$)	(VII-14)
Danskammer Point Unit 3:	$t = 145.013(QP)^{-0.996}$	(r^2 = 1 by defn.)	(VII-15)
Danskammer Point Unit 4:	$t = 73.317(QP)^{-0.999}$	($r^2 = 1.0$)	(VII-16)
Lovett Unit 4:	$t = 93.87\ (QP)^{-1}$	(r^2 = 1 by defn.)	(VII-17)
Lovett Unit 5:	$t = 252.0\ (QP)^{-1}$	(r^2 = 1 by defn.)	(VII-18)

The equations used for Indian Point were taken from Eqs. 3-IV-56a and 3-IV-56b (Exhibit UT-3) for Units 2 and 3, respectively, and are:

Indian Point Unit 2: $t = 36.3696 - 0.053861(QP) + 0.0000262(QP)^2$ (VII-19)

Indian Point Unit 3: $t = 12.6599 - 0.00779(QP) + 0.0000024(QP)^2$. (VII-20)

It should be noted that these exposure durations make no allowance for time spent in the thermal plume by plant entrained organisms after discharge to the river (Transcript p. 9113). Any systematic underestimate that might result with respect to the estimated thermal component of entrainment mortality will be related to how quickly this thermal plume is dispersed. Since an organism is likely to remain within this thermal plume for a period of at least a few minutes, the estimate of the thermal component of entrainment mortality would be an underestimate.

Table VII-7. Observed and predicted exposure durations as a function of plant flow

Plant	Unit	Flow (1000 gpm)	Exposure duration (min) Observed	EAI[a]	ORNL[b]
Bowline Point[c]	1&2	185	10.90	8.54	11.21
		257	7.84	7.34	8.06
		316	6.38	6.35	6.55
		384	5.25	5.22	5.38
Roseton[d]	1&2	218	9.60	6.96	9.56
		376	5.58	5.65	5.75
		418	5.35	5.30	5.21
		561	3.98	4.11	3.96
		641	3.49	3.45	3.50
Indian Point[e]	2	560	14.6	14.42	--
		700	11.6	11.50	--
		840	9.7	9.61	--
	3	560	8.5	9.05	--
		700	6.7	8.38	--
		840	5.6	7.81	--
Danskammer Point[f]	3	41	3.59	--	3.59
		82	1.80	--	1.80
	4	50	1.47	--	1.47
		100	0.74	--	0.74
		150	0.49	--	0.49
Lovett[f]	4	104.3	0.9	--	0.9
	5	120.0	2.1	--	2.0

[a]Exhibit UT-3, p. 3-IV-57.

[b]Eqs. (VII-13) - (VII-18).

[c]Exhibit UT-7, Table 2.3-2.

[d]Exhibit UT-6, Table 2.3-4 (T-K).

[e]Exhibit UT-9, Tables 1-3 and 1-6 (using identical flows at Units 2 and 3).

[f]Attachment A, transmittal of January 10, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle.

4.1.3 Exposure Temperatures

The exposure temperature experienced by an entrained organism is the sum of the river ambient temperatures (T_A) and the incremental temperature (ΔT) added to the cooling water due to plant operation. A proportional increment of the ΔT is used to reflect recirculation (R) effects. Thus, the full relationship of the exposure temperature (T_E) to the above three quantities is given by:

$$T_E = T_A + (1+R)\ \Delta T \quad . \qquad \text{(VII-21)}$$

Table VII-5 gives the utilities' recirculation estimates for five Hudson River plants. Since recirculation has been factored out of the ambient temperatures at Bowline Point and Indian Point (see subsection 4.1.1), it is necessary to retain R in Eq. (VII-21) for these two plants, as well as for the other plants.

The rise in water temperature through the condenser (ΔT) is a function of plant cooling water flow (discussed in the previous section) and plant generating load. Projected plant generating loads as a percent of maximum net generating load for Bowline Point, Roseton, and Indian Point were taken from Table C-2 in Exhibit UT-3 and are shown in Table VII-8 for April through August (day vs night generating loads have been recombined according to the definition of a 15-hour day and 9-hour night). In order to represent diurnal variations in plant generating loads in the model for each month from April through August, hourly generating loads averaged within a month were used in the thermal component of the entrainment mortality model (see Tables 2.1C-11 through 2.1C-20 of Exhibit UT-6A, and Tables 2.1B-21 through 2.1B-30 of Exhibit UT-7A). For any monthly generating load entered into the model, all hourly generating loads for that month were multiplied by the ratio of this monthly generating load to the average generating load of the twenty-four hourly values. No diurnal variation for Indian Point was used.

Table VII-8. Monthly projected generating load as percent of dependable maximum net generation by unit and plant, and dependable maximum net generation

Plant	Unit	April	May	June	July	August	Dep. Max. Net Gen.[a] (Mw)
Bowline Point[b]	1	74.3	71.7	73.0	77.2	72.4	600.0
	2	74.3	72.9	74.4	81.6	71.6	600.0
Roseton[b]	1&2	80.4	76.5	72.3	77.0	78.6	600.0
Indian Point[b]	2	100.0	100.0	100.0	100.0	100.0	900.0
	3	100.0	100.0	100.0	100.0	100.0	910.0
Danskammer Point[c]	3	76.0	74.0	70.0	70.0	78.0	121.7
	4	74.0	72.0	65.0	67.0	67.0	234.0
Lovett	4	--	--	--	--	--	195.0
	5	--	--	--	--	--	202.0

[a]Attachment A, transmittal of January 10, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle.

[b]Exhibit UT-3, Appendix C-2.

[c]Attachment B, transmittal of January 10, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle.

Since no projected generating loads were available for Danskammer (see letter of March 8, 1979 from Dr. Kenneth Marcellus to Dr. Douglas Vaughan), historical generating loads were used as inputs for the projected runs of the entrainment mortality model (see transmittal of January 10, 1979, Attachment B, from Dr. Kenneth Marcellus to Dr. Webster Van Winkle). Using selection criteria similar to those used in selecting plant flows, 1975 monthly averaged generating load data were used for Unit 3 and 1976 data were used for Unit 4. Days for which Unit 3 or 4 were down were not used in the calculations. These were the most recent years for which the respective units were operating during most of the entrainment season and for which the data were available prior to submission of the utilities' direct testimony.

Since the hourly generating loads for Danskammer Point Units 3 and 4 were available only on sheets of paper rather than computer tape, five days when the units were operating were selected for each month using a random number table. Hourly averaged generating loads were calculated from these data subsets by unit and month for the purpose of representing diurnal variations in arriving at ORNL's f-factor estimates.

The equations used for calculating ΔT (°F) for Bowline Point, Roseton, and Indian Point from Exhibit UT-3 (p. 3-IV-60) are:

Bowline Point: $\Delta T = 4.28929 + 0.2341(GL) - 0.0294(QP)$ (VII-22)

Roseton: $\Delta T = [102.0(GL) + 1308.0]/QP$ (VII-23)

Indian Point: $\Delta T = 74.0 - 0.1259(QP) + 0.000068(QP)^2$ (VII-24)

where GL = the net generating load as a percent of the "dependable maximum net generation," and QP = the plant flow (x 1000 gallons per minute). The equation for Indian Point does not take account of any change in maximum dependable net generation. Thus the 1978 uprating at Indian Point Unit 3 (letter of February 13, 1979 from Dr. Kenneth Marcellus to Henry Gluckstern) and any future upratings at Indian Point Units 2 or 3 leading to percent net generation greater than 100% are

not currently reflected in the estimated ΔT using Eq. (VII-24) (letter of February 13, 1979 from Dr. Kenneth Marcellus to Henry Gluckstern). Thus, Eq. (VII-24) predicts a ΔT with six pumps of 16.2°F for Units 2 and 3, while at 1068 MWe ("ultimate uprated capacity") the ΔT with six pumps is 17.5°F at Units 2 and 3 (letter of February 13, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle). This underestimate of ΔT by 1.3°F (0.7°C) may cause a significant underestimate of the f-factor when exposure temperatures are just below the threshold (Fig. VII-5). Since Indian Point Unit 3 has a higher ΔT than Indian Point Unit 2 at 100% capacity, Eq. (VII-24), which approximates the ΔT for Unit 2, underestimates the ΔT for Indian Point Unit 3 (see letter of November 22, 1978 from Dr. Kenneth Marcellus to Marcia Mulkey). Hence, Indian Point Unit 3 operating at 91% of full power results in the same ΔT as Indian Point Unit 2 at 100% capacity. In light of future upratings and the greater ΔT at Indian Point Unit 3 as compared to Unit 2, ORNL does not believe that estimates of the thermal f-factor for Indian Point (both units combined) are at all likely to overestimate this thermal f-factor as a result of using a projected generating load of 100%.

The equations used for calculating ΔT at Units 3 and 4 at Danskammer Point were derived from equations presented in Attachment A of the transmittal dated January 10, 1979 from Dr. Kenneth Marcellus to Dr. Webster Van Winkle. These equations of ΔT (°F) as a function of cooling water flow and plant generation are:

$$\text{Unit 3: } \Delta T = [9.345(GL) + 125.8]/QP \qquad \text{(VII-25a)}$$

$$\text{Unit 4: } \Delta T = [18.810(GL) + 177.7]/QP \qquad \text{(VII-25b)}$$

where GL and QP are as defined in the previous paragraph.

4.2 PROBIT MODEL FOR THERMAL MORTALITY

The data used in developing the predictive model for the thermal component of entrainment mortality are based on laboratory experiments using hatchery-reared fish (Exhibit UT-11, p. 2-1). The results of these experiments, performed in 1976 and 1977, are given in Appendix B to the Hudson River Thermal Effects Studies for Representative Species, Final Report (Ecological Analysts, Inc. 1978c) (sent to ORNL by Dr. Kenneth Marcellus on January 17, 1979). ORNL has restricted itself to the 1976 data for striped bass, white perch, and alewives (a clupeid) which were available to the utilities at the time when their direct testimony was filed. However, we noted only minor differences for striped bass when the 1977 data were included in some of our initial analyses.

Some additional laboratory data were not used in developing the probit regressions by EAI (Ecological Analysts, Inc. 1978c) or by ORNL. Egg stage data for all populations were not used in developing the thermal mortality regressions, nor were any exposure durations greater than 60 minutes used. In these experiments mortality was assessed 24 hours after the thermal exposure.

The thermal mortality data for striped bass consisted primarily of data for yolk-sac and post yolk-sac larvae, with one test run in 1977 for juveniles having a mean total length of 52 mm (Ecological Analysts, Inc. 1978c, Table 5.2-2). No post yolk-sac larvae or entrainable juveniles were tested in the 1976 white perch studies (Ecological Analysts, Inc. 1978c, Table 5.2-3) or in the 1976 alewife studies (Ecological Analysts, Inc. 1978c, Table 5.2-7). Since the data in 1976 consisted only of yolk-sac larvae for white perch and clupeids, and since it has been noted that yolk-sac larvae of striped bass and alewives are more tolerant than post yolk-sac larvae and juveniles (Ecological Analysts, Inc. 1978c, pp. 5.2-9 and 5.2-21,), these regressions developed for white perch and alewives are likely to underestimate the true thermal mortality when applied to all entrainable life-stages.

Test run LS-015 for striped bass (Ecological Analysts, Inc. 1978c, Table 5.2-2) and test run LS-032 for white perch (Ecological Analysts, Inc. 1978c, Table 5.2-3) were deleted from consideration by EAI due to start up problems and high control mortality (Robert Kellogg, Ecological Analysts, personal communication). Ecological Analysts, Inc., in developing the final 1976 probit regression equation for striped bass (letter of June 23, 1978 from Dr. Kenneth Marcellus to Henry Gluckstern), used only those data from 1976 (and from early 1977) which are marked by the letter I (Ecological Analysts, Inc. 1978c, Table 5.1-1). In all, 32 out of 69 data points (46%) in 1976 were discarded for striped bass, 45 out of 110 data points (41%) in 1976 were discarded for white perch, and 35 out of 128 data points (27%) in 1976 were discarded for alewives. EAI's selective deletion of data points apparently was done in an attempt to correct for bias when an unweighted regression is performed using the probit transformation on a data set having test temperatures from well below temperatures causing thermal mortality to well above temperatures causing complete thermal mortality. This procedure of selective data deletion causes a bias, and it also causes the r^2 (proportion of variance explained by model) for the regression to be much larger than if the data were not deleted.

Finney (1964) describes a weighted, iterative regression scheme for estimating the coefficients in a probit regression. This technique provides maximum likelihood estimates of the coefficients. The technique, furthermore, uses all of the data available to the investigator. The r^2 value associated with the final iteration corresponds to an estimate of the proportion of variability explained by the regression equation for that iteration. The weighting factor used in this regression (Finney 1964, p. 89) gives more weight to observed mortalities near 0.5 and less weight to mortalities near 0.0 and 1.0 where the probit transformation approaches $-\infty$ and $+\infty$, respectively. We used this weighted, iterative scheme, because it provides more accurate and reliable estimates than the unweighted approach and associated selective data rejection used by Ecological Analysts. The coefficients and r^2 stabilized at three decimal places

by the 14th iteration for striped bass, while only four iterations were needed for white perch and alewife. The probit regressions for these populations are as follows:

$$\text{Striped Bass: } M_t = -7.771 - 0.096\ T_A + 2.300\ \log_{10}t + 0.346\ T_E \quad \text{(VII-26)}$$

$$\text{White Perch: } M_t = -15.814 - 0.112\ T_A + 2.796\ \log_{10}t + 0.545\ T_E \quad \text{(VII-27)}$$

$$\text{Alewife: } M_t = -14.194 - 0.015\ T_A + 2.158\ \log_{10}t + 0.473\ T_E \quad \text{(VII-28)}$$

where T_A, t, and T_E are ambient temperature, exposure duration, and exposure temperature, respectively, and M_t is the probit corresponding to the thermal mortality [see Eq. (VII-7)]. The r^2 values for these three populations based on the 1976 data are 0.44 (striped bass), 0.37 (white perch), and 0.51 (alewife). Thus, the regression for striped bass explains 44% of the variability in the laboratory experiments on striped bass yolk-sac and post yolk-sac larvae, while the regressions for white perch and alewife explain 37 and 51%, respectively, of the variability in the laboratory experiments on yolk-sac larvae of these two species.

The larval table (or field) data for the discharge station can be partitioned into three temperature regimes (< 30°C, 30-33°C, > 33°C). The immediate thermal f-factor can then be calculated from data for each of the latter two temperature regimes by converting to survival and dividing through by the proportion surviving plant passage when the discharge temperature is under 30°C and the mechanical mortality can be assumed minimal [analogous to Eq. (VII-4)]. This procedure permits one to compare the field data to the results of the laboratory thermal studies. These immediate thermal f-factors, plotted against the mean discharge temperature of the two discharge temperature regimes (i.e., 30-33°C and > 33°C), have been super-imposed on graphs displaying the thermal mortality curves based on laboratory data for striped bass (Fig. VII-6), white perch (Fig. VII-7), and clupeids including American shad (Fig. VII-8). An approximate 68% confidence interval (± 1 standard error) about the predicted thermal f-factor has also been displayed in

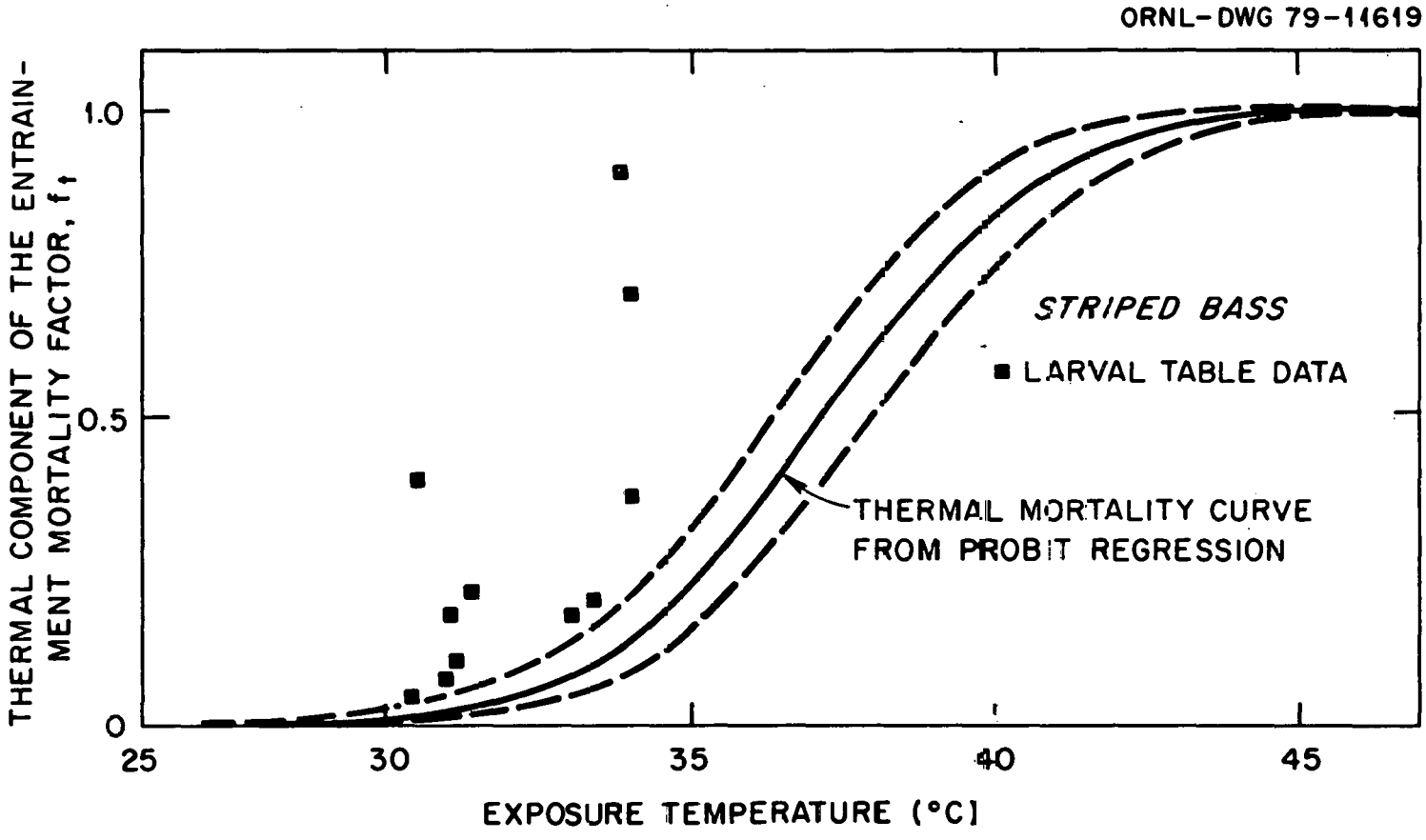

Figure VII-6 Comparison of larval table data (■) with a plot of the thermal component of the entrainment mortality factor, f_t, for striped bass [Eq. (VII-26)] as a function of exposure temperature (°C). The ambient temperature and transit time have been set at 25°C and 10 minutes, respectively. Upper and lower 68% confidence intervals (---) about the middle estimate (——) of the thermal component of the f-factor are also shown.

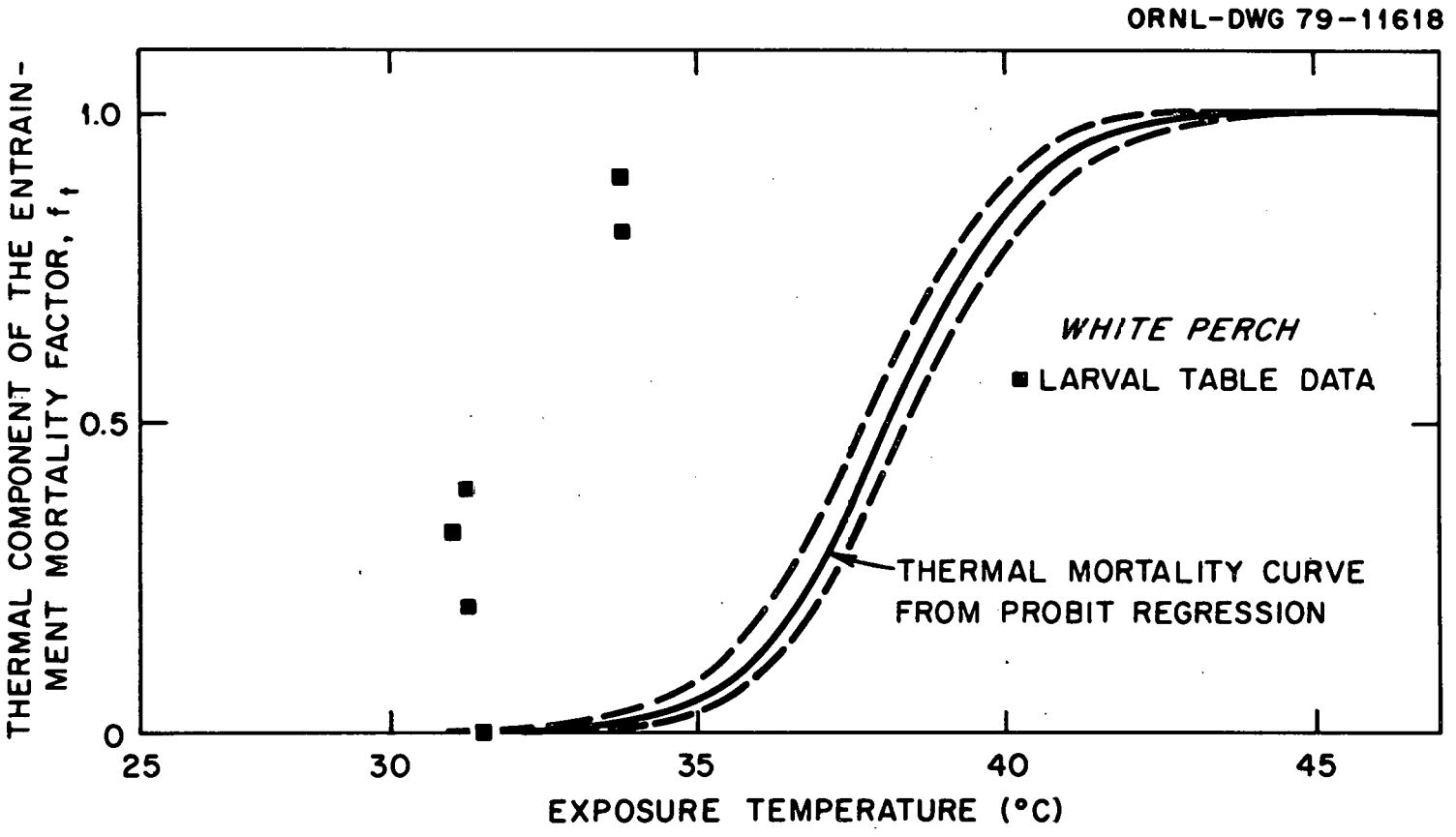

Figure VII-7 Comparison of larval table data (■) with a plot of the thermal component of the entrainment mortality factor, f_t, for white perch [Eq. (VII-27)] as a function of exposure temperature (°C). The ambient temperature and transit time have been set at 25°C and 10 minutes, respectively. Upper and lower 68% confidence intervals (---) about the middle estimate (——) of the thermal component of the f-factor are also shown.

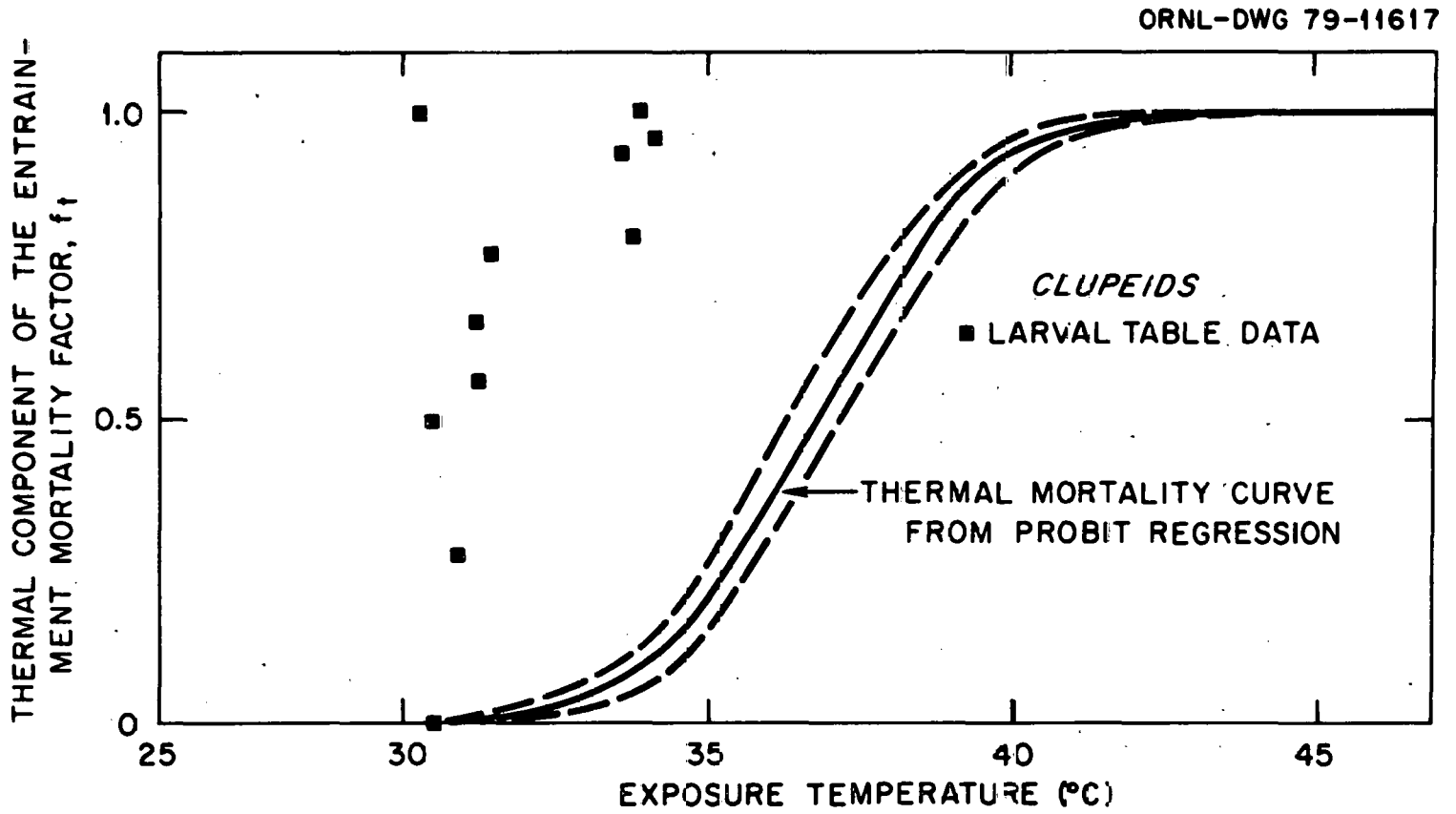

Figure VII-8 Comparison of larval table data (■) with a plot of the thermal component of the entrainment mortality factor, f_t, for alewives [Eq. (VII-28)] as a function of exposure temperature (°C). The ambient temperature and transit time have been set at 25°C and 10 minutes, respectively. Upper and lower 68% confidence intervals (---) about the middle estimate (——) of the thermal component of the f-factor are also shown.

Figs. VII-6, VII-7, and VII-8. However, this confidence interval is only based on the error in the predictive model for the thermal component using experimental data from the laboratory. This confidence interval would necessarily become wider if the uncertainty in the input variables were incorporated. The thermal mortality curves are based on a transit time of 10 minutes and an ambient temperature of 25°C. Since most of the plotted points from the larval table data lie above the thermal mortality curve (i.e., the thermal mortalities from larval table data are higher than thermal mortalities predicted by the model), the thermal mortality model most likely will seriously underpredict the true f-factors. Whether this tendency to underpredict results from averaging various inputs (see discussion on "threshold" in Section 4) to the model, from synergistic effects (Section 4.3), or from some other bias is unknown.

4.3 COMBINING COMPONENTS OF MORTALITY

Once thermal entrainment mortalities were estimated, they were combined with estimates of the mechanical entrainment mortality. The overall direct entrainment mortality ($f_{i,D}$) was calculated in the manner of conditional mortalities, i.e.,

$$f_{i,D} = 1 - (1-f_t)(1-f_m) \quad , \qquad \text{(VII-29)}$$

where f_t and f_m are the f-factors corresponding to the thermal and mechanical components, respectively. This formulation assumes that the two sources of mortality act independently of each other; that is, any organism stressed by the mechanical buffeting during plant passage is no more likely or less likely to die from thermal stresses than is an organism that has not been subjected to mechanical buffetting. Since it is more realistic to expect some synergistic effects (compounding mortality when undergoing several stresses), this combined or overall estimate of the f-factor will tend to understate the true entrainment mortality. Furthermore, any additional mortality, as a result of chlorination or due to an increased chance of thermal mortality of

organisms recirculated from discharge to intake, also will lead to an increased likelihood that the true f-factor has been understated.

The immediate (non-latent) mechanical component of the entrainment mortality model was calculated from the larval table data collected at five Hudson River plants (Bowline Point, Roseton, Indian Point, Danskammer Point, and Lovett). In calculating this f-factor, data from discharge stations were used only when temperatures were less than 30 C. This temperature is sufficiently low that essentially no mortality due to thermal stress is expected.

The sample sizes for the larval table data by life-stage and population at the intake and discharge (< 30°C) sampling stations of five Hudson River plants are presented in Table VII-9. In general, the data were insufficient to estimate the mechanical component of the f-factor at most plants for yolk-sac larvae and juveniles for the three populations being considered (striped bass, white perch, and clupeids), so estimates were based on data pooled across the five plants (see discussion on pooling in Section 2). The sample size for post yolk-sac larvae for the three populations considered was sufficient at all plants. Table VII-10 presents the immediate mechanical mortalities used in the entrainment mortality model for each population by plant and life-stage.

Twenty-four-hour latent mortalities have been computed from larval table data pooled over five Hudson River plants (Bowline Point, Roseton, Indian Point, Danskammer Point, and Lovett). If the pooled samples did not contain at least five live organisms at both the intake and discharge, then the rules discussed in Section 2 for insufficient data were applied. Table VII-11 gives the estimates of the latent mortality factors by life-stage for each population. These latent mortality factors are combined with the immediate (thermal and mechanical) mortality and the indirect mortality in the manner described by Eqs. (VII-1) and (VII-29).

Runs of the ETM have been made with and without the introduction of latent mortality into the entrainment mortality model. In both of

Table VII-9. Sample sizes by life-stage and population at the intake and discharge of five Hudson River plants used in determining base mechanical mortality (from larval table data provided on magnetic tapes to ORNL by the utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	Bowline Point (1975+1976)	Roseton (1975+1976)	Indian Point (Unit 3) (1977)	Danskammer Point (1975)	Lovett (1976)	Total
INTAKE:							
Striped Bass	Y	12	5	13	1	25	56
	P	254	193	396	54	94	991
	J	13	40	5	2	0	60
White Perch	Y	1	1	0	0	0	2
	P	180	478	56	36	42	792
	J	7	77	0	4	0	88
Clupeids	Y	0	0	0	0	0	0
	P	70	1525	41	200	338	2174
	J	9	521	16	33	1	580
DISCHARGE[b]:							
Striped Bass	Y	1	16	12	0	13	42
	P	251	181	207	61	87	787
	J	12	2	1	0	0	15
White Perch	Y	1	3	2	0	0	6
	P	176	127	7	51	42	403
	J	5	4	0	2	0	11
Clupeids	Y	0	2	0	0	0	2
	P	74	854	20	285	396	1629
	J	1	151	0	41	1	194

[a]Y = yolk-sac larvae, P = post yolk-sac larvae, J = entrainable juveniles.

[b]Includes samples collected at less than 30°C only.

Table VII-10. Immediate mechanical mortalities[a] for four Hudson River plants by population and life-stage with lower and upper estimates representing ± one standard error about the middle estimate (calculated from data tapes provided by utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[b]	Bowline Point	Roseton	Indian Point	Danskammer Point
Lower estimate					
Striped Bass	Y	0.33	0.33	0.33	0.33
	P	0.13	0.18	0.16	0.0
	J	0.0	0.0	0.0	0.0
White Perch	Y	0.33	0.33	0.33	0.33
	P	0.0	0.31	0.58	0.0
	J	0.0	0.0	0.0	0.0
Clupeids	Y	0.37	0.37	0.37	0.37
	P	0.0	0.41	0.12	0.34
	J	0.46	0.46	0.46	0.46
Middle estimate					
Striped Bass	Y	0.44	0.44	0.44	0.44
	P	0.17	0.23	0.23	0.03
	J	0.0	0.0	0.0	0.0
White Perch	Y	0.44	0.44	0.44	0.44
	P	0.0	0.38	0.78	0.0
	J	0.04	0.04	0.04	0.04
Clupeids	Y	0.39	0.39	0.39	0.39
	P	0.15	0.44	0.41	0.43
	J	0.51	0.51	0.51	0.51
Upper estimate					
Striped Bass	Y	0.54	0.54	0.54	0.54
	P	0.22	0.29	0.29	0.26
	J	0.0	0.0	0.0	0.0
White Perch	Y	0.54	0.54	0.54	0.54
	P	0.0	0.46	0.99	0.17
	J	0.13	0.13	0.13	0.13
Clupeids	Y	0.42	0.42	0.42	0.42
	P	0.34	0.47	0.71	0.51
	J	0.67	0.67	0.67	0.67

[a]Discharge temperature less than 30°C.

[b]Y = yolk-sac larvae, P = post yolk-sac larvae, J = entrainable juveniles.

Table VII-11. Twenty-four-hour latent mortalities pooled over five Hudson River plants by population and life-stage, with lower and upper estimates representing ± one standard error about the middle estimate (from larval table data on magnetic tapes provided by utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	Estimate		
		Lower	Middle	Upper
Striped Bass	Y	0.0	0.13	0.42
	P	0.11	0.15	0.19
	J	0.05	0.11	0.17
White Perch	Y	0.0	0.13	0.42
	P	0.0	0.0	0.0
	J	0.11	0.19	0.27
Clupeids	Y	0.0	0.0	0.0
	P	0.0	0.0	0.0
	J	0.0	0.74[b]	1.0

[a]Y = yolk-sac larvae, P = post yolk-sac larvae, J = entrainable juveniles.

[b]See Section 3.2.

these sets of runs the values for indirect mortality were considered a constant proportion of the direct mortality.

In arriving at ORNL's estimates of the f-factor to be used in the projected ETM runs, lower, middle, and upper estimates of the f-factor have been used (e.g., Tables VII-10, VII-11 and VII-12). Prior to combining the component estimates based on immediate mechanical, latent, and thermal mortalities, one standard error was subtracted or added to each in order to determine the lower or upper estimates.

The standard error [s.e.(f)] for each of the immediate mechanical and latent mortalities was computed from the larval table data using the following equation (Fleiss 1973),

$$s.e.(f) = \frac{1}{P_i} \sqrt{\frac{P_d\,(1-P_d)}{n_d} + (1-f)^2\,\frac{P_i\,(1-P_i)}{n_i}} \quad , \qquad \text{(VII-30)}$$

where P_i and P_d are the proportion alive in the intake and discharge samples, respectively, while n_i and n_d are the sample sizes associated with the intake and discharge samples, respectively. The standard error of the estimate of the thermal entrainment mortality was computed from the normal equations of the regression model as a function of the ambient temperature, transit time, and exposure temperature (Draper and Smith 1966).

Since the entrainment mortality model was not used for Lovett, lower, middle, and upper estimates of the f-factor have been calculated directly from the Lovett larval table data using discharge samples collected at all temperatures. Table VII-12 contains estimates of the f-factor at Lovett with and without the latent mortality factor.

Assuming a parameter is normally-distributed, adding and subtracting one standard error to the estimate of this parameter results in an interval having a probability of about 2/3 of encompassing the true value of the parameter. This probability does not carry through when the various sources of mortality are combined. However, this range does suggest a spectrum of values that we feel would likely include the true f-factor. In consideration of the many sources of bias, as well

Table VII-12. Entrainment mortality factors for Lovett with and without latent mortality by population and life-stage with lower and upper estimates representing ± one standard error about the middle estimate (larval table data from tapes provided by utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	Lower	Middle	Upper
Without 24-hour latent:				
Striped Bass	Y	0.36	0.47	0.59
	P	0.34	0.42	0.51
	J	0.0	0.07	0.14
White Perch	Y	0.36	0.47	0.59
	P	0.34	0.47	0.62
	J	0.17	0.27	0.36
Clupeids	Y	0.53	0.57	0.62
	P	0.0	0.10	0.21
	J	0.63	0.69	0.74
With 24-hour latent:				
Striped Bass	Y	0.36	0.55	0.77
	P	0.41	0.51	0.61
	J	0.05	0.18	0.31
White Perch	Y	0.36	0.55	0.77
	P	0.34	0.47	0.62
	J	0.26	0.42	0.55
Clupeids	Y	0.53	0.57	0.62
	P	0.0	0.10	0.21
	J	0.63	0.92	1.0

[a]Y = yolk-sac larvae, P = post yolk-sac larvae, J = entrainable juveniles.

as Figs. (VII-6) through (VII-8), it seems more likely that the true f-factor lies between the middle and the upper estimate than that it lies between the lower and the middle estimate.

Appendix F presents a series of plots illustrating the seasonal trend in the estimated total f-factor for striped bass (with latent mortality) by week from April 1 through August 31. The plots are arranged by life-stage (yolk-sac larva, post yolk-sac larva, and entrainable juvenile), units of plants (Bowline Point Units 1 and 2, Roseton, Indian Point Units 2 and 3, and Danskammer Point Units 3 and 4), and day versus night.

5. CRITIQUE OF UTILITIES' ENTRAINMENT MORTALITY MODEL

This section discusses differences between our handling of data in the development of the entrainment mortality model and Ecological Analysts' (EAI) methodology. We also consider the employment of the EAI entrainment mortality model as input to Lawler, Matusky, and Skelly's (LMS) Real Time Life Cycle (RTLC) model used for prediction of power plant impacts on Hudson River fish populations.

5.1 EAI'S ENTRAINMENT MORTALITY MODEL

As discussed in the previous section, EAI's entrainment mortality model derives separate estimates of the f-factor for the thermal and mechanical components of entrainment mortality. The thermal component of the f-factor is obtained via a probit regression which relates the proportion of entrained organisms killed by the plant after 24 hours to ambient river temperature, transit time from condenser to river discharge, and the cooling water temperature after receiving heat input from the condenser.

In their consideration of ambient temperature for Bowline Point and Indian Point, EAI did not attempt to correct for the effect of cooling water recirculation at these plants on their estimates of ambient temperature. The coefficient of the ambient temperature provides a numerical description of the relationship between the ambient temperature (independent variable) and thermal mortality (dependent variable). Since the coefficients of the ambient temperature from the probit regressions [Eq. (VII-26) through (VII-28)] are negative for the three fish populations being considered (striped bass, white perch, and alewives), a higher ambient temperature will result in a lower estimated thermal f-factor. Thus, removal of the recirculation effect from the calculated river ambient temperature should result in a lower, but more accurate, estimate of the true river ambient temperature. Equation (VII-11) in Section 4 presents a correction factor which has been subtracted from the calculated river ambient temperature at Bowline Point and Indian Point in the ORNL work.

EAI used linear regressions in relating transit time to cooling water flow rate at Bowline Point and Roseton. However, the expected underlying relationship would be better described as a power curve, such as Eq. (VII-12). Using the data given in Table VII-7, the proportion of the variability explained by the regression (r^2) increases from 0.95 for EAI's linear regression to 1.00 for ORNL's power curve regression at Bowline Point. At Roseton the improvement in r^2 is from 0.89 for EAI's linear regression to 0.997 for ORNL's power curve regression. For the higher flow rates at Bowline Point and Roseton, the differences are sufficiently small to result in little if any bias in the estimated thermal component of the f-factor (Table VII-7). Since the plant flows tend to be high when the thermal mortality "threshold" is approached, the practical differences between these two approaches in estimating the transit time at Bowline Point and Roseton are not expected to result in any significant differences in estimated f-factor.

The selective deletion of large portions of the 1976 thermal studies data for striped bass, white perch, and alewives by EAI has resulted in a regression equation whose coefficients are biased and whose r^2 is overestimated. Maximum likelihood estimates of the probit regression coefficients were obtained by ORNL from an iterative procedure, with greater weight given to data points having mortalities near 0.5 [This methodology is set forth in Finney (1964)]. Using the 1976 laboratory data base, the "best" estimates of the coefficients of the probit regression are obtained by this weighted, iterative scheme (Section 4.2).

EAI used only initial survival data ("stunned" treated as "live") in obtaining estimates of the mechanical component of the entrainment mortality factor. Using just this data base ignores possible delayed mortality which is significant for some life-stages of some populations, such as striped bass post yolk-sac larvae and entrainable juveniles (Table VII-11). For some life-stages of some populations, the sample sizes or proportion alive in the intake sample may be insufficient to permit a statistically significant latent f-factor to be computed (Appendix D). As a result we have calculated a latent f-factor by

life-stage and population (pooled across plants) as an additional component of entrainment mortality (Table VII-11). Both historical and projected f-factors have been calculated with and without this latent component of entrainment mortality. We believe that latent effects should be included in impact assessments, despite the difficulty in obtaining precise estimates of these latent effects.

Finally, EAI has assumed that no synergistic effects arise from competing sources of mortality. However, mechanical stress by itself may not kill a particular organism during entrainment, but in the presence of a thermal stress, the mechanical stress might prove fatal. Conversely, a thermal stress might prove fatal to an organism in the presence of a mechanical stress, whereas the organism may survive otherwise. EAI combined the thermal and mechanical components of the entrainment mortality using Eq. (VII-29). This equation assumes that the two sources of mortality act independently on the organism. Since, in all likelihood, these competing sources of mortality do not act independently, the resultant f-factor obtained by combining the thermal and mechanical components will underestimate the actual f-factor. We have the same potential underestimate in our work, but we believe it is necessary to acknowledge this, as well as other methodological limitations resulting in biased f-factors.

5.2 LMS'S INPUTS TO THE RTLC MODEL

In discussing the "threshold effect" (Section 4), the point was made that any averaging of inputs to EAI's entrainment mortality model can result in an underestimate of the thermal component of the f-factor. This bias results from the non-linear relationship between the independent variables (ambient temperature, exposure duration, and exposure temperature) and the dependent variable (thermal mortality). When below the threshold, the thermal mortality calculated from averaged independent variables will be less than the average of the thermal mortality calculated over the observed range of the independent variables. As the threshold is approached from the direction of low

mortality (Fig. VII-5), the thermal component of the f-factor predicted using averaged independent variables will increasingly underestimate the actual thermal component.

In generating f-factors as input to their Real Time Life Cycle (RTLC) model, LMS simplified the inputs to EAI's entrainment mortality model in two places. First, plant generating loads were averaged within the month while maintaining only day/night differences (Table C-2, Exhibit UT-3). Second, monthly 90th percentiles, rather than EAI's daily 90th percentiles, were used by LMS for the ambient temperature at Poughkeepsie (Table C-3, Exhibit UT-3). The prediction of no thermal mortality at Bowline Point and Roseton by LMS (Table C-4, Exhibit UT-3) is probably the result of these averaging processes, which has the effect of underestimating the actual thermal f-factor on those occasions when conditions were higher than average.

6. REFERENCES CITED

Carpenter, E. J., S. J. Anderson, and B. B. Peck. 1972. Entrainment of Marine Plankton through Millstone Unit One. Fourth Semi-Annual Report to Northeast Utilities Service Company, February 1, 1972 to August 1, 1972. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Dey, W. P. 1978. Growth and mortality of young-of-the-year striped bass in the Hudson River estuary. Abstract of paper presented at the American Fisheries Society, 108th Annual Meeting, August 20-25, 1978, University of Rhode Island, Kingston, Rhode Island.

Draper, N. R., and H. Smith. 1966. Applied Regression Analysis. John Wiley and Sons, New York. 407 pp.

Ecological Analysts, Inc. 1976. Bowline Point Generating Station Entrainment Survival and Abundance Studies, Volume I. 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1977. Bowline Point Generating Station Entrainment and Impingement Studies, 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts, Inc. 1978a. Roseton Generating Station Entrainment Survival Studies, 1976 Annual Report. Prepared for Central Hudson Gas & Electric Corporation.

Ecological Analysts, Inc. 1978b. Indian Point Generating Station Entrainment Survival and Related Studies, 1977 Annual Report. Prepared for Consolidated Edison Company of New York, Inc.

Ecological Analysts, Inc. 1978c. Hudson River Thermal Effects Studies for Representative Species, Final Report. Prepared for Central Hudson Gas & Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. Appendix B: Thermal Tolerance Data.

Exhibit UT-3. Supplement I to 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. T. McFadden and J. P. Lawler. Submitted to Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-4. 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. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. 1977.

Exhibit UT-6. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-6A. Appendices. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-7. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

Exhibit UT-7A. Appendices. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

Exhibit UT-9. Indian Point Unit No. 2, Indiand Point Unit No. E. Near-field effects of once-through cooling system operation on Hudson River biota. Consolidated Edison Company of New York, Inc., Power Authority of the State of New York. July 1977.

Exhibit UT-11. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. July 1977.

Exhibit UT-11A. Appendices. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. July 1977.

Finney, D. J. 1964. Probit Analysis. Cambridge University Press, Cambridge, Great Britain.

Fleiss, J. L. 1973. Statistical Methods for Rates and Proportions. John Wiley & Sons, New York. 223 pp.

Marcy, B. C., Jr. 1971. Survival of young fish in the discharge canal of a nuclear power plant. J. Fish. Res. Board Can. 28:1057-1060.

Marcy, B. C., Jr. 1973. Vulnerability and survival of young Connecticut River fish entrained at a nuclear power plant. J. Fish. Res. Board Can. 30:1195-1203.

McGroddy, P. M., and R. L. Wyman. 1977. Efficiency of nets and a new device for sampling living fish larvae. J. Fish. Res. Board Can. 34:571-574.

O'Connor, J. M., and S. A. Schaffer. 1977. The effects of sampling gear on the survival of striped bass ichthyoplankton. Ches. Sci. 18(3):312-315.

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill Book Co., New York. 312 pp.

Van Winkle, W., S. W. Christensen, and J. S. Suffern. 1979. Incorporation of sublethal effects and indirect mortality in modeling population-level impacts of a stress, with example involving power-plant entrainment and striped bass. ORNL/NUREG/TM-288. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

CHAPTER VIII
CONDITIONAL ENTRAINMENT MORTALITY RATE ESTIMATES FOR SIX HUDSON RIVER FISH POPULATIONS

Joint Testimony of
John Boreman, Ph.D.
C. Phillip Goodyear, Ph.D.

National Power Plant Team
U.S. Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

PREPARED FOR THE
U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION II

May 1979

1. INTRODUCTION

This chapter presents conditional entrainment mortality rates for six Hudson River fish populations. These rates were derived from Empirical Transport Model (ETM) runs using the methodology and input parameter values described in chapters I-VII of this exhibit. Differences between ETM estimates and conditional entrainment mortality rate estimates presented by the utilities are due to differences in the input parameter values or the methodologies used, as discussed in the earlier chapters of this exhibit.

Several ETM runs were made for each fish population. Runs with historical flow conditions were made to compare ETM estimates to conditional entrainment mortality rates estimated by the utilities in exhibits UT-3 and UT-4. Runs with projected flow conditions provide a basis for determining the probable impact of Hudson River power plants with expected once-through and closed-cycle operating conditions. Projected flow runs are necessary because not all units involved in this case were fully operative during 1974 and 1975 (e.g., Roseton and Indian Point Unit 3, p. 2-VI-9, Exhibit UT-3), and other, older units are expected to be "phased out" over the next few years (e.g., units at Lovett, Danskammer, and Indian Point, p. 5-180, Barnthouse et al. 1977).

Physical input parameter values used in the ETM runs are presented in Chapter II of this exhibit. Historical runs were made with the actual average daily power plant flow rates for each week during the 1974 and 1975 entrainment periods of each fish population. Projected runs were based on the estimated average daily power plant flow rates for each month of the respective entrainment periods. These projected runs did not include projected flow rates for Indian Point Unit 1, Lovett units 1-3, and Danskammer units 1 and 2 due to the expectation of little or no use of these units in the future (Barnthouse et al. 1977).

Life stage duration and distribution input parameter values used in the ETM runs for each fish population are presented in chapters III and IV of this testimony. Values for these parameters specific for 1974 and 1975 were used in the historical runs. Projected runs were made separately for 1974 life stage durations and distributions and 1975 life stage durations and distributions to acknowledge the observed annual variations in these biological parameters. The entrainment period for each fish population during 1974 or 1975 was also incorporated directly into the projected runs; that is, if the entrainment period for a population was May 1 to August 31 during 1974, the same entrainment period (May 1 to August 31) was used in the projected runs with 1974 life stage durations and distributions. Furthermore, the temporal distribution of egg recruitment for a given fish population during a specific year was used in the projected runs with the life stage durations and distributions for that year. Only 1974 conditions were used for American shad and only 1975 conditions were used for Atlantic tomcod due to lack of sufficient data for the other year, as discussed in chapters III, IV, and VI of this exhibit and in the testimony on life histories (Boreman 1979).

Values used in the ETM for the ratio of the average intake to average regional concentration (W-factor) of an entrainable life stage of each fish population were derived from estimates presented in chapters V and VI of this exhibit. Estimates presented in Chapter VI, based on the River Data Methodology (RDM), were used whenever values based on the Gear Bias Cancelling (GBC) or Modified Utility (MU) methods presented in Chapter V were missing for a given life stage at a particular plant for 1974-1976. The W-factor estimates based on the GBC and MU methods are presented in Chapter V as separate seasonal averages for day and night. These estimates, therefore, were combined to derive seasonal daily averages by using a geometric mean of the day and night values weighted for 15 hr of daylight (0600-2059 hr) and 9 hr of darkness (2100-0559 hr). Even though these hours do not coincide exactly with the hours of day and night as experienced by ichthyoplankton, these hours were used by the utilities for defining day and night hours of operation for Roseton and Bowline (Table 2.1A-1, Exhibit UT-6A and Table 2.1A-1, Exhibit UT-7A).

The mortality due to plant passage (f-factor) input values used in the ETM runs are presented in Chapter VII of this exhibit. Historical and projected ETM runs were made separately for immediate and 24-hr latent f-factors. Historical and projected ETM runs for yolksac, post yolksac, and juvenile life stages of each fish population were made with f-factors based on pooled larval table data. The f-factors for eggs of all populations were derived from studies on striped bass egg entrainment mortality conducted by NYU at Indian Point during 1973-1977 (0.66), since no other data are available (Section 2, Chapter VII). Projected runs for striped bass, white perch, and Alosa spp. (blueback herring and alewives) were also conducted with f-factors derived from the larval table data in combination with a modified version of the Ecological Analysts, Inc. (EAI) thermal mortality model. Derivations of the f-factors based on the pooled larval table and thermal mortality model approaches are presented in Chapter CII of this exhibit.

2. ENTRAINMENT MORTALITY ESTIMATES - POOLED f-FACTORS

Historical and projected conditional entrainment mortality estimates for six fish populations inhabiting the Hudson River estuary using pooled larval table f-factor values are listed in tables VIII-1 and VIII-2. These estimates are based on ETM run results which are presented in appendices G to L for striped bass, white perch, Alosa spp. (blueback herring and alewife), American shad, Atlantic tomcod, and bay anchovy, respectively.

2.1 STRIPED BASS

2.1.1 Historical

Estimated conditional entrainment mortality rate estimates for striped bass were 11.1-14.5 percent for 1974 and 18.2-18.4 percent for 1975 (Table VIII-1). Based on individual ETM run results in Appendix G-1, Indian Point Unit 2 imposed the highest mortality rates of any plant during both 1974 (≤ 7-6.0 percent) and 1975 (8.0-8.6 percent). Post yolksac larvae experienced the highest mortality rate of any life stage

Table VIII-1. Historical Conditional Entrainment Mortality Rate Estimates Expressed as Percentages for Six Hudson River Fish Populations Based on ETM Run Results Listed in Appendices G to L

Population	1974 GBC[a]	1974 MU	1975 GBC	1975 MU
All plants:				
Striped bass	14.5	11.1	18.4	18.2
White perch	10.9	11.7	13.0	13.6
Alosa spp.[b]	4.1	3.5	6.1	11.2
American shad		13.6[c]		
Atlantic tomcod			5.2	8.4
Bay anchovy	54.1	77.8	34.8	46.0
Roseton, Indian Pt. 2, and Bowline only:				
Striped bass	8.0	6.8	12.8	13.0
White perch	6.9	7.8	9.6	8.7
Alosa spp.[b]	1.8	2.0	4.0	5.9
American shad		8.6[c]		
Atlantic tomcod			4.3	7.1
Bay anchovy	36.2	65.1	25.9	36.6

[a]W-factor methodology (Chapter V)

[b]blueback herring and alewife

[c]RDM W-factor (Chapter VI)

Table VIII-2. Projected Conditional Entrainment Mortality Rate Estimates, Expressed as Percentages, for Six Hudson River Fish Populations Based on ETM Run Results Listed in Appendices G to L

Population	Once-through	Closed-cycle	Range of differences
All plants:			
Striped bass	16.0 - 21.7	4.4 - 8.3	7.7 - 17.3
White perch	15.7 - 17.1	3.2 - 4.1	11.6 - 13.9
Alosa spp.[a]	6.2 - 11.1	1.3 - 4.2	2.0 - 9.8
American shad	20.5	4.1	16.4
Atlantic tomcod	6.6 - 7.3	2.3	4.3 - 5.0
Bay anchovy	44.3 - 78.6	12.7 - 25.2	19.1 - 65.9
Roseton, Indian Pt. 2 and 3, and Bowline only:			
Striped bass	14.1 - 17.4	2.2 - 3.3	10.8 - 15.2
White perch	13.4 - 15.3	1.3 - 1.4	12.0 - 14.0
Alosa spp.[a]	4.7 - 7.9	0.3 - 0.4	4.3 - 7.6
American shad	17.9	0.9	17.0
Atlantic tomcod	6.0 - 7.0	1.8 - 1.9	4.1 - 5.2
Bay anchovy	38.1 - 75.3	2.2 - 7.9	30.2 - 73.1

[a]blueback herring and alewife

(5.2-9.7 percent in 1974 and 12.3-12.6 percent in 1975, Appendix G-2).

The utilities' estimated conditional entrainment mortality rates for striped bass were 8.1 percent and 11.9 percent for 1974 and 1975, respectively (Table 2-VI-1, Exhibit UT-3). These rates reflect operation of Indian Point Unit 2 and Bowline in 1974, and Indian Point Unit 2, Bowline, and Roseton in 1975. The utilities' estimate for 1974 was higher than the ETM estimate for similar operating conditions (6.3-7.6 percent, derived form Appendix G-1). The utilities' estimate for 1975 was approximately one percent lower than the ETM estimate.

2.1.2 Projected

Projected conditional entrainment mortality rate estimates for striped bass, with all plants operating with once-through cooling, range from 16.0 to 21.7 percent (Table VIII-2). Indian Point will impose the highest rates of any plant (8.5-13.1 percent, Appendix G-4), and post yolksac larvae will experience the highest rates of any life stage (Appendix G-5).

Projected conditional entrainment mortality rates for striped bass due to operation of Bowline, Indian Point, and Roseton with once-through cooling were estimated by the utilities using the Real-Time Life Cycle Model (RTLCM). The projected rates based on the RTLCM are 5.8 percent with the 1974 data base and 8.1 percent with the 1975 data base (Table 3-VIII-1, Exhibit UT-3). The projected rates based on the ETM are approximately 8-9 percent higher: 14.1-14.9 percent with the 1974 data base and 15.8-17.4 percent with the 1975 data base (Appendix G-6). The principal cause for the differences between the RTLCM and ETM estimates is the lower W-factors used in the RTLCM, as discussed in Chapter V of this exhibit.

Closed-cycle cooling conditions at Bowline, Indian Point, and Roseton will reduce the total entrainment mortality to 4.4-8.3 percent (Table VIII-2). Based on the RTLCM, the utilities project a conditional entrainment mortality rate due to operation Bowline, Indian Point, and

Roseton with closed-cycle cooling (other plants not considered) of 1.6 percent with the 1974 data base and 3.2 percent with the 1975 data base. Under similar operating conditions, the conditional entrainment mortality rate based on the ETM, is 2.2-3.3 percent (Table VIII-2).

2.2 WHITE PERCH

2.2.1 Historical

White perch experienced an estimated total conditional entrainment mortality rate of 10.9-11.7 percent in 1974 and 13.0-13.6 percent in 1975 (Table VIII-1). Of all plants, Indian Point Unit 2 imposed the highest rates during both 1974 and 1975 (3.9-4.9 percent during 1974 and 3.3-4.5 percent during 1975, Appendix H-1). Of all life stages, post yolksac larvae experienced the highest mortality rates during both years (6.0-6.2 percent during 1974 and 7.5-8.3 percent during 1975, Appendix H-2).

The utilities estimated a conditional entrainment mortality rate for white perch due to operation of only Bowline and Indian Point Unit 2 of 5.5 percent during 1974 (Table 2-VII-1, Exhibit UT-3). Under similar operating conditions, the estimated rate based on the ETM is 6.3-7.3 percent (derived from Appendix H-1). The utilities' conditional entrainment mortality rate of white perch due to operation of Bowline, Indian Point Unit 2, and Roseton during 1975 was 6.3 percent (Table 2-VII-1, Exhibit UT-3), as compared to an estimate of 8.7-9.6 percent based on the ETM with similar conditions (Table VIII-1). The lower estimates by the utilities are principally due to the shorter entrainment periods used in their methodology. Their entrainment periods during 1974 and 1975 ended in mid-July (Marcellus 1978), while the entrainment periods used in the ETM ended in early September (Table IV-7, Chapter IV).

The utilities also present estimates of the conditional entrainment mortality rate imposed on white perch during 1974 and 1975 by Bowline alone (Table 9.5-1, Exhibit UT-7) and Roseton alone (Table 9.5-1, Exhibit UT-6). These estimates are based on the LMS empirical method, as discussed

in Chapter I of this exhibit. The utilities' estimates for 1974 are 1.6 percent for Bowline and 0.5 percent for Roseton; comparable ETM estimates are 2.5 percent for Bowline and 0.6 percent for Roseton (Appendix H-1). The utilities' estimates for 1975 are 0.4 percent for Bowline and 1.8 percent at Roseton, while the ETM estimates are 1.9 percent at Bowline and 3.7-4.2 percent at Roseton. The principal cause of differences between the two sets of estimates (utilities and ETM) is due to the difference in the methodologies used, as discussed in Chapter I.

2.2.2 Projected

Once-through cooling at all plants will impose an estimated conditional entrainment mortality rate of 15.7-17.1 percent on white perch. Indian Point will impose the highest rate of any plant (6.8-7.4 percent, Appendix H-4) and post yolksac larvae will experience the highest rate of any life stage (Appendix H-5). The projected conditional entrainment mortality rates for white perch are lower than the projected rates for the congeneric striped bass. As shown in figures 1, 2, 7, and 8 in the testimony on life histories (Boreman 1979), entrainable life stages of white perch were distributed more upriver than striped bass during 1974 and 1975 and, therefore, were less abundant in regions containing the power plants.

Closed-cycle cooling at Bowline, Indian Point, and Roseton would reduce the conditional mortality rate of white perch to 3.2-4.1 percent (Table VIII-2). Most of this mortality would be imposed by Lovett and Danskammer, since the rate imposed by Bowline, Indian Point, and Roseton alone would be 1.3-1.4 percent (Table VIII-2).

2.3 BLUEBACK HERRING AND ALEWIFE

2.3.1 Historical

The estimated conditional entrainment mortality rate of *Alosa* spp. (blueback herring and alewife) was 3.5-4.1 percent during 1974 and 6.1-11.2 percent during 1975 (Table VIII-1). Danskammer imposed the highest mortality rate during 1974 (0.9-1.7 percent, Appendix I-1) and Roseton

and Danskammer imposed the highest rates during 1975 (3.1-4.8 percent and 2.0-5.7 percent, respectively, Appendix I-1). Juveniles experienced the highest rates of any life stage both years (Appendix I-2).

The utilities present no multiplant conditional entrainment mortality estimates for Alosa spp. during 1974 or 1975. However, estimates for Bowline alone and Roseton alone appear in exhibits UT-7 and UT-6, respectively. The utilities estimate that Bowline imposed a conditional entrainment mortality rate of 0.1 percent on Alosa spp. (blueback herring, alewife, and American shad) during 1974, and a rate of 0.03 percent during 1975 (Table 9.5-2, Exhibit UT-7). Estimates for Alosa spp. (blueback herring and alewife only) at Bowline during 1974 and 1975, based on the ETM, are 0.4 percent and 0.1 percent (Appendix I-1). According to the utilities, Roseton imposed an estimated conditional entrainment mortality rate on Alosa spp. (all three species) of 0.5 percent during 1974 and 1.1 percent during 1975 (Table 9.5-2, Exhibit UT-6), while the ETM estimates for Roseton are 0.4-0.5 percent for 1974 and 3.1-4.8 percent for 1975. The ETM estimates were higher even though American shad were not included. As for white perch, the lower estimates presented by the utilities for Alosa spp. are due to a difference in the methodologies used to calculate the conditional rates, as discussed in Chapter I.

2.3.2 Projected

The ETM-estimated conditional entrainment mortality rates for Alosa spp. ranged from 6.2-11.1 percent with once-through cooling at all plants (Table VIII-2). Juveniles will experience the highest entrainment mortality rates of any life stage (Appendix I-5), and Roseton will impose the highest rate of any plant (3.1-6.4 percent, Appendix I-4) Even though the W-factors and f-factors for Alosa spp. are higher, their projected conditional entrainment mortality rates are much lower than the projected rates for striped bass or white perch. The entrainable life stages of Alosa spp. were distributed more upriver, above the regions containing power plants, than the two Morone spp. during 1974 and 1975 (Figures 13 and 14, Boreman 1979) which is the main reason for the lower entrainment impact estimates.

Closed-cycle cooling conditions at Bowline, Indian Point, and Roseton would reduce the projected conditional entrainment mortality rate to 1.3-4.2 percent (Table VIII-2). Most of this input would be imposed by the plants still operating with once-through cooling (Lovett and Danskammer), since the projected rate with Bowline, Indian Point, and Roseton operating alone and with closed-cycle cooling would be 0.3-0.4 percent (Table VIII-2).

2.4 AMERICAN SHAD

2.4.1 Historical

American shad experienced an estimated conditional mortality rate of 13.6 percent during 1974 (Table VIII-1). Indian Point Unit 2 imposed the highest mortality rate of any plant (4.9 percent, Appendix J-1), while juveniles experienced the highest rate, by far, of any life stage (13.0 percent, Appendix J-2).

The utilities estimated a conditional entrainment mortality rate imposed by Bowline and Indian Point Unit 2 alone on American shad of 1.6 percent during 1974 (Table 2-VII-3, Exhibit UT-3), while the ETM estimate is 7.9 percent for the same conditions. The higher rate based on the ETM is due to higher W-factors and a much longer entrainment period used in the ETM. The utilities used a W-factor of 0.5 for all life stages (Table 2-VII-3, Exhibit UT-3), whereas, the W-factors used in the ETM were greater than 0.8 (Table VI-7, Chapter VI) for the entrainable life stages of American shad. The ETM entrainment period ended in mid-August (Table IV-7, Chapter IV), while the utilities' entrainment period ended in mid-July (Marcellus 1978). Since the juvenile life stage is by far the most vulnerable to entrainment (Appendix J-2), the added weeks in the entrainment period were very important in determining the total conditional entrainment mortality rate of American shad.

2.4.2 Projected

With once-through cooling at all plants, American shad will experience an estimated conditional entrainment mortality rate of 20.5 percent (Table

VIII-2). The highest mortality rate of any plant will be imposed by Indian Point (9.0 percent, Appendix J-4), and juveniles will experience the highest entrainment mortality of any life stage (19.5 percent, Appendix J-5).

Projected conditional entrainment mortality rates for American shad will be much higher than those of the congeneric blueback herring and alewife. Based on the 1974 distribution data, the early juvenile life stage of American shad was distributed much further downriver than the other Alosa spp. during 1974 (Figure 19, Boreman 1979) and, therefore, was relatively more abundant in the regions containing the power plants.

The projected conditional entrainment mortality rate of American shad with Bowline, Indian Point, and Roseton operating under closed-cycle cooling conditions would be 4.1 percent (Table VIII-2). Most of this impact would be imposed by the plants still operating with once-through cooling (Lovett and Danskammer), since the combined rate imposed by the plants operating with closed-cycle cooling would be 0.9 percent (Table VIII-2).

2.5 ATLANTIC TOMCOD

2.5.1 Historical

The estimated conditional entrainment mortality rate of Atlantic tomcod during 1975 was 5.2-8.4 percent (Table VII-1). Indian Point Unit 2 imposed the highest mortality rate of any plant (2.1-5.0 percent, Appendix K-1), while post yolksac larvae and juveniles had the highest life stage mortality rates (3.4-3.6 percent and 1.4-4.6 percent, respectively, Appendix K-2).

The utilities estimated a conditional entrainment mortality rate imposed by Bowline, Indian Point Unit 2, and Roseton of 4.0 percent for Atlantic tomcod during 1975. The ETM estimate for similar plant operating conditions during 1975 is 4.3-7.1 percent (Table VIII-1). The higher rates estimated by the ETM are due to higher W-factors for some life

stages and a longer entrainment period. Neither the utilities estimate nor the ETM estimate incorporate possible entrainment mortality of the egg life stage. The utilities began their entrainment period on March 9 (p. 14.14, Exhibit UT-4); no eggs were collected by TI in their 1975 Long River Survey on or after that date (Marcellus 1977).

2.5.2 Projected

Once-through cooling at all plants will impose an estimated total conditional entrainment mortality rate on Atlantic tomcod of 6.6-7.3 percent (Table VIII-2). Of all plants, Indian Point will impose the highest rate (4.8-5.7) percent, Appendix K-4), while post yolksac larvae will experience the highest rate of any life stage (3.1-4.0 percent, Appendix K-5).

The projected conditional entrainment mortality rates for Atlantic tomcod, based on the ETM, are the lowest for any population included in our analyses. The distributions of entrainable life stages of Atlantic tomcod during 1975 were generally below the regions containing power plants (Figure 23, Boreman 1979). In addition, the f-factors for tomcod yolksac larvae were the lowest of any population included in our analyses (Chapter VII), and the W-factors for juvenile tomcod at Bowline and Lovett were 0 and 0.02-0.09, respectively (Chapter V).

Closed-cycle cooling conditions at Bowline, Indian Point, and Roseton would reduce the projected conditional entrainment mortality rate to 2.3 percent. The highest entrainment mortality rate would still be imposed by Indian Point (1.6-1.7 percent, Appendix K-7).

2.6 BAY ANCHOVY

2.6.1 Historical

The estimated total conditional entrainment mortality rate for bay anchovy was 54.1-77.8 percent in 1974 and 34.8-46.0 percent in 1975 (Table VIII-1). Indian Point Unit 2 imposed the highest mortality rates of any plant during both years (14.3-53.7 percent during 1974 and 11.2-24.3 percent during 1975, Appendix L-1). Juveniles experienced the

highest mortality rates of any life stage (42.3-69.2 percent during 1974 and 19.5-24.5 percent during 1975, Appendix L-2). The utilities present no estimates of historical or projected conditional entrainment mortality rates for the bay anchovy.

2.6.2 Projected

The estimated total conditional entrainment mortality rate for bay anchovies with once-through cooling at all power plants is 44.3-78.6 percent (Table VIII-2). The highest mortality rates of any plant will be imposed by Indian Point (21.8-65.7 percent, Appendix L-4), while juveniles will experience the highest entrainment mortality of any life stage (27.4-68.3 percent, Appendix L-5).

The projected conditional entrainment mortality rates for bay anchovy population in the Hudson River are the highest of the six populations examined. The relatively higher rates are caused by high W-factors and high f-factors, as well as a concentration of the bay anchovy population in regions containing power plants, especially in the vicinities of Bowline, Lovett, and Indian Point (Figure 28, Boreman 1979). As indicated in the testimony on life histories (Boreman 1979), an unknown fraction of the entrainable population of bay anchovy is probably located outside the regions of the river included in the ETM analyses, i.e., below RM 14. Therefore, the conditional entrainment mortality rates presented in Table VIII-2 for bay anchovy reflect reductions in the fraction of the population inhabiting RM 14-140 only.

Closed-cycle cooling conditions at Bowline, Indian Point, and Roseton would reduce the conditional entrainment mortality rate of the fraction of the bay anchovy population between RM 14-140 to 12.7-25.2 percent (Table VIII-2). Most of this impact would be imposed by the plants still operating with once-through cooling, since the rates imposed by Bowline, Indian Point and Roseton alone with closed-cycle cooling would be 2.2-7.9 percent (Table VIII-2).

3. ENTRAINMENT MORTALITY ESTIMATES - THERMAL MODEL f-FACTORS

ETM runs with projected once-through power plant flow conditions were made for striped bass, white perch, and Alosa spp. (blueback herring and alewife) incorporating component thermal model f-factors instead of pooled larval table f-factors. The derivation and a listing of the component thermal model f-factor values used in the ETM runs is presented in Chapter VII of this exhibit. All other input parameter values, except power plant flow rates, were the same values used in the projected runs with once-through cooling and pooled larval table f-factors.

Power plant flow rates used in the ETM runs with the component thermal model f-factors were based on the weekly rates listed in Table VII-6 in Chapter VII of this exhibit. However, the weekly flow rates for each unit or plant that are listed in this table do not account for scheduled down-time. Therefore, each rate was multiplied by a coefficient that represents the average fraction of each week that the individual unit or plant is scheduled to be down for maintenance. These coefficients and their sources are listed in Table VIII-3.

The power plant flow rates and f-factors presented in Chapter VII encompass the period April 1-August 31. However, the projected entrainment period for white perch extends one week into September (Table IV-7, Chapter IV). Since no flow rates were calculated for weeks past August 31 in Chapter VII, the daily flow rate for the last week in August was used for the first week of September. This procedure may result in an overestimate of entrainment mortality for cohorts still present in entrainable life stages during the first week of September, since projected rates listed in Table II-4 of Chapter II declined in September for all plants. However, the cohorts still present in entrainable life stages past August 31 represent less than 0.1 percent of the white perch initial egg deposition (Table IV-3, Chapter IV). As such, the bias in the resultant total conditional entrainment mortality rate is negligible.

Results of ETM runs incorporating projected once-through power

Table VIII-3. Coefficients Used to Adjust Projected Power Plant Flow Rates to Account for Scheduled Down Time

Week	Bowline[a]		Roseton[b]	Indian Point[c]		Danskammer[d]		Lovett[e]
	Unit 1	Unit 2		Unit 2	Unit 3	Unit 3	Unit 4	
4/1 - 4/7	0	1	0.9	0.78	1	0.55	0.55	1
4/8 - 4/14	0	1	0.9	0.78	1	0.55	0.55	1
4/15 - 4/21	0.20	1	0.9	0.78	1	0.55	0.55	1
4/22 - 4/28	0.20	1	0.9	0.78	1	0.55	0.55	1
4/29 - 5/5	0.20	1	0.9	0.79	0.82	0.56	0.56	1
5/6 - 5/12	0.54	1	0.9	0.80	0.74	0.57	0.57	1
5/13 - 5/19	1	1	0.5	0.80	0.74	0.57	0.57	1
5/20 - 5/26	1	1	0.5	0.80	0.74	0.57	0.57	1
5/27 - 6/2	1	1	0.5	0.84	0.74	0.62	0.62	1
6/3 - 6/9	1	1	0.5	0.93	0.74	0.76	0.76	1
6/10 - 6/16	1	1	0.93	0.93	0.74	0.76	0.76	1
6/17 - 6/23	1	1	1	0.93	0.74	0.76	0.76	1
6/24 - 6/30	1	1	1	0.93	0.74	0.76	0.76	1
7/1 - 7/7	1	1	1	0.99	1	0.85	0.85	1
7/8 - 7/14	1	1	1	0.99	1	0.85	0.85	1
7/15 - 7/21	1	1	1	0.99	1	0.85	0.85	1
7/22 - 7/28	1	1	1	0.99	1	0.85	0.85	1
7/29 - 8/4	1	1	1	0.99	1	0.93	0.93	1
8/5 - 8/11	1	1	1	0.99	1	0.99	0.99	1
8/12 - 8/18	1	1	1	0.99	1	0.99	0.99	1
8/19 - 8/25	1	1	1	0.99	1	0.99	0.99	1
8/26 - 9/1	1	1	1	0.99	1	0.99	0.99	1
9/2 - 9/8	1	1	1	0.99	1	0.99	0.99	1

[a] based on Table 2.1-7 of exhibit UT-7
[b] based on Table 2.1-1 of exhibit UT-6
[c] based on Table 1-1 of exhibit UT-9
[d] based on the combined average daily flow rates per month of units 3 and 4, as listed in Table II-4, divided by the combined average daily rates as listed in Table VII-6
[e] values taken directly from Table VII-6; assumes no thermal component in once-through flow conditions

plant flow conditions and component f-factors derived by the thermal model are listed in Appendices M-O for striped bass, white perch, and Alosa spp. (blueback herring and alewife), respectively. Table VIII-4 presents estimated conditional entrainment mortality rates for the three populations based on the values listed in these appendices.

3.1 STRIPED BASS

The estimated conditional entrainment mortality rate for striped bass with projected once-through power plant flow conditions and f-factors derived by the thermal model are 10.4-32.1 percent for all plants and 9.3-25.9 percent for Bowline, Indian Point, and Roseton only (Table VIII-4). Indian Point will impose the highest mortality of any plant (6.5-20.6 percent, Appendix M) and post yolksac larvae will experience the highest entrainment mortality of any life stage (5.7-20.7 percent, Appendix M). The projected conditional entrainment mortality rates with middle f-factor values (15.7-24.4 percent, Table VIII-4) are similar to the range of projected values obtained with the pooled larval table f-factors (16.0-21.7 percent, Table VIII-2).

3.2 WHITE PERCH

Based on thermal model f-factor values, white perch will experience a total conditional entrainment mortality rate of 10.7-23.1 percent with all plants operating, and 9.6-21.2 percent with only Bowline, Indian Point, and Roseton operating (Table VIII-4). Of all plants, Indian Point will impose the highest entrainment mortality rate (6.4-13.7 percent, Appendix N). Post yolksac larvae will experience the highest entrainment mortality of any life stage (6.5-14.8 percent, Appendix N). Compared to the range of projected conditional entrainment mortality rates calculated with the pooled larval table f-factors (15.7-17.1 percent, Table VIII-2), the range of estimated projected rates based on the middle thermal model f-factors is similar (15.2-18.9 percent, Table VIII-4).

Table VIII-4. Projected Conditional Entrainment Mortality Rate Estimates, Expressed as Percentages, for Three Hudson River Fish Populations Based on ETM Run Results Listed in Appendices M-O

Population	f-factor value[a]		
	Lower	Middle	Upper
All plants			
Striped bass	10.4 - 16.8	15.7 - 24.4	21.6 - 32.1
White perch	10.7 - 15.4	15.2 - 18.9	19.7 - 23.1
Alosa spp.[b]	3.2 - 8.0	5.3 - 10.5	6.5 - 11.7
Bowline, Indian Point 2 and 3, and Roseton only:			
Striped bass	9.3 - 12.5	14.0 - 19.1	19.1 - 25.9
White perch	9.6 - 14.7	13.5 - 18.0	17.5 - 21.2
Alosa spp.[b]	2.4 - 4.3	4.0 - 6.6	4.9 - 7.8

[a] lower = component thermal model f-factor value minus one standard error
middle = component thermal model f-factor value
upper = component thermal model f-factor value plus one standard error

[b] blueback herring and alewife

3.3 BLUEBACK HERRING AND ALEWIFE

The estimated total conditional entrainment mortality rate of Alosa spp. (blueback herring and alewife) with thermal model f-factor values and once-through flow conditions at all plants will be 3.2-11.7 percent (Table VIII-4). Bowline, Indian Point, and Roseton will impose a combined mortality rate of 2.4-7.8 percent (Table VIII-4). Of all plants, Roseton will impose the highest conditional entrainment mortality rate (1.7-5.7 percent, Appendix O) and, of all life stages, juveniles will experience the highest rate (1.8-6.0 percent, Appendix O). The range of projected conditional entrainment mortality rates based on the middle f-factors (5.3-10.5 percent, Table VIII-4) is slightly lower than the range of rates based on the pooled larval table f-factors (6.2-11.1 percent, Table VIII-2).

4. SUMMARY

The most probable ranges of estimated conditional entrainment mortality rates for six Hudson River fish populations, based on projected once-through and closed-cycle flow conditions are those listed in Table VIII-2. These estimates are based on the pooled larval table f-factors, rather than the component thermal model f-factors. As discussed in Section 4.2 of Chapter VII of this exhibit, the pooled larval table f-factors have less bias and, therefore, are probably relatively more accurate than the thermal model f-factors.

The Hudson River population of bay anchovies between RM 14-140 will experience the highest entrainment mortality, followed by (in descending order) striped bass, American shad, white perch, Alosa spp. (blueback herring and alewife), and Atlantic tomcod (Table VIII-2). Based on a comparison of the projected conditional entrainment mortality rates with once-through and closed-cycle cooling conditions in Table VIII-2, closed-cycle cooling would reduce the projected rates of all six populations to a considerable extent.

5. REFERENCES CITED

Barnthouse, L. W., J. B. Cannon, S. W. Christensen, A. H. Eraslan, J. L. Harris, K. H. Kim, M. E. LaVerne, H. A. McLain, B. D. Murphy, R. J. Raridon, T. H. Row, R. D. Sharp, and W. Van Winkle. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point Generating Station. Oak Ridge National Laboratory. ORNL/TM-5877/V2.

Boreman, J. 1979. Life histories of seven fish species that inhabit the Hudson River estuary. 94 pp. Exhibit EPA-

Exhibit UT-3. Supplement I to influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden and J. P. Lawler. Submitted to Consolidated Edison Company of New York, Inc. July 1977.

Exhibit UT-4. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. 1977.

Exhibit UT-6. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-6A. Appendixes. Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Central Hudson Gas and Electric Corporation. July 1977.

Exhibit UT-7. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

Exhibit UT-7A. Appendixes. Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota. Orange and Rockland Utilities, Inc. July 1977.

Exhibit UT-9. Indian Point Unit 2, Indian Point Unit No. 3. Near-field effects of once-through cooling system operation on Hudson River biota. Consolidated Edison Company of New York, Inc., Power Authority of the State of New York. July 1977.

Marcellus, K. L. 1977 (pers. comm.). Letter to Henry Gluckstern (EPA) dated November 30, 1977.

Marcellus, K. L. 1978 (pers. comm.). Letter to Henry Gluckstern (EPA) dated November 20, 1978.

APPENDICES A THROUGH P

TO

ENTRAINMENT IMPACT ESTIMATES FOR SIX FISH POPULATIONS INHABITING THE HUDSON RIVER ESTUARY

Joint Testimony of

John Boreman, Ph.D.[1]
Lawrence W. Barnthouse, Ph.D.[2]
Douglas S. Vaughan, Ph.D.[2]
Sigurd W. Christensen, Ph.D.[2]
K. Deva Kumar, Ph.D.[2]
Bernadette Kirk[2]
Webster Van Winkle, Ph.D.[2]

[1]National Power Plant Team
United States Fish and Wildlife Service
2929 Plymouth Road
Ann Arbor, Michigan 48105

[2]Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

PREPARED FOR THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II

May 1979

APPENDIX A

(UNDER SEPARATE COVER)

BOREMAN, J., C. P. GOODYEAR, and S. W. CHRISTENSEN. 1978. AN EMPIRICAL TRANSPORT MODEL FOR EVALUATING ENTRAINMENT OF AQUATIC ORGANISMS BY POWER PLANTS. FWS/OBS-78/90. BIOLOGICAL SERVICES PROGRAM, FISH AND WILDLIFE SERVICE, U.S. DEPARTMENT OF INTERIOR, WASHINGTON, D.C.

APPENDIX B

SOURCES OF DATA USED TO COMPUTE W-FACTORS USING THE MU AND GBC METHODS

LAWRENCE W. BARNTHOUSE, Ph.D.

K. DEVA KUMAR, Ph.D.

AND

BERNADETTE L. KIRK

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

APPENDIX B

Descriptions of the methods employed to collect the plant and river ichthyoplankton data we used to compute W-factors using the MU and GBC methods can be found in the following Exhibits and reports:

(1) Bowline- Exhibit UT-7A.
(2) Lovett- Annual Reports for the years 1975 (Ecological Analysts 1976) and 1976 (Ecological Analysts 1977).
(3) Indian Point- Exhibit UT-9.
(4) Roseton and Danskammer- Exhibit UT-6A.

The ichthyoplankton data are contained on magnetic tapes obtained from Consolidated Edison, Orange and Rockland, and Central Hudson. Each data set contains analyses of the ichthyoplankton composition of individual samples collected at a particular power plant and/or river transect during a given year. The data records generally contain the site at which a particular sample was collected, the data and time of collection, the volume of the sample, and either the number of organisms belonging to a particular population or the density (number of organisms per 1000 m^3) broken down by life-stage.

This appendix contains descriptions of the data sets obtained for each plant: the years and populations for which data are available, the period during which each population was collected, and the specific dates included in the computation of each W-factor.

B.1 Bowline/Lovett

Data collected during 1975 and 1976 at the Bowline and Lovett river transect stations and Bowline Pond are contained on a tape prepared by Lawler, Matusky, and Skelly and provied to EPA on October 31, 1977. All of the populations treated in Chapter 5, i.e., striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa, are included in the data sets contained on this tape. This same tape contains abundance data for these same populations and collected at the Bowline transect

stations, Bowline Pond, and the Bowline intake and discharge during 1974. Since these data are not broken down by life-stage (yolk-sac larvae, post yolk-sac larvae, and juveniles are all lumped as "larvae"), they could not be used to compute W-factors. However, the densities of the various striped bass life-stages collected in each river, pond, and plant sample during 1974 are contained on a second tape, provided to EPA on November 21, 1977. By combining data files from the October 31 tape (which contain sample volumes but no life-stage breakdowns) with the corresponding files from the November 21 tape (which contain life-stage breakdowns but no sample volumes) we were able to create a data set that could be used to compute 1974 W-factors for striped bass.

Bowline and Lovett intake data for the years 1975 and 1976 are contained on a tape prepared by Ecological Analysts. This tape was provided to EPA on January 19, 1978 (an earlier copy of the tape, provided on November 16, 1977, was found to be defective). All of the populations considered in Chapter 5 are included in the 1975 data sets for both plants. Although the 1976 data for Bowline appears complete, the tape does not contain 1976 bay anchovy abundance data for Lovett. Thus, we could not compute 1976 W-factors for bay anchovy entrained at Lovett.

Tables B-1 through B-5 list, for each population and year, the period during which each life-stage was observed in the Bowline and Lovett vicinities and the specific dates used to compute the W-factors.

B.2 Indian Point

The Indian Point plant and river abundance data collected by NYU are available for all the populations, life-stages, and years considered in Chapter 5. The 1974 and 1975 data are contained on a tape provided to EPA on November 30, 1977. The 1976 data are contained on a second tape, provided on November 21, 1977 (this same tape contains the 1974 striped bass density data for Bowline). Tables B-6 through B-8 list, for each population and year, the period during which each life-stage was observed in the Indian Point vicinity and the specific dates used to compute the W-factors.

Table B-1. Periods of occurrence of striped bass life-stages in the Bowline vicinity during 1974 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/22	5/22
	YSL	5/22-7/02	5/22,6/05,6/19,6/26 (day only), 7/02
	PYSL	6/05-7/02	6/05,6/19,6/26 (day only), 7/02
	Juveniles	6/19-8/01	--[a]

[a]W-factors not computed due to insufficient data.

Table B-2. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Bowline vicinity during 1975 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/20-6/10	5/20,5/27,6/03,6/10
	YSL	5/20-6/17	5/20,5/27,6/03,6/10,6/17
	PYSL	5/27-7/29	5/27,6/03,6/10,6/17,6/24, 7/01,7/08,7/15,7/22,7/29
	Juveniles	6/24-8/05	--[a]
White perch	Eggs[b]	5/20-6/24	5/20,5/27,6/03,6/10,6/17,6/24
	YSL	5/20-6/03	5/20,5/27,6/03,
	PYSL	5/27-8/05	5/27,6/03,6/10,6/17,6/24,7/01, 7/08,7/15,7/22,7/29,8/05
	Juveniles	7/08-7/22	--[a]
Atlantic tomcod	Eggs	--	--[a]
	YSL	2/26-4/22	2/26(night only),3/04,3/11 3/18,3/25(night only),3/28(day only),4/01,4/08,4/15,4/22
	PYSL	3/11-5/06	3/11,3/18,3/25(night only),3/28 (day only),4/01,4/08,4/15,4/22
	Juveniles	5/06-6/17	5/06,5/13,5/20,5/27,6/03,6/10
Bay anchovy	Eggs	6/10-8/12	6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05,8/12
	YSL[b]	7/01-8/19	7/01,7/08,7/15,7/22,7/29, 8/05,8/12,8/19
	PYSL	6/03-8/26	6/03,6/10,6/17,6/24,7/01,7/08 7/15,7/22,7/29,8/05,8/12,8/19 8/26
	Juveniles[c]	6/17-8/26	6/17,6/24,7/01,7/08,7/15,7/22 7/29,8/05,8/12,8/19,8/26
Alosa	Eggs	5/20	--[a]
	YSL	5/06-5/13	--[a]
	PYSL	5/06-7/01	5/06,5/13,5/20,5/27,6/03 6/10,6/17,6/24,7/01
	Juveniles	--	--[a]

[a]W-factors not computed due to insufficient data.

[b]Nighttime W-factor not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

Table B-3. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Bowline vicinity during 1976 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/04-6/01	5/04,5/11,5/18,5/25,6/01
	YSL	5/18-6/15	5/18,5/25,6/01,6/08,6/15
	PYSL	6/01-7/13	6/01,6/08,6/15,6/22,6/29, 7/06,7/13
	Juveniles	7/06-7/13	--[a]
White perch	Eggs[b]	5/18-7/06	5/18,5/25,6/01,6/08,6/15, 6/22,6/29,7/06
	YSL	5/18-6/01	--[a]
	PYSL	5/04-7/13	5/04,5/11,5/18,5/25,6/01,6/08, 6/15,6/22,6/29,7/06,7/13
	Juveniles	8/10	--[a]
Atlantic tomcod	Eggs	--	--[a]
	YSL	3/02-3/23	3/02,3/09,3/16,3/23
	PYSL	3/02-6/29	3/02,3/09,3/16,3/23,3/30,4/06 4/13,4/20,4/27,5/04,5/11,5/18 5/25,6/01,6/08,6/15,6/22,6/29
	Juveniles	4/20-8/17	4/20,4/27,5/04,5/11,5/18,5/25 6/01,6/08,6/15,6/22,6/29,7/06 7/13,7/20,7/27,8/03,8/10,8/17
Bay anchovy	Eggs	7/20-8/24	7/20,7/27,8/03,8/10,8/17,8/24
	YSL	7/27-8/03	--[a]
	PYSL[c]	6/29-8/24	6/29,7/06,7/13,7/20,7/27,8/03 8/10,8/17,8/24
	Juveniles	7/27-8/24	7/27,8/03,8/10,8/17,8/24
Alosa	Eggs	4/20-5/18	--[a]
	YSL	5/04-5/18	--[a]
	PYSL	4/13-8/24	4/13,4/20,4/27,5/04,5/11,5/18 5/25,6/01,6/08,6/15,6/22,6/29 7/06,7/13,7/20,7/27,8/03,8/10 8/17,8/24
	Juveniles	4/27-7/06	--[a]

[a]W-factors not computed due to insufficient data.

[b]Nighttime W-factor not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

Table B-4. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Lovett vicinity during 1975 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs[a,b]	5/13-6/10	6/10
	YSL[b]	5/13-6/24	6/10,6/17,6/24
	PYSL[b]	5/13-7/01	6/10,6/17,6/24,7/01
	Juveniles	7/08-8/19	--[c]
White perch	Eggs	5/20-6/10	--[b,c]
	YSL	5/20-6/10	--[b,c]
	PYSL[b]	5/06-7/15	6/10,6/17,6/24,7/01,7/08,7/15
	Juveniles	7/08-7/22	--[c]
Atlantic tomcod	Eggs	--	--[c]
	YSL	2/26-4/08	3/11,3/18,3/25(night only), 3/28,(day only),4/01,4/08
	PYSL	3/04-8/19	3/11,3/18,3/25(night only),3/28 (day only),4/01,4/08,4/15,4/22 4/29,5/06,5/13,5/20,5/27,6/03 6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05,8/12,8/19
	Juveniles	4/08-8/26	4/08,4/15,4/22,4/29,5/06,5/13 5/20,5/27,6/03,6/10,6/17,6/24 7/01,7/08,7/15,7/22,7/29,8/05 8/12,8/19,8/26
Bay anchovy	Eggs	6/10-8/05	6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05
	YSL	6/10-8/05	6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05
	PYSL[b]	6/04-8/26	6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05,8/12,8/19,8/26
	Juveniles[a]	6/10-8/26	6/10,6/17,6/24,7/01,7/08,7/15 7/22,7/29,8/05,8/12,8/19,8/26
Alosa	Eggs	5/06-6/10	--[b,c]
	YSL[b,d]	5/06-6/10	6/10
	PYSL[b]	4/29-6/24	6/10,6/17,6/24
	Juveniles	6/17	--[c]

[a]Daytime W-factor not computed due to insufficient data.

[b]Data collected prior to June 10 excluded for all populations except Atlantic tomcod (see Chapter 5, Section 4.1).

[c]W-factors not computed due to insufficient data.

[d]Nighttime W-factor not computed due to insufficient data.

Table B-5. Periods of occurrence of striped bass, white perch, Atlantic tomcod, and Alosa life-stages in the Lovett vicinity during 1976 and specific dates used in the calculation of W-factors[a]

Striped bass	Eggs	5/04-6/22	5/04,5/11,5/18,5/25, 6/01(day only)
	YSL	5/04-6/29	5/04,5/11,5/18,5/25,6/01 (day only)6/08,6/15,6/22,6/29
	PYSL	5/18-7/06	5/18,5/25,6/01(day only)6/08, 6/15,6/22,6/29
	Juveniles	7/06-8/03	--[b]
White perch	Eggs	5/11-6/29	5/11,5/18,5/25,6/01(day only) 6/08,6/15,6/22,6/29
	YSL	5/11-6/29	5/11,5/18,5/25,6/01(day only) 6/08,6/15
	PYSL	5/11-7/20	5/11,5/18,5/25,6/01(day only) 6/08,6/15,6/22,6/29,7/13,7/20
	Juveniles	8/10	--[b]
Atlantic tomcod	Eggs	2/06-2/09	--[b]
	YSL	2/06-3/30	3/09,3/16,3/23,3/30
	PYSL	3/02-4/27	3/09,3/16,3/23,3/30,4/06 (day only)4/13,4/20,4/27
	Juveniles	3/02-6/29	3/09,3/16,3/23,3/30,4/06 (day only)4/13,4/20,4/27,5/04 5/11,5/18,5/25,6/01(day only) 6/08,6/15,6/22,6/29
Alosa	Eggs	5/11-6/22	--[b]
	YSL[c]	5/11-6/08	5/11,5/18,5/25,6/08
	PYSL	4/27-6/29	4/27,5/04,5/11,5/18,5/25,6/01 (day only),6/08,6/15,6/22,6/29 7/06,7/13,7/20,7/27,8/03,8/10
	Juveniles	--	--[b]

[a]No bay anchovy abundance data was available for the Lovett intake.

[b]W-factors not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

Table B-6. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Indian Point vicinity during 1974 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs[a]	5/07-6/11	5/07,5/14,5/21,5/28,6/04,6/11
	YSL	5/07-6/25	5/07,5/14(day only),5/21 (day only),5/28,6/04,6/11,6/18 6/25
	PYSL	5/07-7/09	5/07,5/14(day only),5/21 (day only),5/28,6/04,6/11,6/18 6/25,7/02,7/09
	Juveniles	6/11-7/09	--[b]
White perch	Eggs	5/21-6/25	5/21,(day only),5/28,6/04, 6/11,6/18,6/25
	YSL	5/14-7/16	5/14,(day only),5/21,(day only) 5/28,6/04,6/11,6/18,6/25,7/02, 7/09,7/16(day only)
	PYSL	5/14-7/23	5/14,(day only),5/21,(day only) 5/28,6/04,6/11,6/18,6/25,7/02, 7/09,7/16,(day only),7/23
	Juveniles	6/18	--[b]
Atlantic tomcod	Eggs	--	--[b]
	YSL	3/26	--[b]
	PYSL	3/26-4/02	--[b]
	Juveniles	5/07-9/17	5/07,5/14,(day only),5/21,(day only),5/28,6/04,6/11,6/18,6/25, 7/02,7/09,7/16,(day only),7/23, 7/30,(day only),8/06,8/13,(day only),8/20,8/27,(day only),9/03 (day only),9/17
Bay anchovy	Eggs	6/18-8/27	6/18,6/25,7/02,7/09,7/16,(day only),7/23,7/30(day only)8/06 8/13(day only),8/20,8/27(day only)
	YSL	7/16-8/13	7/16,7/23,7/30,8/06,8/13,
	PYSL	6/18-10/15	6/18,6/25,7/02,7/09,7/16(day only),7/23,7/30(day only),8/06 8/13(day only),8/20,8/27(day only),9/03(day only),9/17,10/15
	Juveniles	7/02-11/12	7/02,7/09,7/16(day only),7/23 8/06,8/13(day only),8/20,8/27 (day only),9/3(day only),9/17 10/15,11/12
Alosa	Eggs	5/21-6/11	--[b]
	YSL	4/23-6/11	4/23(day only),5/07,5/14(day only),5/21(day only),5/28,6/04 6/11
	PYSL	4/23-7/02	4/23(day only),5/07,5/14(day only),5/21(day only),5/28,6/04 6/11,6/18,6/25,7/02
	Juveniles	6/11-8/20	--[b]

[a]Nighttime W-factor not computed due to insufficient data.

[b]W-factors not computed due to insufficient data.

Table B-7. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Indian Point vicinity during 1975 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/12-6/16	5/12,5/21,5/27,6/02,6/09,6/16
	YSL	5/12-6/23	5/12,5/21,5/27,6/02,6/09,6/16 6/23
	PYSL	5/21-7/17	5/21,5/27,6/02,6/09,6/16,6/23 6/30,7/07,7/16
	Juveniles	6/16-7/07	--[a]
White perch	Eggs[b]	5/21-6/16	5/21,5/27,6/02,6/09,6/16
	YSL	5/12-6/23	5/12,5/21,5/27,6/02,6/09, 6/16,6/23
	PYSL	5/21-7/21	5/21,5/27,6/02,6/09,6/16,6/23, 6/30,7/07,7/16,7/21(day only)
	Juveniles	7/16-12/09	--[a]
Atlantic tomcod	Eggs	1/23	--[a]
	YSL	--	--[a]
	PYSL	1/23-8/18	--[a]
	Juveniles	5/05-8/18	5/05,5/12,5/21,5/27,6/02,6/09 6/16,6/23,6/30,7/07,7/16,7/21 (day only),8/11(day only), 8/18(night only)
Bay anchovy	Eggs	6/09-7/07	6/09,6/16,6/23,6/30,7/07
	YSL	6/02-7/07	6/02,6/09,6/16,6/23,6/30,7/07
	PYSL	6/09-9/15	6/09,6/16,6/23,6/30,7/07,7/16 7/21(day only),8/11(day only), 8/18(night only),8/25(day only) 9/15
	Juveniles	6/09-10/13	6/09,6/16,6/23,6/30,7/07,7/16 7/21(day only),8/11(day only), 8/18(night only),8/25(day only) 9/15,10/13
Alosa	Eggs	4/28-6/02	--[a]
	YSL	5/05-6/02	5/05,5/12,5/21,5/27,6/02,6/09
	PYSL	5/05-7/07	5/05,5/12,5/21,5/27,6/02,6/09 6/16,6/23,6/30,7/07
	Juveniles	5/21-10/13	--[a]

[a]W-factors not computed due to insufficient data.

[b]Nighttime W-factor not computed due to insufficient data.

Table B-8. Periods of occurrence of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa life-stages in the Indian Point vicinity during 1976 and specific sampling dates used in the calculation of W-factors

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/03-6/22	5/03,5/10,5/17(day only),5/24 6/01,6/08,6/15,6/22
	YSL	5/10-6/29	5/10,5/17(day only),5/24,6/01 6/08,6/15,6/22,6/29
	PYSL	5/24-7/13	5/24,6/01,6/08,6/15,6/22,6/29 7/06,7/13
	Juveniles	7/06-8/02	--[a]
White perch	Eggs	5/17-6/29	5/17(day only),5/24,6/01,6/08 6/15,6/22,6/29
	YSL	5/03-6/22	5/03,5/10,5/17(day only),5/24 6/01,6/08,6/15,6/22
	PYSL	5/03-7/06	5/03,5/10,5/17(day only),5/24, 6/01,6/08,6/15,6/22,6/29,7/06
	Juveniles	7/13-11/09	--[a]
Atlantic tomcod	Eggs	--	--[a]
	YSL	--	--[a]
	PYSL	4/12-7/27	4/12[a]
	Juveniles[b]	4/12-7/27	4/12,5/03,5/10,5/17,5/24,6/01 6/08,6/15
Bay anchovy	Eggs	7/20-8/24	7/20,7/27,8/02(day only),8/24
	YSL	7/06-8/24	7/06,7/13,7/20,7/27,8/20(day only),8/24
	PYSL	6/22-9/14	6/22,6/29,7/06,7/13,7/20,7/27 8/02(day only),8/24,9/14(day only)
	Juveniles[c]	7/13-09/14	7/13,7/20,7/27,8/24
Alosa	Eggs	5/03-6/01	--[a]
	YSL	5/03-6/15	5/03,5/10,5/17(day only),5/24 6/01,6/08,6/15
	PYSL	5/03-7/20	5/03,5/10,5/17(day only),5/24 6/01,6/08,6/15,6/22,6/29,7/06 7/13,7/20
	Juveniles	6/01-10/12	--[a]

[a]W-factors not computed due to insufficient data.

[b]Nighttime W-factor not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

B.3 Roseton/Danskammer

Data collected during 1975 and 1976 at the Roseton/Danskammer river transect stations and at the Roseton and Danskammer intakes are contained on a tape prepared by LMS. This tape was provided to EPA on October 31, 1977 (this same tape contains the Bowline and Lovett river transect data for 1975-76). Abundance data for all life-stages of striped bass, white perch, Atlantic tomcod, bay anchovy, and Alosa are available for both plants for both years. The tape also contains the 1974 Roseton intake and Roseton/Danskammer river transect data for each population. Like the 1974 data provided for Bowline, all life-stages (except eggs) are lumped, and therefore most of the data could not be used to compute W-factors. The densities of striped bass contained in each sample collected at the Roseton/Danskammer river stations and at the Roseton intake, broken down by life-stage, are contained in a tape provided to EPA on November 21, 1977 (the same tape contains the 1974 data for Bowline and the 1976 data for Indian Point). By combining data files from the October 31 tape (which contain sample volumes but no life-stage breakdowns) with the corresponding files from the November 21 tape (which contain life-stage breakdowns but no sample volumes) we were able to create a data set that could be used to compute 1974 W-factors for striped bass. As explained in Chapter 5, the 1974 Roseton intake data were excluded from all computations because of insufficient sampling effort. The 1974 Roseton/Danskammer river transect data, however, were used to compute W-factors for striped bass using the GBC method. Tables B-9 through B-13 list, for each population and year, the period during which each life-stage was observed in the Roseton and Lovett vicinities and the specific dates used to compute the W-factors.

Table B-9. Periods of occurrence of striped bass life-stages in the Roseton vicinity during 1974 and specific sampling dates used in the calculation of W-factors[a]

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/07-6/04	5/07,5/21,6/04
	YSL	5/07-7/02	5/07,5/21,6/04,6/18,7/02
	PYSL	6/04-7/16	6/04,6/18,7/02,7/16
	Juveniles	6/18-7/30	--[b]

[a]Only the GBC method was used to compute W-factors.

[b]W-factors not computed due to insufficient data.

Table B-10. Periods of occurrence of striped bass, white perch, Atlantic tomcod, and Alosa life-stages in the Roseton vicinity during 1975 and specific sampling dates used in the calculation of W-factors[a]

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs[b]	5/19-5/29	5/22,5/29
	YSL	5/15-6/06	5/15,5/22,5/29,6/02,6/05
	PYSL	5/22-7/17	5/22,5/29,6/02,6/05,6/09,6/19 6/23,6/26,7/17
	Juveniles	--	--[c]
White perch	Eggs	5/05-6/23	5/05,5/08,5/15,5/22,5/29,6/02 6/05,6/09,6/19,6/23
	YSL	5/15-6/02	5/15,5/22,5/29,6/02
	PYSL	5/19-7/17	5/22,5/29,6/02,6/05,6/09,6/19, 6/23,6/26,7/17
	Juveniles	6/23-8/14	--[c]
Atlantic tomcod	Eggs	1/09-3/27	--[c]
	YSL	2/13-3/20	--[c]
	PYSL	1/09-4/21	--[c]
	Juveniles	5/15	--[c]
Alosa	Eggs	4/03-7/30	4/21,5/05,5/08,5/15,5/22,5/29 6/02,6/05,6/09,6/19,6/23,7/17 7/30
	YSL	5/05-6/05	5/05,5/08,5/15,5/22,5/29,6/02 6/05
	PYSL	5/05-7/17	5/05,5/08,5/15,5/22,5/29,6/02 6/05,6/09,6/19,6/23,7/17
	Juveniles	6/02-10/21	6/02,6/05,6/09,6/19,6/23,7/17 7/30,8/14,8/27,9/11,10/21

[a]No bay anchovy were collected by LMS in the Roseton/Danskammer vicinity in 1975.

[b]Nighttime W-factor not computed due to insufficient data.

[c]W-factors not computed due to insufficient data.

Table B-11. Periods of occurrence of striped bass, white perch, Atlantic tomcod, and Alosa life-stages in the Roseton vicinity during 1976 and specific sampling dates used in the calculation of W-factors[a]

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/06-6/17	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17
	YSL	5/20-6/17	5/20,5/24,5/27,6/01,6/03,6/10 6/14,6/17
	PYSL	5/27-7/15	5/27,6/01,6/03,6/10,6/14,6/17 6/24,7/15
	Juveniles	7/15-8/12	--[b]
White perch	Eggs	5/03-6/24	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17,6/24
	YSL	5/06-7/01	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17,6/24
	PYSL	5/03-7/22	5/06,5/20,5/24,5/27,6/01,6/03, 6/10,6/14,6/17,6/24,7/15
	Juveniles	7/01-8/26	--[b]
Atlantic tomcod	Eggs	--	--[b]
	YSL	3/18	--[b]
	PYSL	2/19-3/25	3/18,3/25
	Juveniles	5/20-6/14	--[b]
Alosa	Eggs	4/01-6/17	4/15,5/06,5/20,5/24,5/27,6/01 6/03,6/10,6/14,6/17
	YSL	5/03-6/14	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17
	PYSL	5/03-8/12	5/06,5/20,5/24,5/27 6/01 6/03 6/10,6/14,6/17,6/24,7/15,7/29 8/12
	Juveniles[c]	6/17-10/14	6/17,6/24,7/15,7/29,8/12,8/26 9/16,10/14

[a]No bay anchovy were collected by LMS in the Roseton/Danskammer vicinity in 1976.

[b]W-factors not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

Table B-12. Periods of occurrence of striped bass, white perch, Atlantic tomcod, and Alosa life-stages in the Danskammer vicinity during 1975 and specific sampling dates used in the calculation of W-factors[a]

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs[b]	5/19-6/02	5/22,5/29,6/02
	YSL	5/15-6/05	5/15,5/22,5/29,6/02,6/05
	PYSL	5/22-7/17	5/22,5/29,6/02,6/05,6/09,6/12 6/19,6/23,6/26,7/17
	Juveniles	6/23	--[c]
White perch	Eggs	5/05-7/02	5/05,5/08(day only),5/15,5/22 5/29,6/02,6/05,6/09,6/19,6/23 6/26
	YSL	5/15-6/05	5/15,5/22,5/29,6/02,6/05
	PYSL	5/22-7/30	5/22,5/29,6/02,6/05,6/09,6/19, 6/23,6/26,7/17,7/30
	Juveniles	6/23-8/27	--[c]
Atlantic tomcod	Eggs	1/09-3/27	--[c]
	YSL	2/13-2/20	--[c]
	PYSL	3/27-4/21	--[c]
	Juveniles	5/15	--[c]
Alosa	Eggs	4/21-7/17	5/05,5/08(day only),5/15,5/22 5/29,6/02,6/05,6/09,6/19,6/23 6/26,7/17
	YSL	5/05-6/05	5/05,5/08(day only),5/15,5/22 5/29,6/02,6/05
	PYSL	5/05-7/17	5/05,5/08(day only),5/15,5/22 5/29,6/02,6/05,6/09,6/19,6/23 6/26,7/17
	Juveniles	6/02-10/21	6/02,6/05,6/09,6/19,6/23,6/26 7/17,7/30,8/14,9/11,10/21

[a]No bay anchovy were collected by LMS in the Roseton/Danskammer vicinity in 1975.

[b]Nighttime W-factor not computed due to insufficient data.

[c]W-factors not computed due to insufficient data.

Table B-13. Periods of occurrence of striped bass, white perch, Atlantic tomcod, and Alosa life-stages in the Danskammer vicinity during 1976 and specific sampling dates used in the calculation of W-factors[a]

Population	Life-stage	Period of occurrence	Dates used
Striped bass	Eggs	5/06-6/17	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17
	YSL	5/17-6/17	5/20,5/24,5/27,6/01,6/03,6/10 6/14,6/17
	PYSL	5/27-7/15	5/27,6/01,6/03,6/10,6/14,6/17 6/24,7/15
	Juveniles	7/15-8/12	--[b]
White perch	Eggs	5/03-7/01	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17,6/24
	YSL	5/06-7/15	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14,6/17
	PYSL	5/06-7/15	5/06,5/20,5/24,5/27,6/01,6/03, 6/10,6/14,6/17,6/24,7/15
	Juveniles	7/01-8/26	--[b]
Atlantic tomcod	Eggs	--	--[b]
	YSL	2/19-3/18	--[b]
	PYSL	2/11-4/01	3/18,3/25,4/01
	Juveniles	5/20-6/14	--[b]
Alosa	Eggs	4/01-7/01	4/01,4/15,5/06,5/20,5/24,5/27 6/01,6/03,6/10,6/14,6/17,6/24
	YSL	5/03-6/14	5/06,5/20,5/24,5/27,6/01,6/03 6/10,6/14
	PYSL	5/03-8/05	5/06,5/20,5/24,5/27 6/01 6/03 6/10,6/14,6/17,6/24,7/15,7/29
	Juveniles[c]	5/20-10/14	5/20,5/24,5/27,6/01,6/03,6/10 6/14,6/17,6/24,7/15,7/29,8/12 8/26,9/16,10/14

[a]No bay anchovy were collected by LMS in the Roseton/Danskammer vicinity in 1976.

[b]W-factors not computed due to insufficient data.

[c]Daytime W-factor not computed due to insufficient data.

REFERENCES CITED

Ecological Analysts 1976. Lovett Generating Station entrainment survival and abundance studies. 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc.

Ecological Analysts 1977. Lovett Generating Station entrainment survival and abundance studies. 1976 Annual Report. Prepared for Orange and Rockland Utilities, Inc.

Exhibit UT-6A. Central Hudson 1977. Appendixes-Roseton Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Exhibit UT-7A. Orange and Rockland 1977. Appendixes- Bowline Point Generating Station. Near-field effects of once-through cooling system operation on Hudson River biota.

Exhibit UT-9. Consolidated Edison 1977. Indian Point Unit no. 2, Indian Point Unit No. 3. Near-field effects of once-through cooling system operation on Hudson River biota.

APPENDIX C

C.1 DERIVATIONS OF COMPONENT F-FACTORS

C.2 DEVELOPMENT OF THE COMPROMISE F-FACTOR

DOUGLAS S. VAUGHAN, Ph.D.

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

APPENDIX C

C.1 DERIVATIONS OF COMPONENT F-FACTORS

In Section VII-1 we introduced equations for estimating the immediate and latent components of the f-factor [Eqs. (VII-4) and (VII-5)]. An equation was also introduced for combining these components (and the indirect component of the entrainment mortality factor) in order to estimate the total f-factor [see Eq. (VII-1)]. In this appendix we discuss the derivation of these equations, as well as some of their underlying assumptions. Later appendices will expand on the problems concerning the precision (Appendix D) and biases (Appendix E) of an estimate.

The derivation of Eq. (VII-4) is presented in Barnthouse et al. (1977). This equation estimates the immediate component of the f-factor. In these calculations young-of-the-year fish (except eggs), which were classified as "live" and "stunned" in the samples, were treated as "alive." This equation assumes that sampling mortality is identical at both the intake and discharge sampling stations. This assumption would not hold if sampling mortality is not independent of plant induced entrainment mortality. The lack of validity of this assumption of independence would result in some overstatement of the f-factor (Exhibit UT-4, p. 8.46).

A similar derivation can be used for the latent component of the f-factor [Eq. (VII-5)] as follows. Define

P_I = probability of an organism being initially alive in the intake.

P_D = probability of an organism alive in the intake being initially alive in the discharge.

P_S = probability of an organism alive at the intake or discharge station being initially classified "alive" in the sorting dish after collection from the intake or discharge station, independent of plant-induced mortality.

P_L = probability of an organism initially classified "alive" in the sorting dish after collection from the intake or discharge station surviving a fixed holding period (say 24 hours), independent of plant-induced latent mortality.

P_{DL} = probability of an organism initially alive in the discharge surviving a fixed period (again, say 24 hours).

Then the probability of an organism being classified "alive" in the intake sample after 24 hours, P_{ILS}, is

$$P_{ILS} = P_I \times P_S \times P_L \quad , \tag{C-1}$$

and the probability of an organism being classified "alive" in the discharge sample after 24 hours, P_{DLS}, is

$$P_{DLS} = P_I \times P_D \times P_S \times P_L \times P_{DL} = P_{ILS} \times P_D \times P_{DL} \tag{C-2}$$

assuming P_S (and P_L) is the same for both intake and discharge samples and are independent of each other. Now, the probability that an organism is classified "alive" after 24 hours, given that it was classified "alive" initially in the intake sample, $P_{\ell,I}$, is [from Eq. (C-1)]

$$P_{\ell,I} = P_{ILS}/(P_I \times P_S) = P_L \quad . \tag{C-3}$$

The probability that an organism is classified "alive" after 24 hours given that it was classified "alive" initially in the discharge sample, $P_{\ell,D}$, is [from Eq. (C-2)]

$$P_{\ell,D} = P_{DLS}/(P_I \times P_D \times P_S) = P_L \times P_{DL} \quad . \tag{C-4}$$

Thus, the probability of an organism surviving 24 hours, given that it survived plant passage, P_{DL}, is [since $P_{\ell,I}$ equals P_L in Eq. (C-4)]

$$P_{DL} = P_{\ell,D}/P_{\ell,I} \quad , \tag{C-5}$$

and the probability of 24-hour latent mortality given initial survival, $f_{\ell,D}$, is

$$f_{\ell,D} = 1 - P_{DL} = 1 - \frac{P_{\ell,D}}{P_{\ell,I}} \quad . \tag{C-6}$$

Refer to Appendix E for conditions under which Eqs. (VII-4) and (C-6) are biased.

Since an organism only dies once, but can survive in the presence of several sources of mortality, we will work with the probabilities of survival, rather than mortality, when combining component estimates in calculating an overall probability of mortality. Assuming independence between surviving the immediate and the latent sources of mortality, the probability of surviving both immediate $(1 - f_{i,D})$ and latent $(1 - f_{\ell,D})$ sources of mortality is given by

$$(1 - f_D) = (1 - f_{i,D})\ (1 - f_{\ell,D}) \quad . \tag{C-7}$$

So the probability of an organism dying due to either immediate or latent effects, f_D, is

$$f_D = 1 - (1 - f_{i,D})\ (1 - f_{\ell,D}) \tag{C-8}$$

Similarly, if we assume that the probability of surviving the indirect component of entrainment mortality, $(1 - f_I)$, is independent of the

direct component (immediate and latent), then the probability of surviving both the direct and the indirect components of entrainment mortality is

$$(1 - f) = (1 - f_{i,D}) (1 - f_{\ell,D}) (1 - f_I) \quad . \qquad (C\text{-}9)$$

Thus, the total probability of being killed as a result of both direct and indirect components of entrainment mortality, f, is

$$f = 1 - (1 - f_{i,D}) (1 - f_{\ell,D}) (1 - f_I) \quad . \qquad (C\text{-}10)$$

REFERENCES CITED

Barnthouse, L. W., J. B. Cannon, S. W. Christensen, A. H. Eraslan, J. L. Harris, K. H. Kim, M. E. LaVerne, H. A. McLain, B. D. Murphy, R. J. Raridon, T. H. Row, R. D. Sharp, and W. Van Winkle. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point generating station. ORNL/TM-5877 (Volume 2). Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Exhibit UT-4. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. 1977.

C.2 DEVELOPMENT OF THE COMPROMISE F-FACTOR

In this appendix we develop a compromise f-factor to be used in the Empirical Transport Model (see Chapter VIII) when apparent contradictory results were obtained for certain calculated f-factors equal to 1.0 (see Tables VII-2 and VII-11). In these cases the standard normal test (Exhibit UT-11, p. 1-11) indicated that the f-factor of 1.0 was significantly greater than zero ($\alpha = 0.05$), while a binomial test (Siegel 1956) failed to reject the null hypothesis that the f-factor was greater than zero (again, $\alpha = 0.05$). Thus, it was felt that a compromise was appropriate.

A range of five potential f-factors was selected (0.0, 0.25, 0.50, 0.75, and 1.0). The proportion alive at the intake was estimated from the larval table data. Given an observed proportion alive at the intake (P_i), the expected proportion alive at the discharge for each of the five potential f-factors (f_j, j=1, ..., 5) is given by

$$P_{d,j} = (1 - f_j)\, P_i, \quad j = 1, \ldots, 5 \quad . \tag{C-11}$$

From the binomial model (Siegel 1956) the probability of observing no survivors in the discharge sample (of fixed sample size, n_d), given that the underlying proportion $P_{d,j}$ survive, is given by

$$w_j \equiv \Pr\,[\text{No survivors in discharge}]$$

$$= \left[1 - P_{d,j}\right]^{n_d}, \quad j = 1, \ldots, 5 \quad . \tag{C-12}$$

Using the range of five potential f-factors (f_j = 0.0, 0.25, 0.5, 0.75, 1.0), a weighted average of these five f-factors (f*) was calculated as follows:

$$f^* = \frac{\sum_{j=1}^{5} w_j \cdot f_j}{\sum_{j=1}^{5} w_j} \quad , \tag{C-13}$$

where w_j is the weighting factor from Eq. (C-12). The average f-factor (denoted f*) was then used as the compromise estimate of the f-factor.

REFERENCES CITED

Siegel, S. 1956. Nonparametric Statistics for the Behavioral Sciences. McGraw-Hill Book Co., New York. 312 pp.

Exhibit UT-11. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. July 1977.

APPENDIX D

DETECTABILITY AND PRECISION OF F-FACTOR ESTIMATES

DOUGLAS S. VAUGHAN, Ph.D.

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

APPENDIX D

DETECTABILITY AND PRECISION OF F-FACTOR ESTIMATES

Whenever a researcher obtains an estimate of a parameter, it is important that the researcher have some idea about the precision of that estimate. The precision of an estimate becomes even more important when, as in this case, that estimated parameter is input to a model used for predictive purposes, since variability in model input parameters can magnify the variability of model output (Gardner et al., submitted; O'Neill, 1973; O'Neill and Gardner, in press).

Also, the greater the precision with which we can estimate a parameter, the greater the chance that we will detect whether the underlying parameter is different from some specified value when the underlying parameter is, in fact, different from that specified value. The failure to detect this difference when it in fact exists refers to the type II (β) error. One minus the type II error ($1 - \beta$) refers to the power of a statistical test. In most statistical tests one begins by setting the type I error (or α), which refers to the probability of finding an apparent difference between the underlying parameter estimated and the hypothesized value of the parameter when the observed difference can, in fact be explained purely by random error (i.e., no real difference). Once the type I error is set, then usually the sample size will determine the level of the type II error (and the power of the statistical test).

For estimates of the f-factor the hypothesis that no difference exists between the intake (P_i) and discharge (P_d) probabilities of survival implies that

$$f = \frac{P_i - P_d}{P_i} = 0 \quad . \qquad \text{(D-1)}$$

If P_i is greater than P_d, then f is greater then zero (but less than or equal to one). Observing P_i to be less than P_d (which implies that the power plant is producing organisms) is assumed to occur only from random sampling error and so f is set to zero.

The statistical test used to evaluate the hypothesis that f = 0 (i.e., detect statistically significant differences between P_i and P_d) uses the test statistic (p. 1-11, Exhibit UT-11):

$$z = \frac{P_i - P_d}{\sqrt{\frac{P_i(1-P_i)}{n_i} + \frac{P_d(1-P_d)}{n_d}}} \quad , \qquad \text{(D-2)}$$

where n_i = number of organisms collected at the intake station, and n_d = number of organisms collected at the discharge station. When the calculated z exceeds a tabled value of the standard normal deviate (as a function of the type I error), then it is concluded that P_i is greater than P_d or that f is greater than zero.

The denominator of equation (D-2) will decrease to zero as both n_i and n_d become very large, so z will become large for a fixed difference (P_i-P_d). Further, if there is a constant ratio between P_i and P_d (f remains the same, then as P_i approaches one (its maximum), the numerator of Eq. (D-2), $(P_i - P_d)$, will become larger, and hence so will z (note in Eq. (D-2) that the denominator will also become larger, but at a slower rate since it lies within a square root sign). The development of the larval table has been an improvement in increasing the precision of estimates of the f-factor by increasing the sampling survival of some organisms at the intake (as well as reducing the differential sampling mortality at the intake compared to the discharge sampling stations). However, expending more effort in collecting larval table data during periods of higher concentrations of yolk-sac larvae and entrainable juvenile would have led to increased sample sizes for these life-stages and improved precision of the estimated f-factors for these life-stages.

For various lifestages and populations a true nonzero f-factor may be completely masked in terms of our ability to "detect" it statistically. If we refer to Tables VII-3 and VII-9, we note that the sample sizes in the larval table data tend to be quite small for yolk-sac larvae and entrainable juveniles. Table D-1 shows the immediate and 24-hour latent survivals at the intake for five Hudson River plants where there are low survivals for bay anchovy (initial and latent) and for clupeids (latent).

Table D-2 gives the minimum f-factor we can expect to detect for a fixed sample size (same size in both intake and discharge samples) and proportion alive in the intake. This table clearly illustrates the principle that increasing sample size or increasing the proportion alive in the intake sample will allow us to detect smaller nonzero f-factors. The larval table was an important step in increasing the estimated P_i, the proportion alive in the intake sample.

Tables D-3 through D-6 illustrate the sample size required to detect a specified f-factor, given a fixed level for both the type I and type II errors and the proportion alive in the intake sample. In order to decrease either the type I or type II error while the other remains constant, it is necessary to either increase the sample size or increase the proportion alive in the intake sample.

Finally, if we refer to Eq. (VII-30), we note that the standard error of estimates of the f-factor will decrease with increasing sample sizes at either the intake or discharge stations or with increasing P_i. A smaller standard error of an estimate implies a more precise estimate.

Table D-1. Intake survivals initially and 24 hour latent (conditioned on initial survival) by populations and life-stage for five Hudson River plants (from larval table data provided on magnetic tapes to ORNL by the utilities on November 16, 1977 and April 5, 1978)

Species	Life-stage[a]	Bowline Point (1975+ 1976)	Roseton (1975+1976)	Indian Point (Unit 3) (1977)	Danskammer Point (1975)	Lovett (1976)	Combined
INITIAL:							
Striped Bass	Y	--	0.80	0.77	--	0.80	0.80
	P	0.81	0.78	0.60	0.41	0.81	0.70
	J	1.0	0.93	0.60	--	--	0.90
White Perch	Y	--	--	--	--	--	--
	P	0.58	0.56	0.66	0.33	0.57	0.56
	J	1.0	0.94	--	--	--	0.94
Clupeids	Y	--	--	--	--	--	--
	P	0.40	0.54	0.34	0.36	0.33	0.48
	J	--	0.64	0.94	0.27	--	0.63
Bay Anchovy	Y	--	--	--	--	0.13	0.07
	P	0.09	0.19	0.11	0.33	0.01	0.08
	J	0.57	0.54	0.62	--	--	0.57
Tomcod	Y	0.82	--	--	--	0.67	0.79
	P	0.54	--	--	--	0.90	0.59
	J	--	--	--	--	--	--
LATENT[b] (24-Hour):							
Striped Bass	Y	0.45	--	0.70	--	0.25	0.40
	P	0.56	0.34	0.89	0.18	0.55	0.61
	J	1.0	0.95	--	--	--	0.94
White Perch	Y	--	--	--	--	--	--
	P	0.55	0.07	0.86	0.08	0.25	0.25
	J	1.0	0.97	--	--	--	0.96
Clupeids	Y	--	--	--	--	--	--
	P	0.0	0.01	0.14	0.0	0.44	0.06
	J	0.0	0.02	0.20	0.0	--	0.03
Bay anchovy	Y	--	--	--	--	--	--
	P	0.02	--	0.08	--	0.0	0.05
	J	0.03	0.0	0.13	--	--	0.03
Tomcod	Y	0.68	--	--	--	0.58	0.67
	P	0.17	--	--	--	0.67	0.29
	J	--	--	--	--	--	--

[a] Y = yolk-sac larvae, P = post yolk-sac larvae, J = entrainable juveniles.

[b] Conditioned on initial survival.

(Note: -- indicates insufficient sample size < 5).

Table D-2. The lowest f-factor detectable as significantly greater than zero using Fleiss' (1973) test for differences in proportions (one-tailed) as a function of the proportion alive in the intake sample (P_i) and sample size (n) with $\alpha = 0.05$

Sample size (n)	Proportion alive in the intake sample (P_i)				
	0.1	0.3	0.5	0.7	0.9
10	a	1.000	0.864	0.667	0.493
20	a	0.827	0.597	0.441	0.301
30	1.000	0.676	0.479	0.347	0.226
40	1.000	0.585	0.410	0.293	0.186
50	0.938	0.522	0.364	0.258	0.160
60	0.862	0.476	0.330	0.232	0.142
70	0.803	0.440	0.303	0.213	0.129
80	0.754	0.411	0.282	0.197	0.118
90	0.713	0.387	0.265	0.184	0.109
100	0.678	0.367	0.251	0.174	0.102
300	0.398	0.210	0.141	0.095	0.053
500	0.309	0.162	0.108	0.072	0.039
700	0.262	0.136	0.091	0.061	0.033
1000	0.220	0.114	0.076	0.050	0.027
3000	0.127	0.065	0.043	0.029	0.015
5000	0.099	0.051	0.033	0.022	0.011
7000	0.083	0.043	0.028	0.019	0.010
10000	0.070	0.036	0.023	0.015	0.008

[a]No value of f is significantly greater than zero for $\alpha = 0.05$.

Table D-3. Sample size, n, required to detect an underlying difference ($P_i > P_d$) such that the entrainment mortality, f, is 0.25 using Fleiss' (1973) test for differences in proportions (one-tailed) for a range of powers, 1-β, two levels of significance, α, and a range of sampling survivals at the intake, P_i

Survival at the intake (P_i)	Power = 1 - β					
	0.990	0.950	0.900	0.800	0.700	0.500
α = 0.05:						
0.1	4183	2921	2344	1736	1357	844
0.3	1134	795	640	477	375	237
0.5	524	370	299	225	178	115
0.7	262	187	153	117	94	63
0.9	117	86	71	56	47	33
α = 0.01:						
0.1	5683	4184	3482	2721	2232	1538
0.3	1537	1135	946	742	611	424
0.5	708	525	439	346	286	201
0.7	352	263	222	176	147	105
0.9	155	118	101	82	70	52

Table D-4. Sample size, n, required to detect an underlying difference ($P_i > P_d$) such that the entrainment mortality, f, is 0.5 using Fleiss' (1973) test for differences in proportions (one-tailed) for a range of powers, $1-\beta$, two levels of significance, α, and a range of sampling survivals at the intake, P_i

Survival at the intake (P_i)	Power = 1 - β					
	0.990	0.950	0.900	0.800	0.700	0.500
α = 0.05:						
0.1	949	676	551	418	336	223
0.3	266	191	156	120	97	66
0.5	129	94	78	60	49	34
0.7	70	52	44	35	29	21
0.9	38	29	25	20	17	13
α = 0.01:						
0.1	1274	950	798	633	527	376
0.3	356	267	225	180	151	109
0.5	172	130	111	89	75	55
0.7	94	72	62	50	43	32
0.9	50	39	34	29	25	20

Table D-5. Sample size, n, required to detect an underlying difference ($P_i > P_d$) such that the entrainment mortality, f, is 0.75 using Fleiss' (1973) test for differences in proportions (one-tailed) for a range of powers, $1-\beta$, two levels of significance, α, and a range of sampling survivals at the intake, P_i

Survival at the intake (P_i)	Power = 1 - β					
	0.990	0.950	0.900	0.800	0.700	0.500
$\alpha = 0.05$:						
0.1	375	274	227	177	146	103
0.3	107	79	66	52	44	32
0.5	54	40	34	27	23	17
0.7	31	24	20	17	14	11
0.9	18	14	12	11	9	8
$\alpha = 0.01$:						
0.1	497	377	320	258	219	162
0.3	142	109	93	76	65	49
0.5	71	55	47	39	34	26
0.7	40	32	28	24	21	16
0.9	23	19	17	15	13	11

Table D-6. Sample size, n, required to detect an underlying difference ($P_i > P_d$) such that the entrainment mortality, f, is 1.0 using Fleiss' (1973) test for differences in proportions (one-tailed) for a range of powers, $1-\beta$, two levels of significance, α, and a range of sampling survivals at the intake, P_i

Survival at the intake (P_i)	Power = 1 - β					
	0.990	0.950	0.900	0.800	0.700	0.500
α = 0.05:						
0.1	183	137	116	93	79	59
0.3	52	40	34	28	24	19
0.5	26	21	18	15	13	11
0.7	15	12	11	9	8	7
0.9	8	7	7	6	6	5
α = 0.01:						
0.1	238	184	159	131	113	87
0.3	68	54	47	39	34	27
0.5	34	28	24	21	19	15
0.7	19	16	15	13	12	10
0.9	11	10	9	8	8	7

REFERENCES CITED

Exhibit UT-11. Survival of entrained ichthyoplankton and macro-invertebrates at Hudson River power plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. July 1977.

Fleiss, J. L. 1973. Statistical methods for rates and proportions. John Wiley & Sons, New York. 223 pp.

Gardner, R. H., R. V. O'Neill, J. B. Mankin, and D. Kumar. Comparative error analysis of six predator-prey models. Ecology (in press).

O'Neill, R. V. 1973. Error analysis of ecological models. pp. 898-908. IN D. J. Nelson (ed.), Radionuclides in Ecosystems. CONF-710501. National Technical Information Service, Springfield, Virginia. 1268 pp.

O'Neill, R. V., and R. H. Gardner. 1979. Sources of uncertainty in ecological models. pp. 447-463. IN B. P. Zeigler, M. S. Elizas, G. J. Klir and T. I. Orens (eds.), Methodology in Systems Modelling and Simulation. North-Holland Publishing Company, Amsterdam.

APPENDIX E

ADDITIONAL BIASES IN ESTIMATES OF THE F-FACTOR

DOUGLAS S. VAUGHAN, Ph.D.

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

APPENDIX E

ADDITIONAL BIASES IN ESTIMATES OF THE F-FACTOR

The term bias, when applied to an estimate of a parameter, refers to a systematic tendency to underestimate or overestimate the parameter. When several biases compete, it is important to know, if possible, the direction of bias due to each source and the likely direction of net bias. It is also desirable to develop a feel for the magnitudes of these biases.

In this appendix we discuss several examples of possible underlying conditions which could cause biases to occur in estimates of the f-factor. These biases stem from simplifing assumptions made in the development of the f-factor equations (see Appendix C.1). We suggest the likely direction of each bias.

We begin this exercise by considering a simple example to illustrate how such biases can arise from sampling procedures. Let us suppose that the sampling process at the discharge station kills all of the live organisms collected. This supposition is independent of the fraction actually killed as a result of plant passage. Employing Eq. (VII-4) from Section VII-1, we note that the proportion of organisms alive in the discharge sampling station ($P_{d,D}$) is:

$$P_{d,D} = 0.0 \quad , \tag{E-1}$$

so that the estimate of the initial f-factor ($f_{i,D}$) is given by

$$f_{i,D} = 1 - \frac{P_{d,D}}{P_{i,D}} = 1 - \frac{0}{P_{i,D}} = 1.0 \quad , \tag{E-2}$$

irrespective of $P_{i,D}$. Thus, the estimate of $f_{i,D}$ equals 1.0 whether the true f-factor ($f_{i,D}$), is 0.0, 0.5, 1.0, or any other value between 0 and 1. Only if the true value of the f-factor is equal

to one is this estimate unbiased. However, if any organism survives passage through the power plant, then the true f-factor is less than 1, and our estimate of complete mortality will overstate the true f-factor.

However, we need not assume such an extreme situation in order for an estimate of the f-factor to be biased. If the sampling-induced mortality at the discharge is not complete, but is merely greater at the discharge than at the intake sampling station, then the estimate of the f-factor from Eq. (VII-4) will still overstate the true f-factor (other conditions being equal), except when the true f-factor is 1.0. Synergistic effects between plant passage stresses and discharge sampling stresses might result in the occurrence of this situation (see p. 8.46, Exhibit UT-4). On the other hand, if the sampling-induced mortality is greater at the intake than at the discharge sampling station (e.g., greater cooling water velocity at the intake as compared to the discharge sampling station), then the estimate of the f-factor will always understate the true f-factor (other conditions being equal), except when the true f-factor is 0.0.

Differential catchability of live organisms at the intake and discharge sampling stations (all else being equal) also results in a bias. For example, if a live organism is more capable of avoiding the sampling gear at the intake than at the discharge sampling station, the resultant estimated f-factor will understate the true f-factor.

Two more conditions can cause an estimate of the f-factor to be biased. Differential catchability in the discharge of plant-survivors as compared to plant-killed organisms will result in a biased estimate of the f-factor. In particular, greater catchability of plant-killed organisms will result in an overestimate of the true f-factor (all else being equal). This phenomena might occur as a result of avoidance behavior by live organisms. On the other hand, if plant-killed organisms are less susceptible to capture in the discharge than are live organisms, then the estimated f-factor will underestimate the true f-factor (all else being equal). Organisms surviving plant effects may have their avoidance capabilities impaired and plant-killed organisms might settle or float to the surface. In this situation the live organisms may be more susceptible to capture by the discharge sampling

gear than plant-killed organisms, thus resulting in an underestimate of the true f-factor.

Assuming that dead organisms are entrained (which might result from the recirculation of cooling water containing some organisms previously killed by the plant), differential catchability at the intake of dead as compared to live organisms will result in a biased f-factor (all other conditions being equal). In particular, if live organisms in the river are capable of avoiding the intake sampling gear and thus are under-represented in the intake sample, but dead organisms in the river are representatively sampled, the estimate of the f-factor will underestimate the true f-factor (all other conditions being equal). On the other hand, if for some reason dead organisms from the river are more under-represented in the intake sampling gear than the live organisms but proportionately represented in the discharge sample, then the estimate of the f-factor will overestimate the true f-factor (all other conditions being equal).

This set of examples is not exhaustive. However, it does indicate some of the potential sources of bias present in almost any sampling program designed to estimate the f-factor.

Considering the larval table data, we might expect some synergistic effects between sampling-induced stresses and plant-induced stresses, leading to a tendency to overestimate the f-factor. However, this tendency is probably more than offset by a tendency to underestimate the true f-factor when we consider:

- Lower catchability of dead organisms in the discharge due to settling to the bottom or floating to the surface.

- Lower catchability of live organisms at the intake as compared to dead organisms at the intake or live organisms at the discharge, because of greater avoidance capability of live organisms at the intake.

REFERENCES CITED

Exhibit UT-4. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on the striped bass and other fish populations. Edited by J. T. McFadden. Prepared for Consolidated Edison Company of New York, Inc. 1977.

APPENDIX F

THERMAL MODEL F-FACTOR FOR FOUR HUDSON RIVER POWER PLANTS

DOUGLAS S. VAUGHAN, Ph.D.

ENVIRONMENTAL SCIENCES DIVISION
OAK RIDGE NATIONAL LABORATORY
OAK RIDGE, TENNESSEE

APPENDIX F

THERMAL MODEL F-FACTORS FOR FOUR HUDSON RIVER POWER PLANTS

The following figures (Figs. F-1 through F-42) illustrate seasonal effects on the estimated f-factor by week from April 1 through August 31. Table F-1 relates the week number appearing on the ordinate axis of these figures with the corresponding dates. This seasonal change in the f-factor is caused by seasonal changes in ambient river temperature and plant operating conditions (see discussion in Section VII-4). These figures (Figs. F-1 through F-42) are plots of the total estimated f-factor for striped bass, including the latent mortality component. The plots are arranged by life-stage, power plant, and day versus night. Each plot shows the total f-factor based on a lower, middle, and upper estimate (described in Section VII-4).

The plots were developed for these life-stages, namely, yolk-sac larvae (Y), post yolk-sac larvae (P), and entrainable juveniles (J), and for seven power plant units, namely, Bowline Point Unit 1 (1), Bowline Point Unit 2 (2), Roseton Units 1 & 2 (3), Indian Point Unit 2 (4), Indian Point Unit 3 (5), Danskammer Point Unit 3 (6), and Danskammer Point Unit 4 (7).

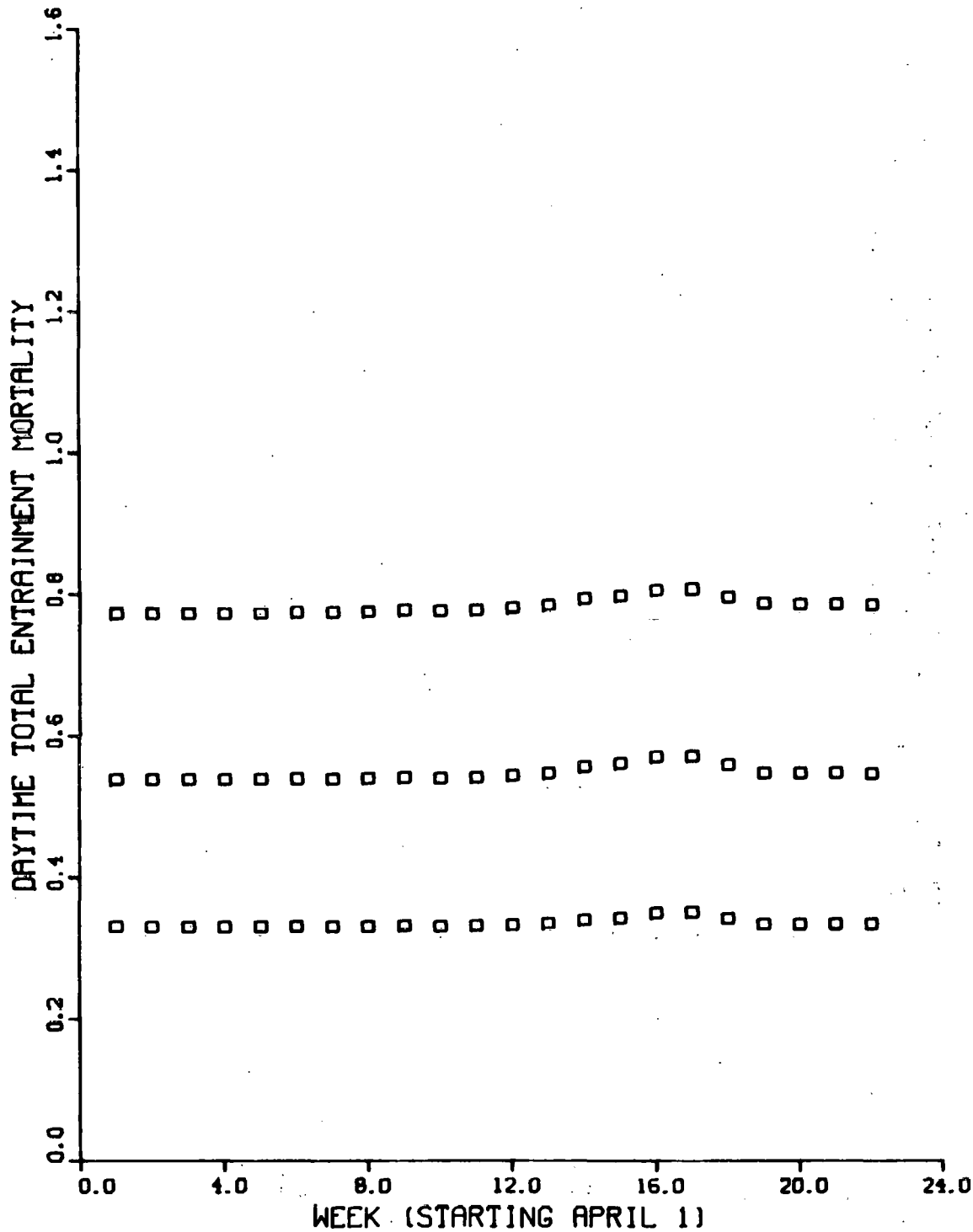

Figure F-1. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-1).

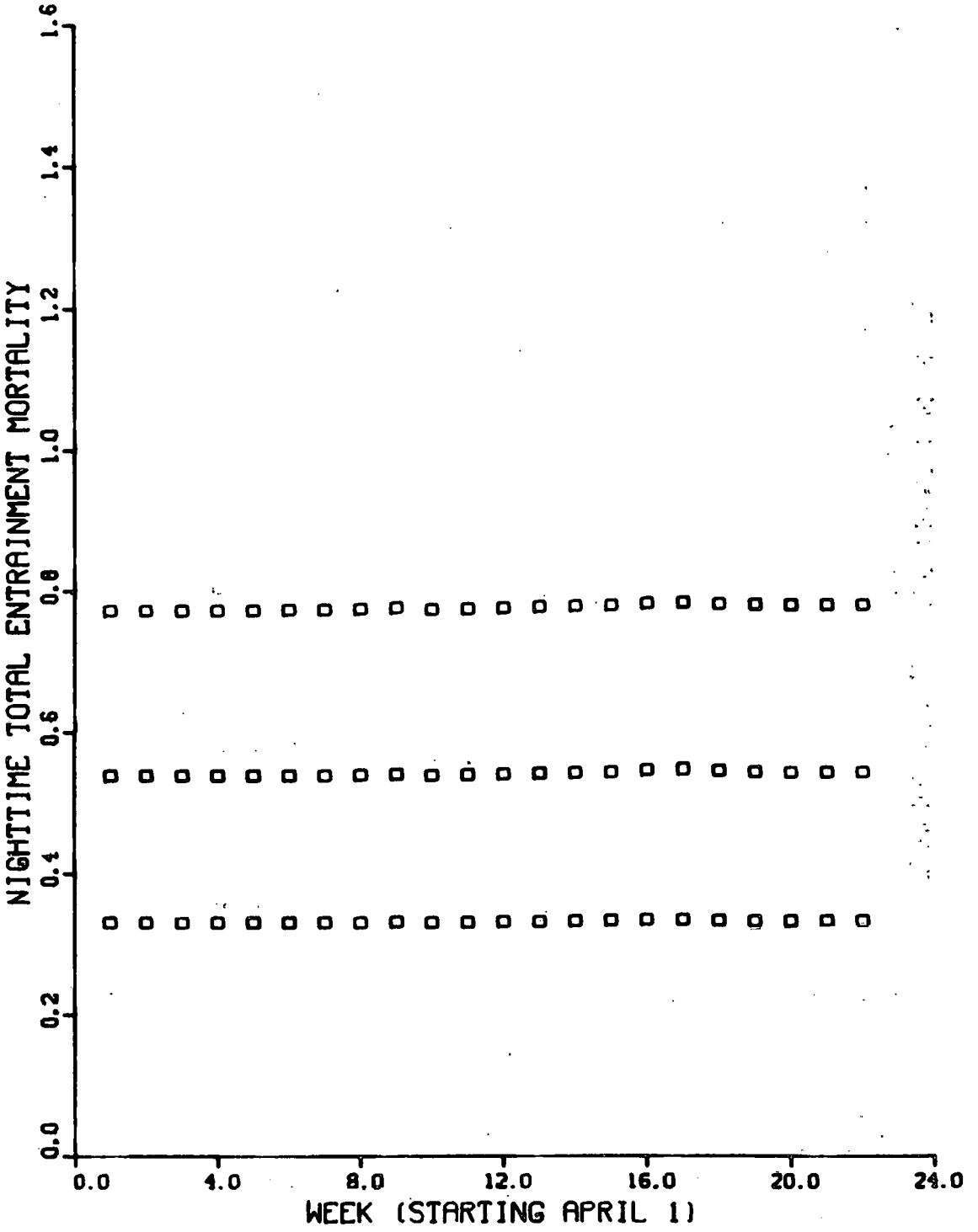

Figure F-2. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-1).

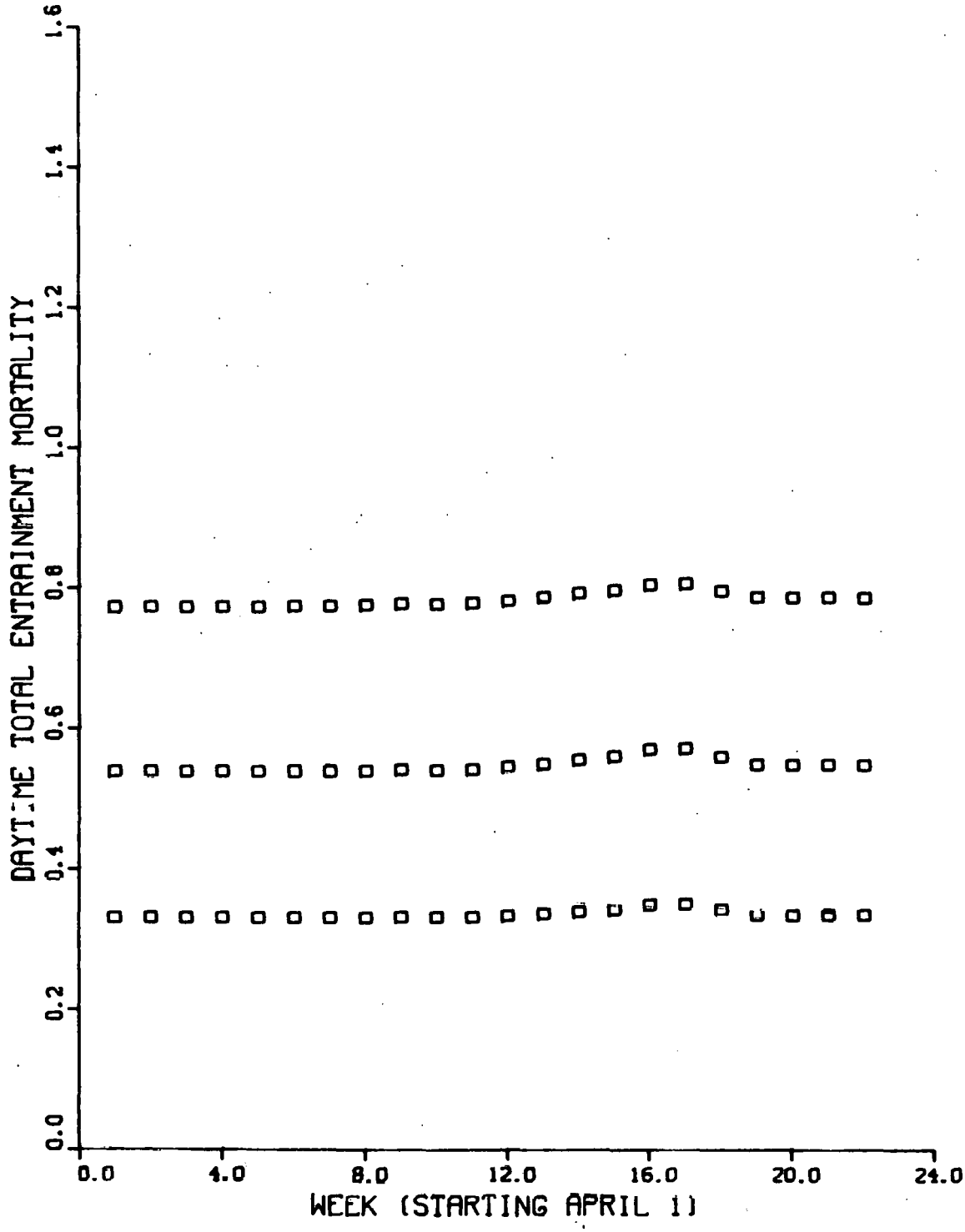

Figure F-3. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-2).

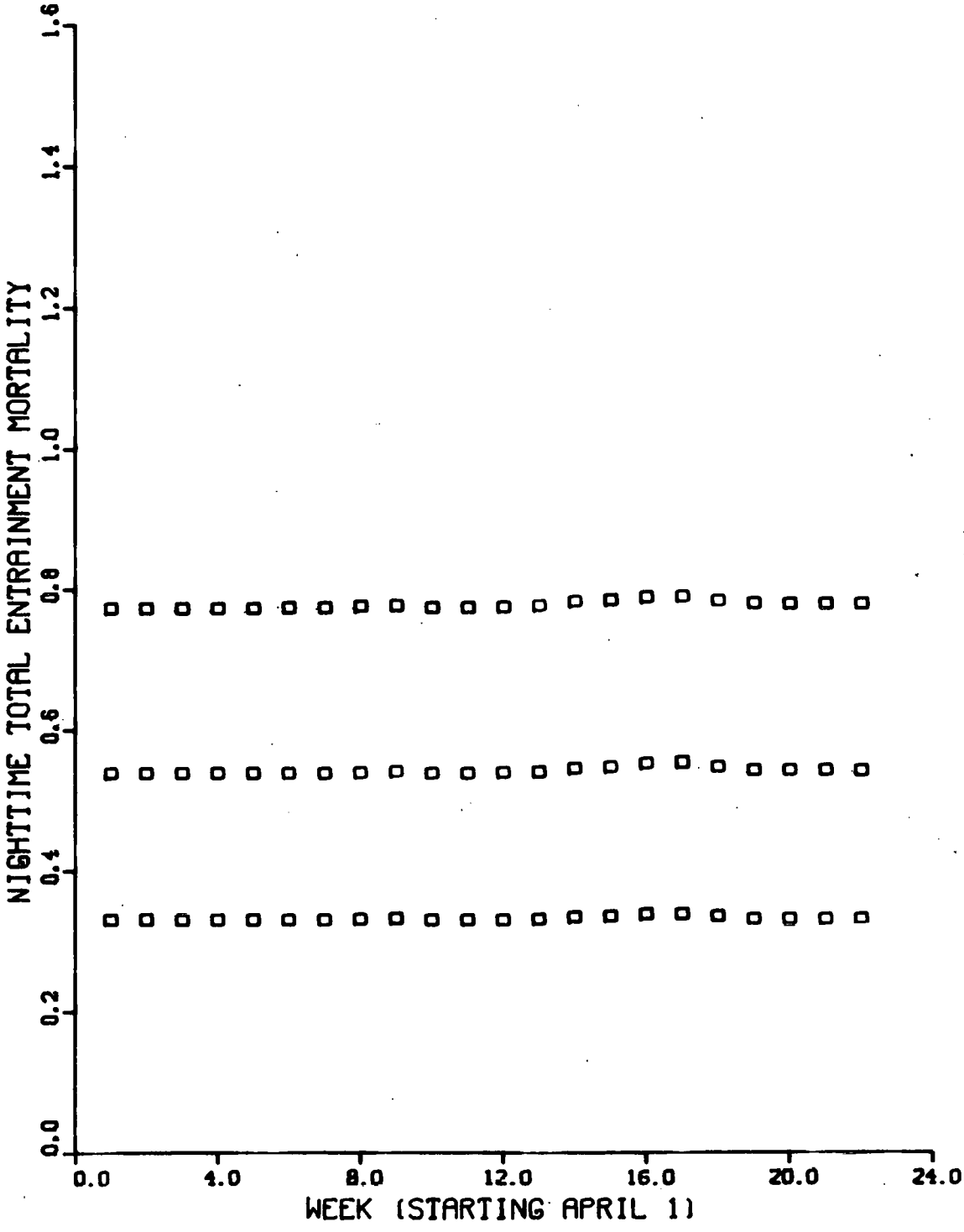

Figure F-4. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-2).

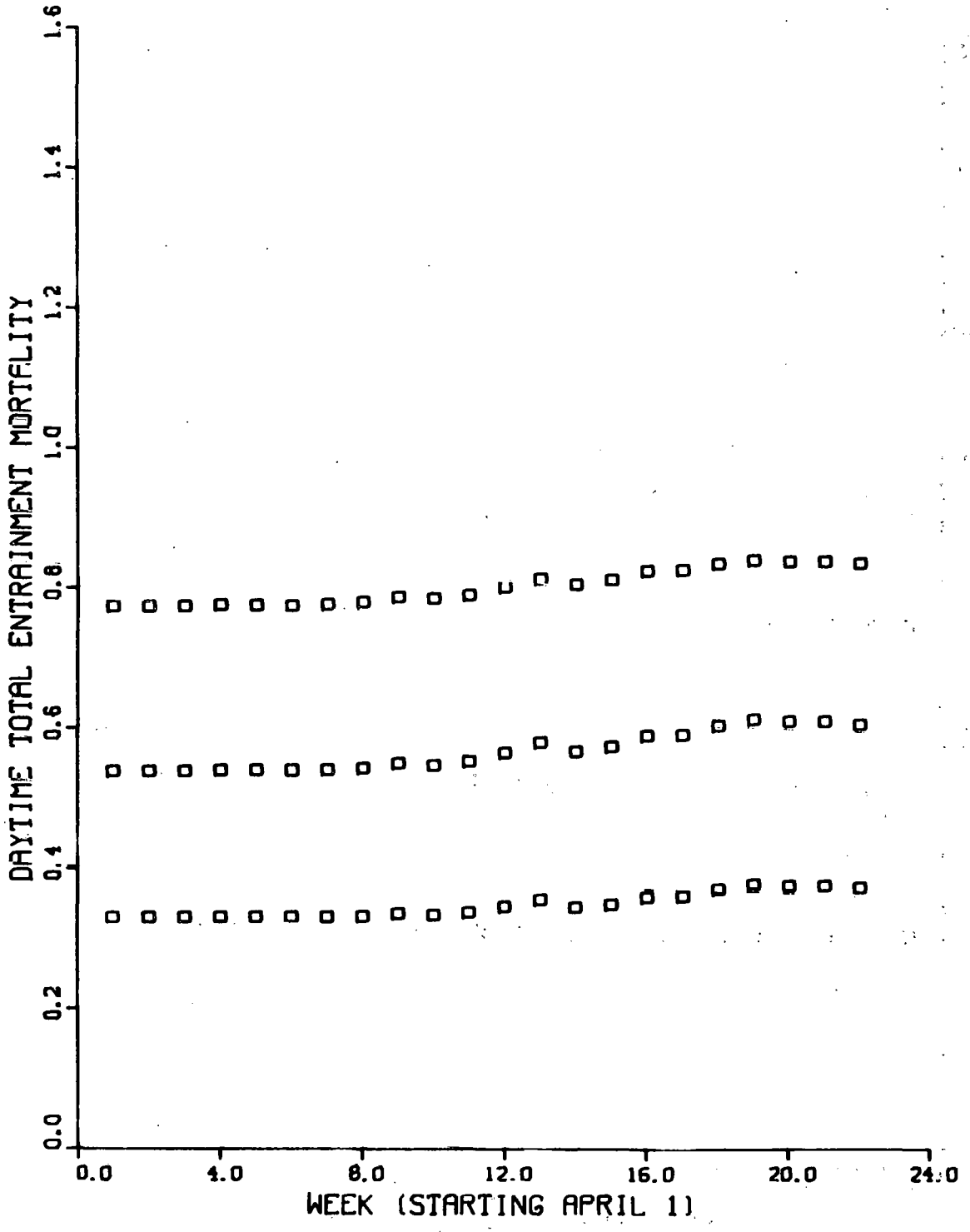

Figure F-5. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-3).

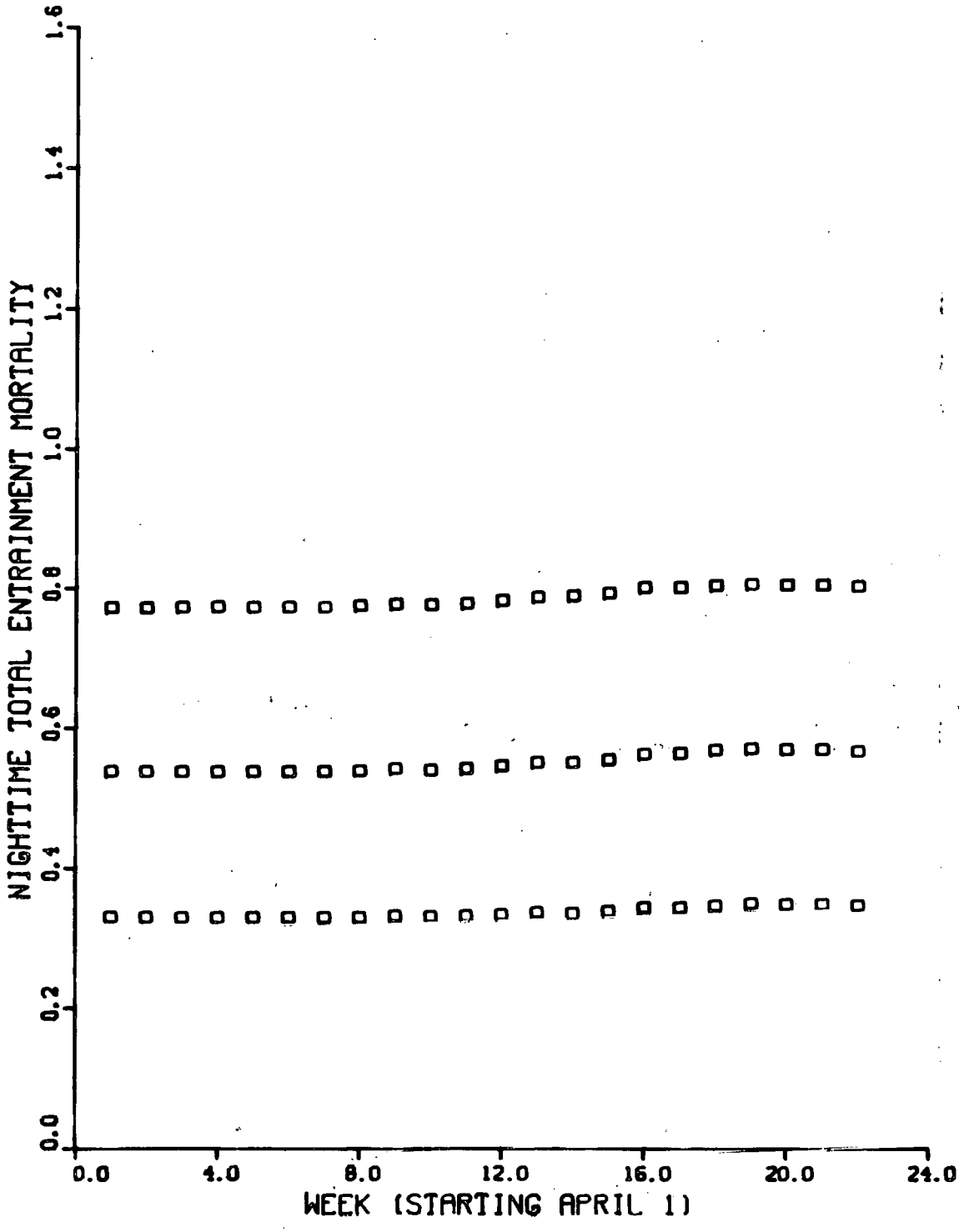

Figure F-6. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-3).

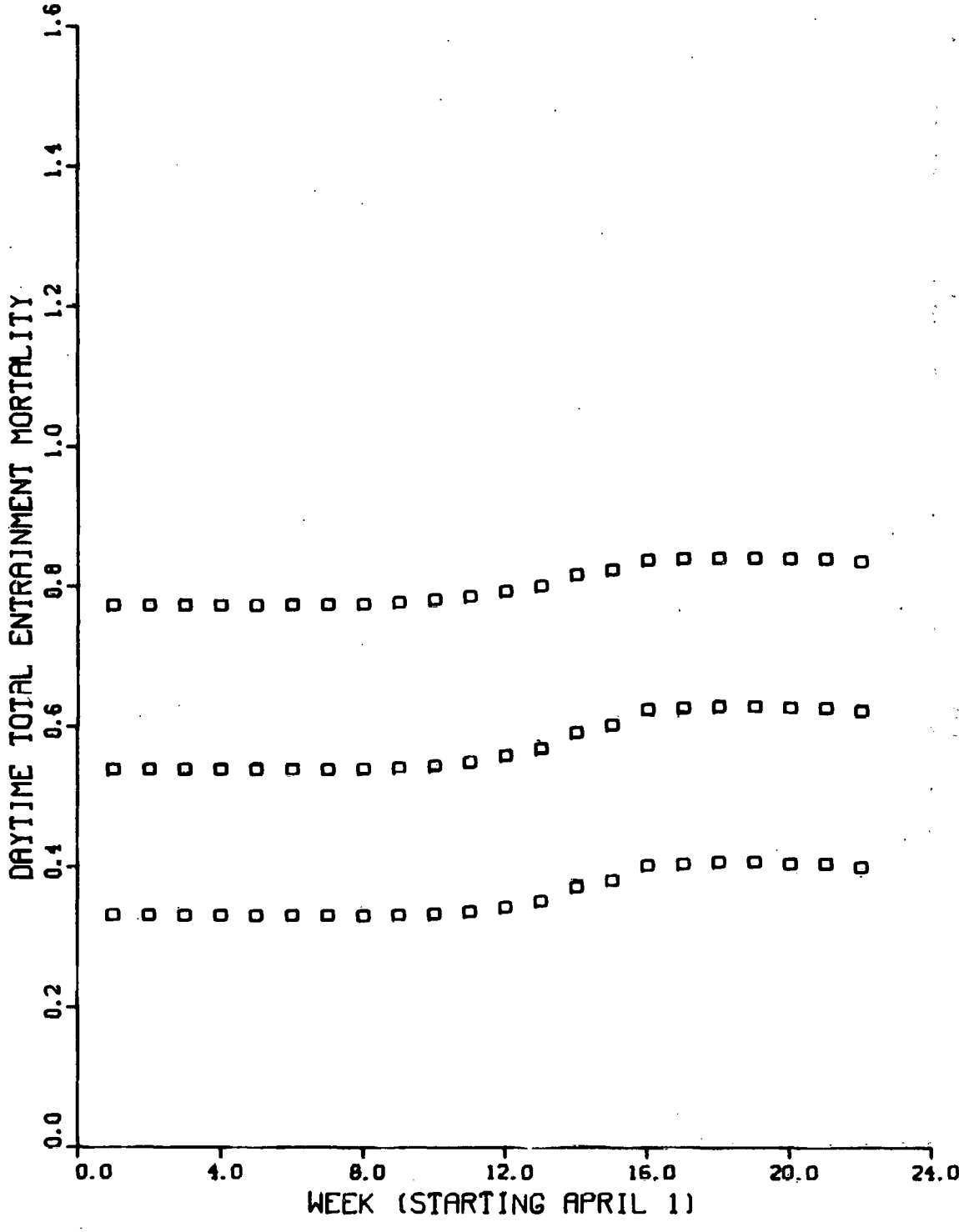

Figure F-7. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-4).

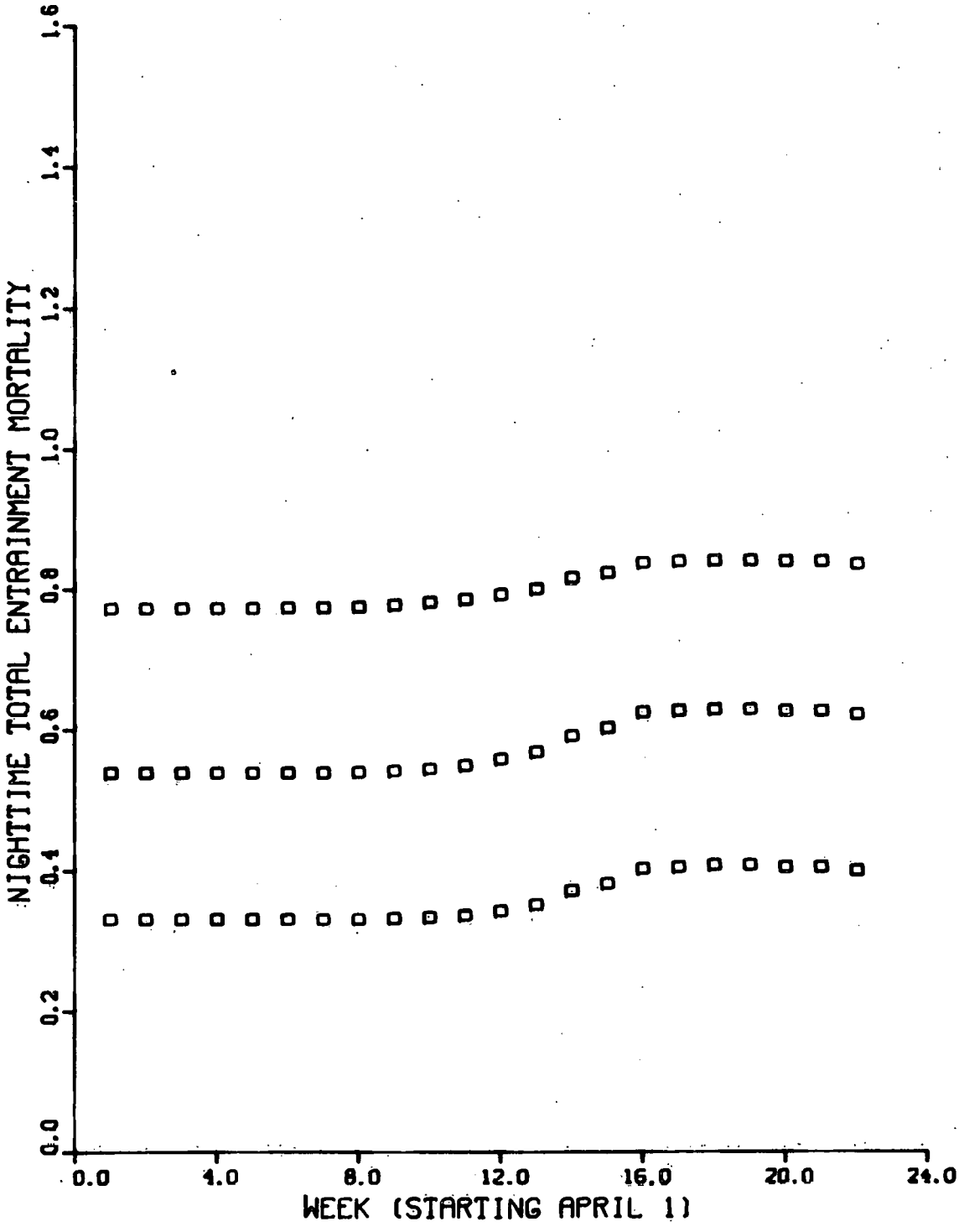

Figure F-8. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-4).

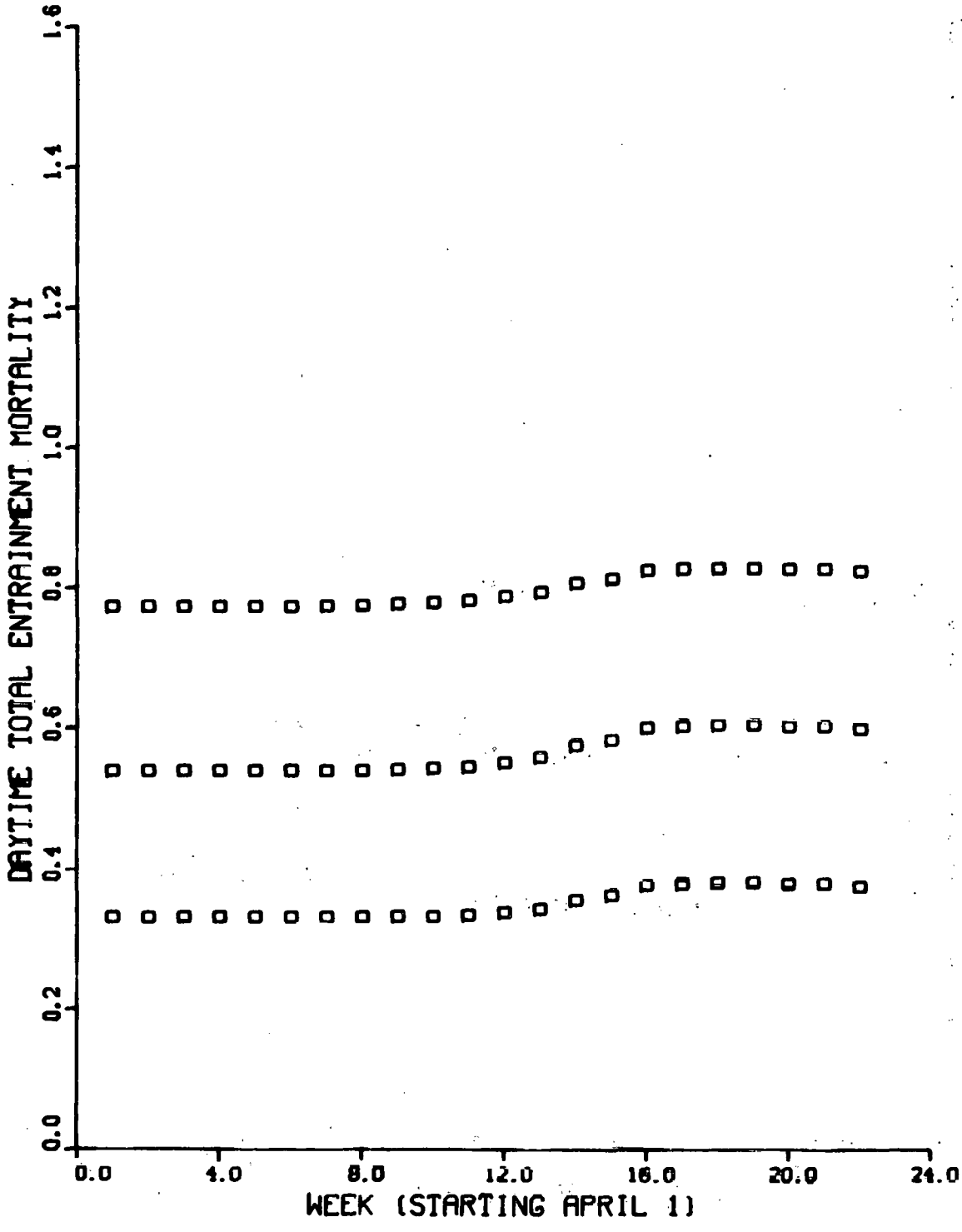

Figure F-9. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-5).

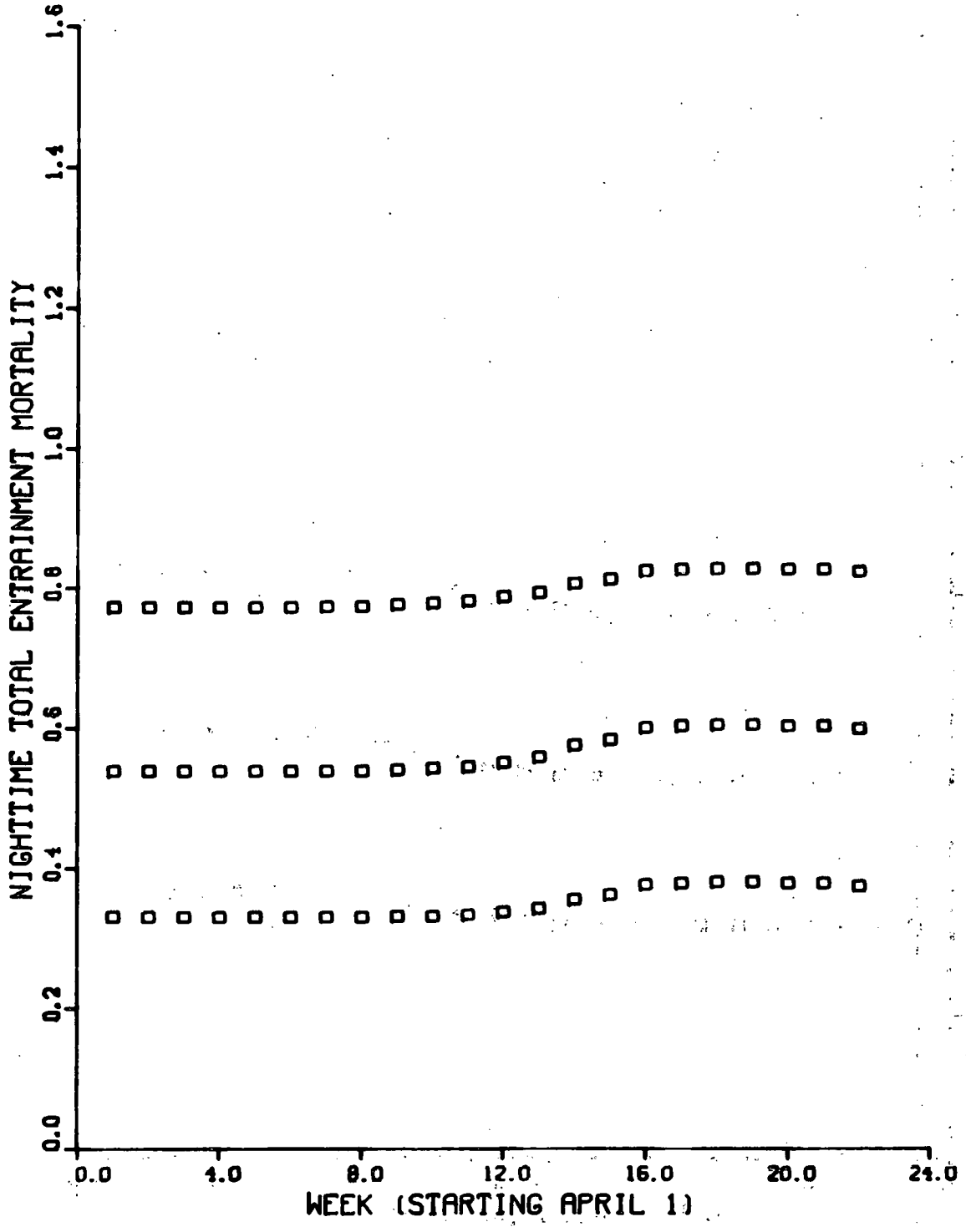

Figure F-10. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-5).

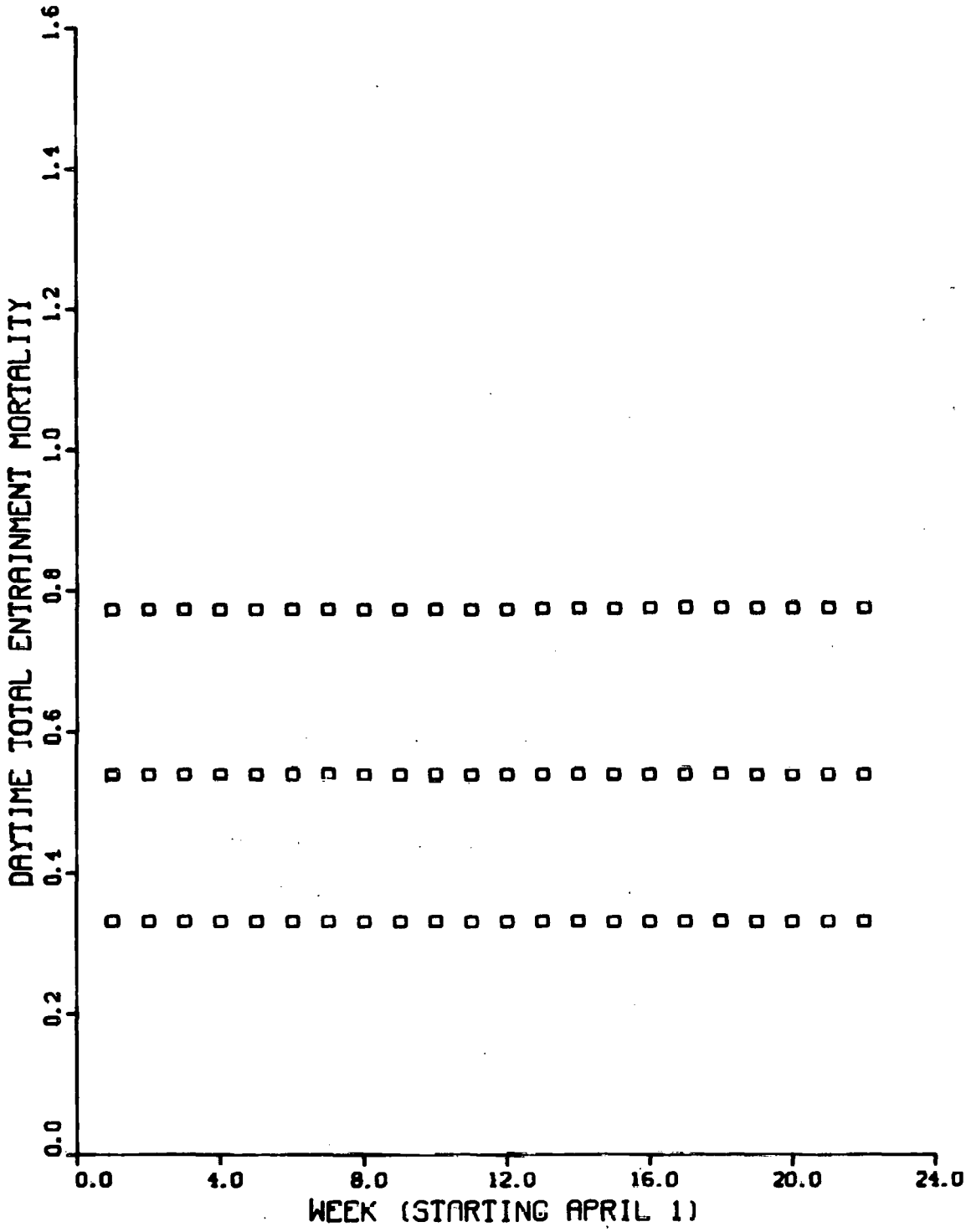

Figure F-11. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-6).

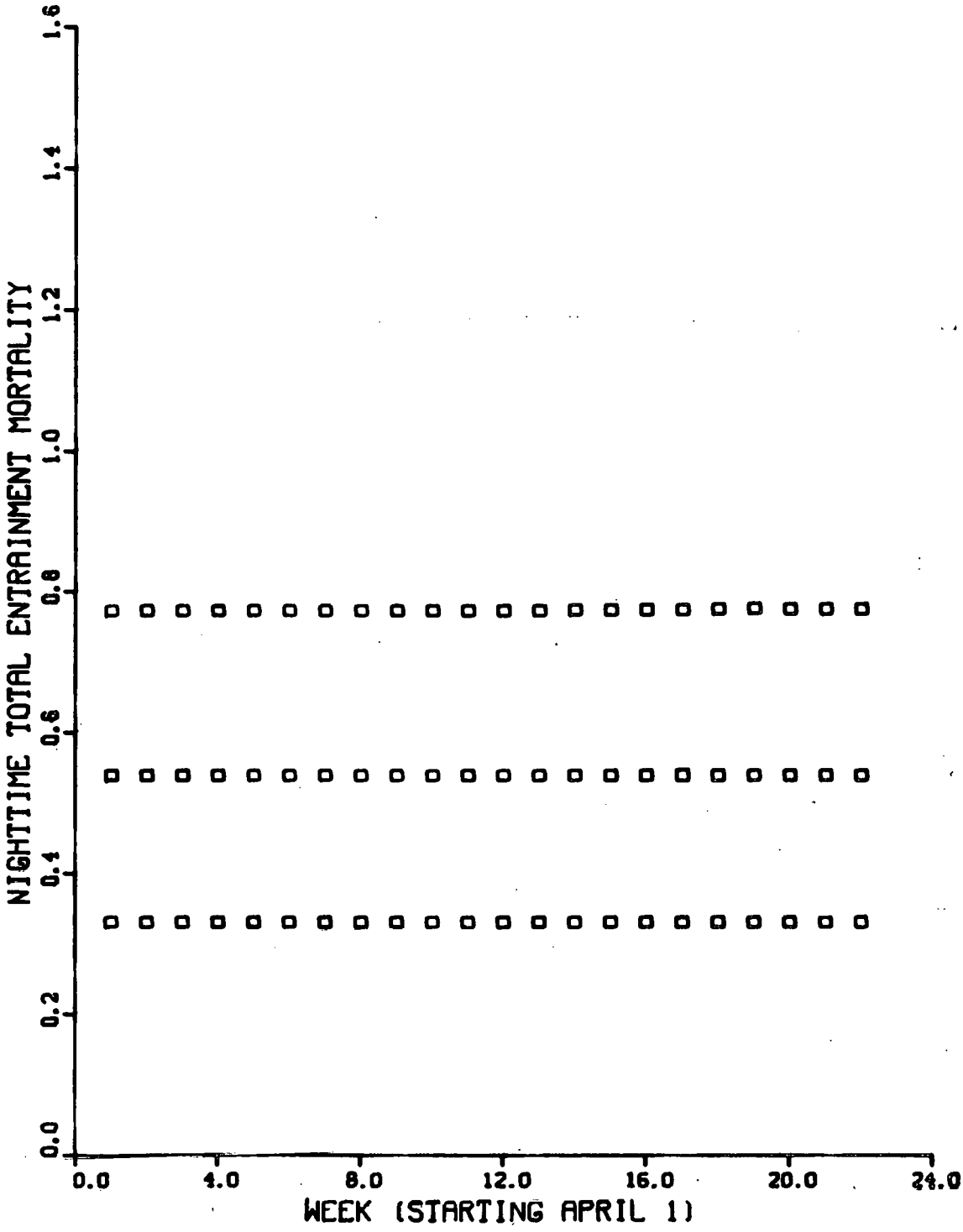

Figure F-12. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-6).

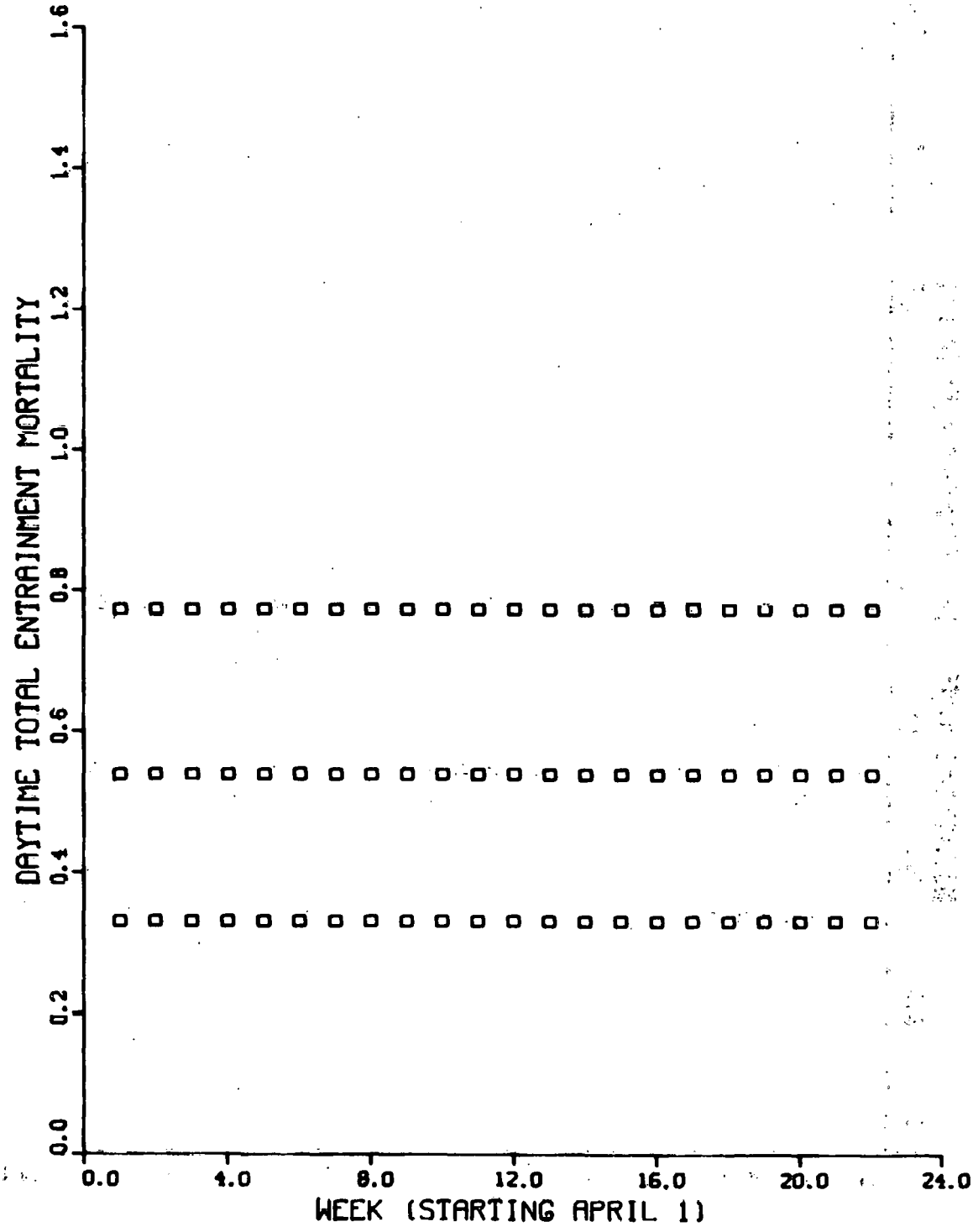

Figure F-13. Daytime total entrainment mortality of striped bass (Stage-Y, Plant-7).

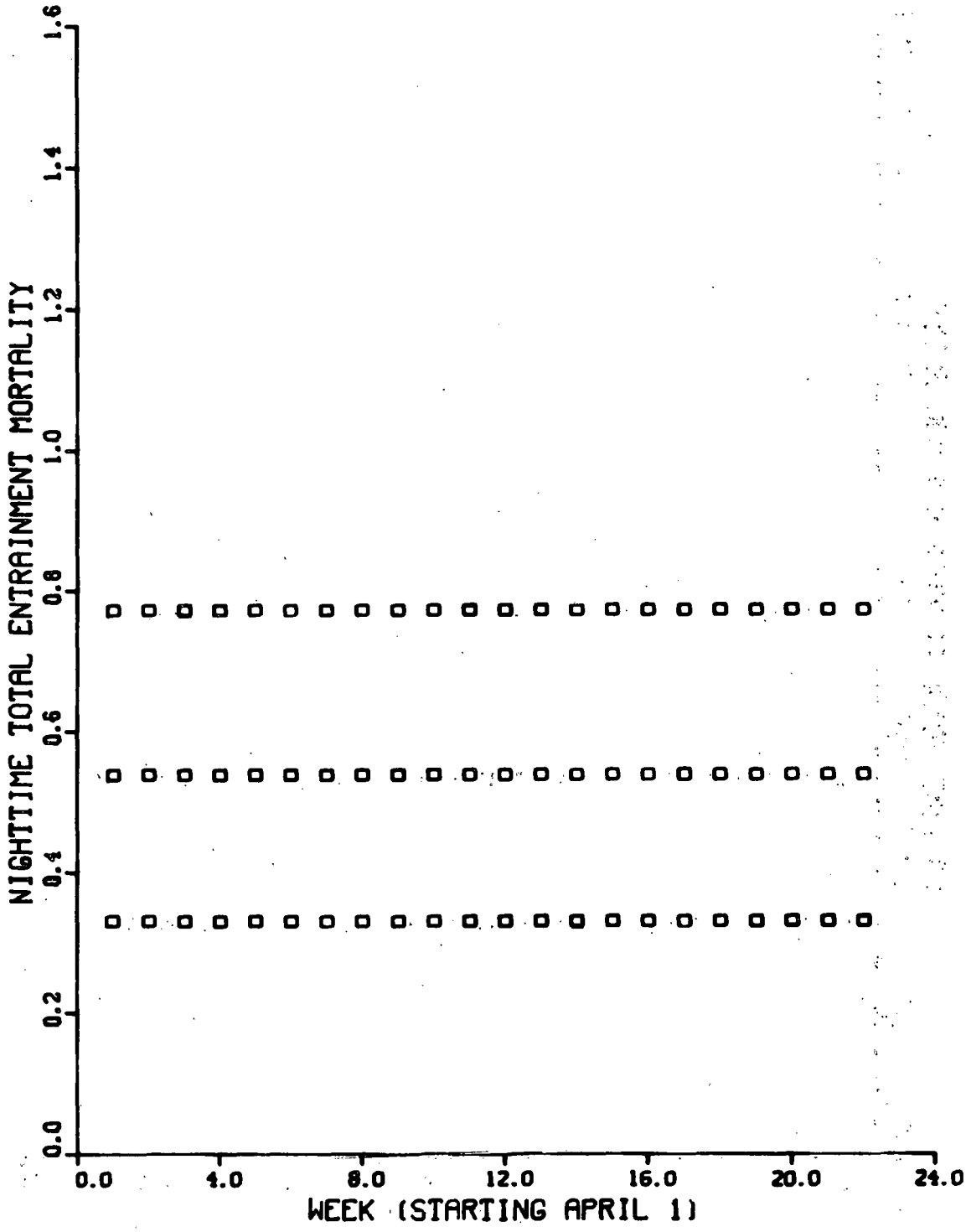

Figure F-14. Nighttime total entrainment mortality of striped bass (Stage-Y, Plant-7).

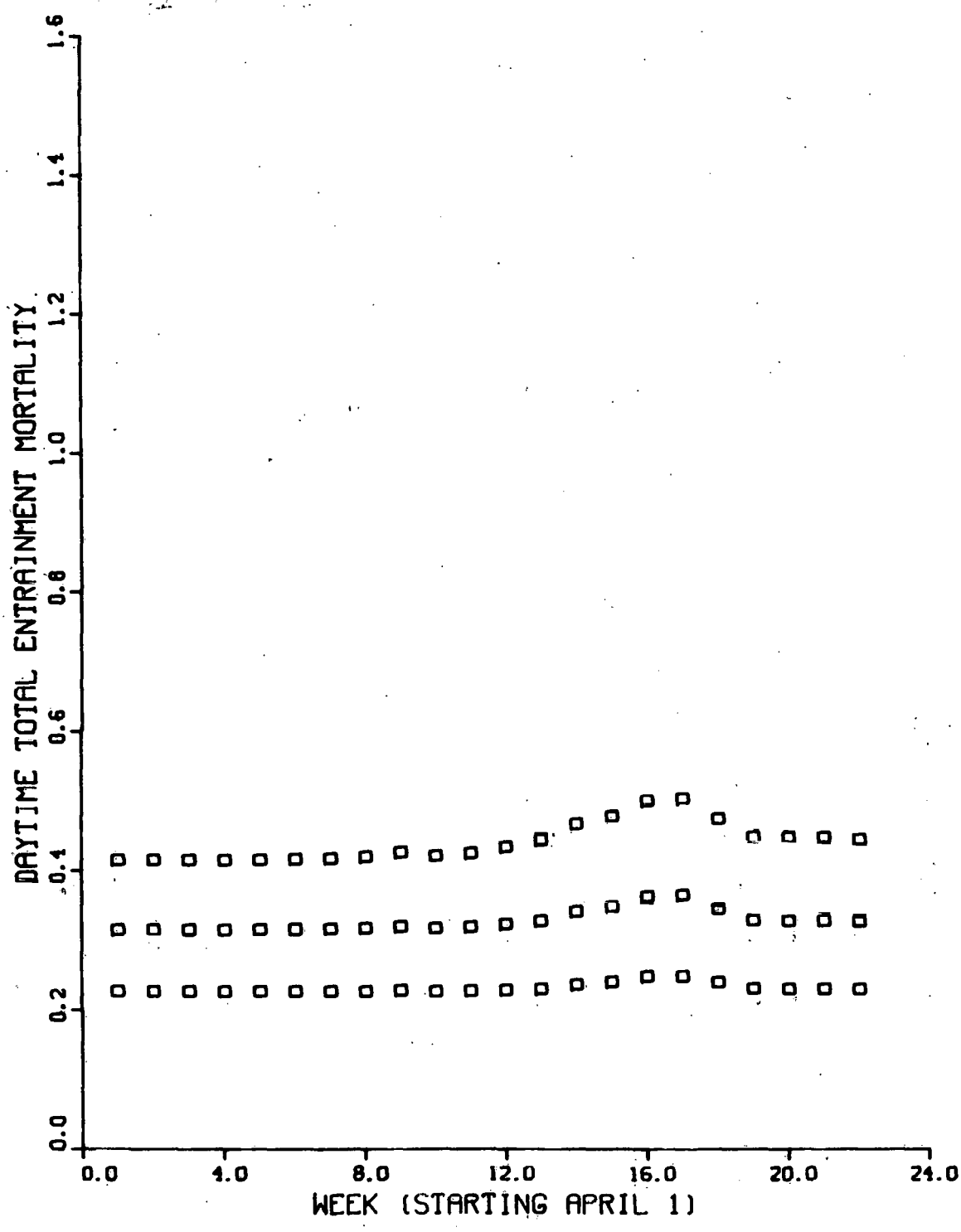

Figure F-15. Daytime total entrainment mortality of striped bass (Stage-P, Plant-1).

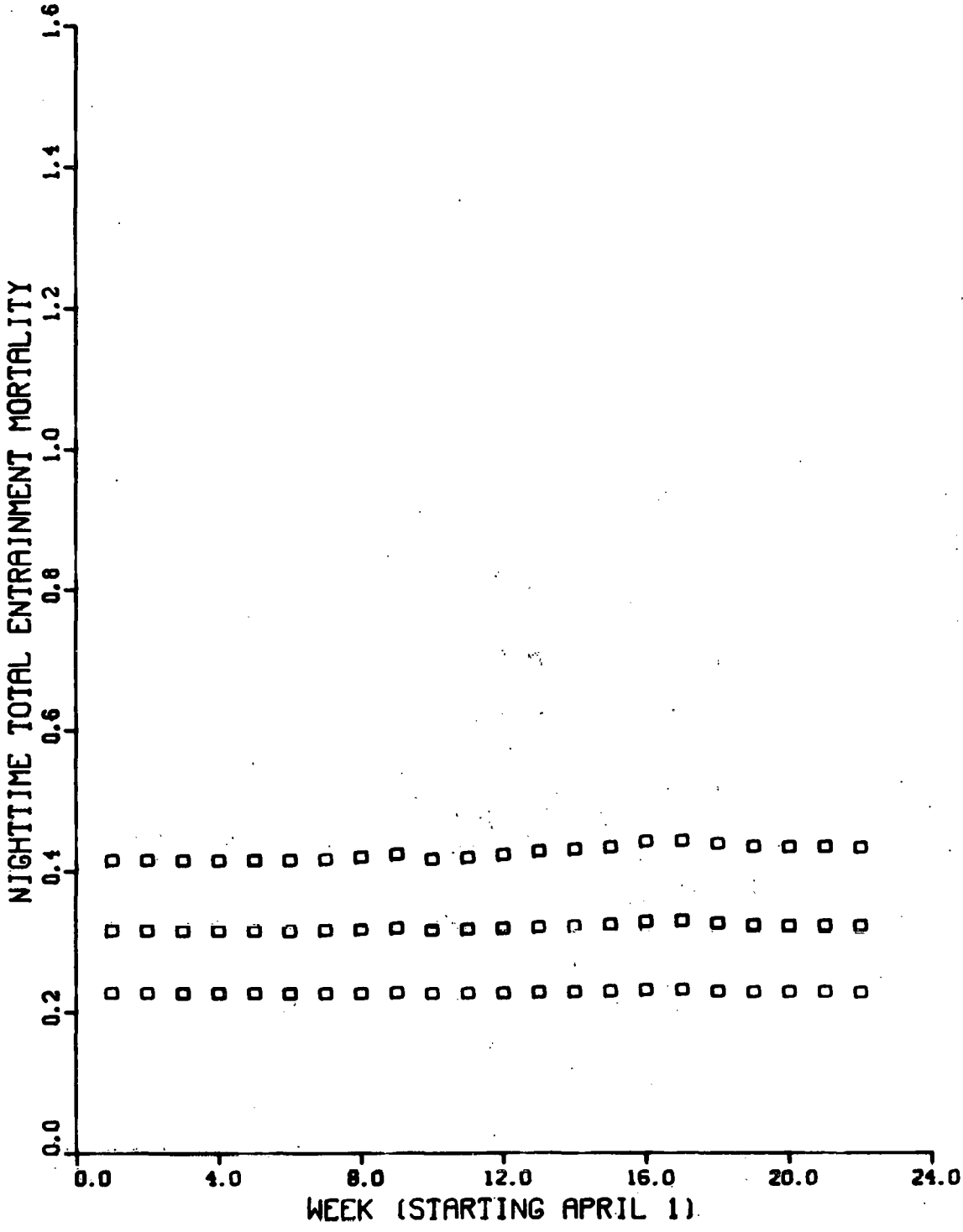

Figure F-16. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-1).

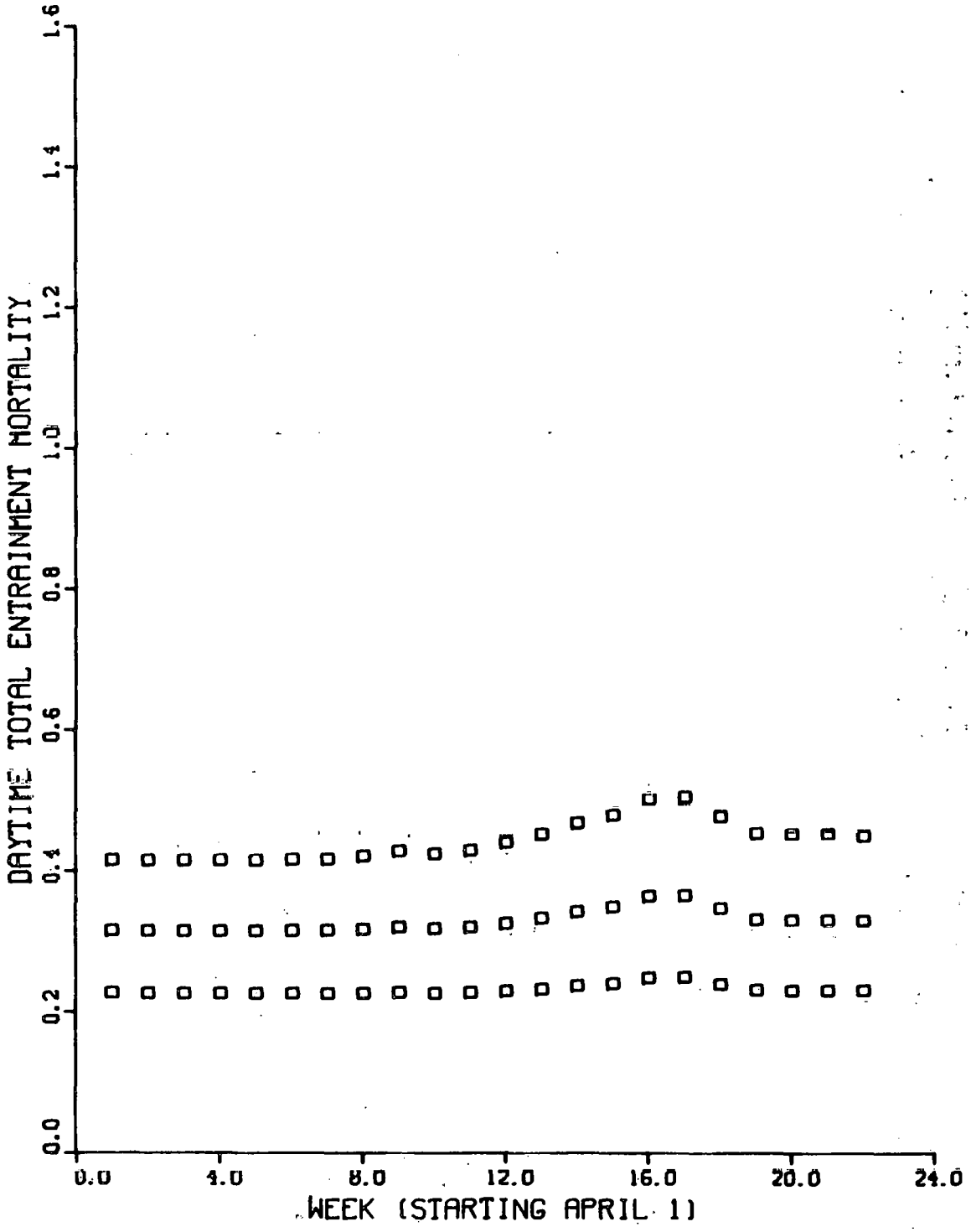

Figure F-17. Daytime total entrainment mortality of striped bass (Stage-P, Plant-2).

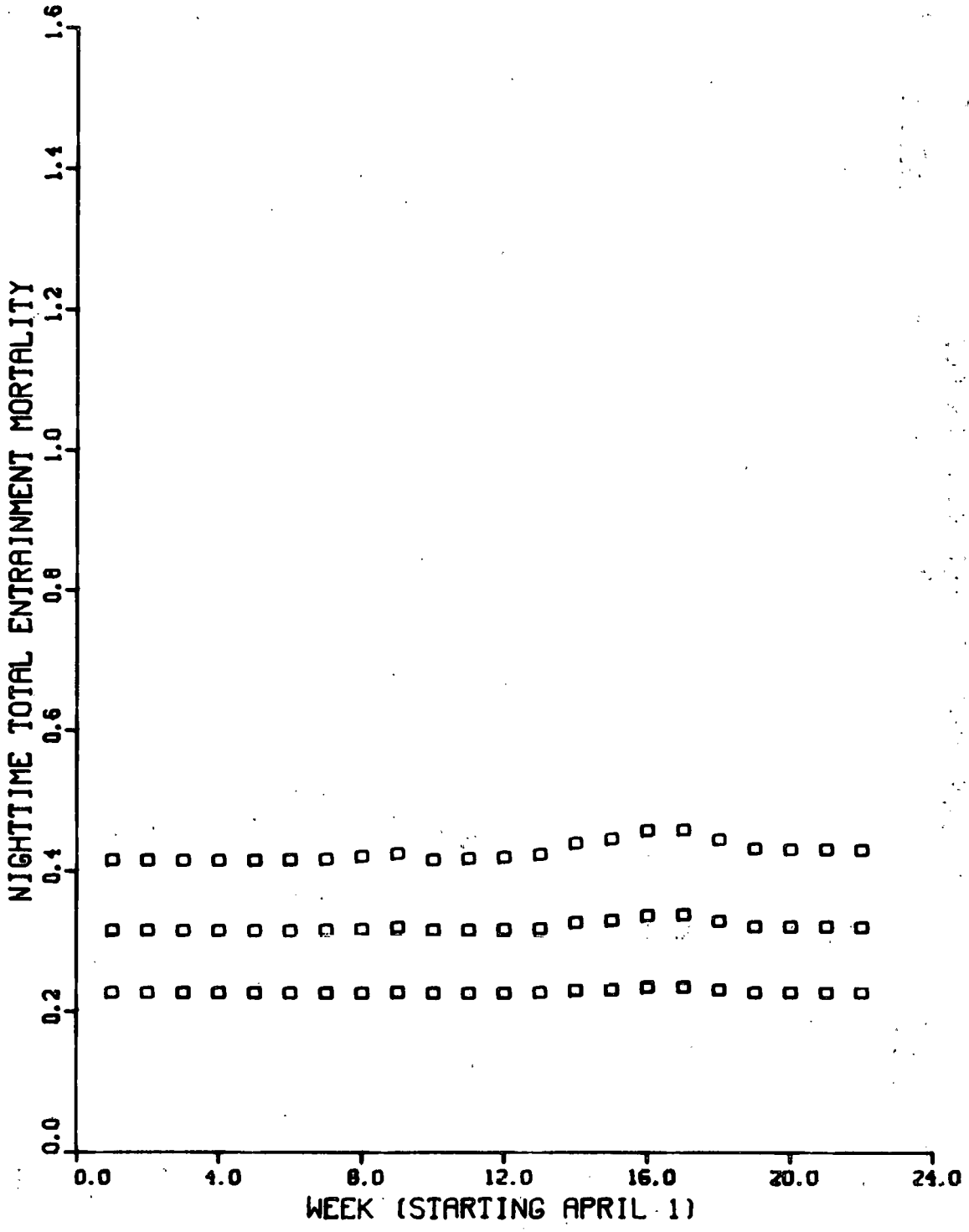

Figure F-18. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-2).

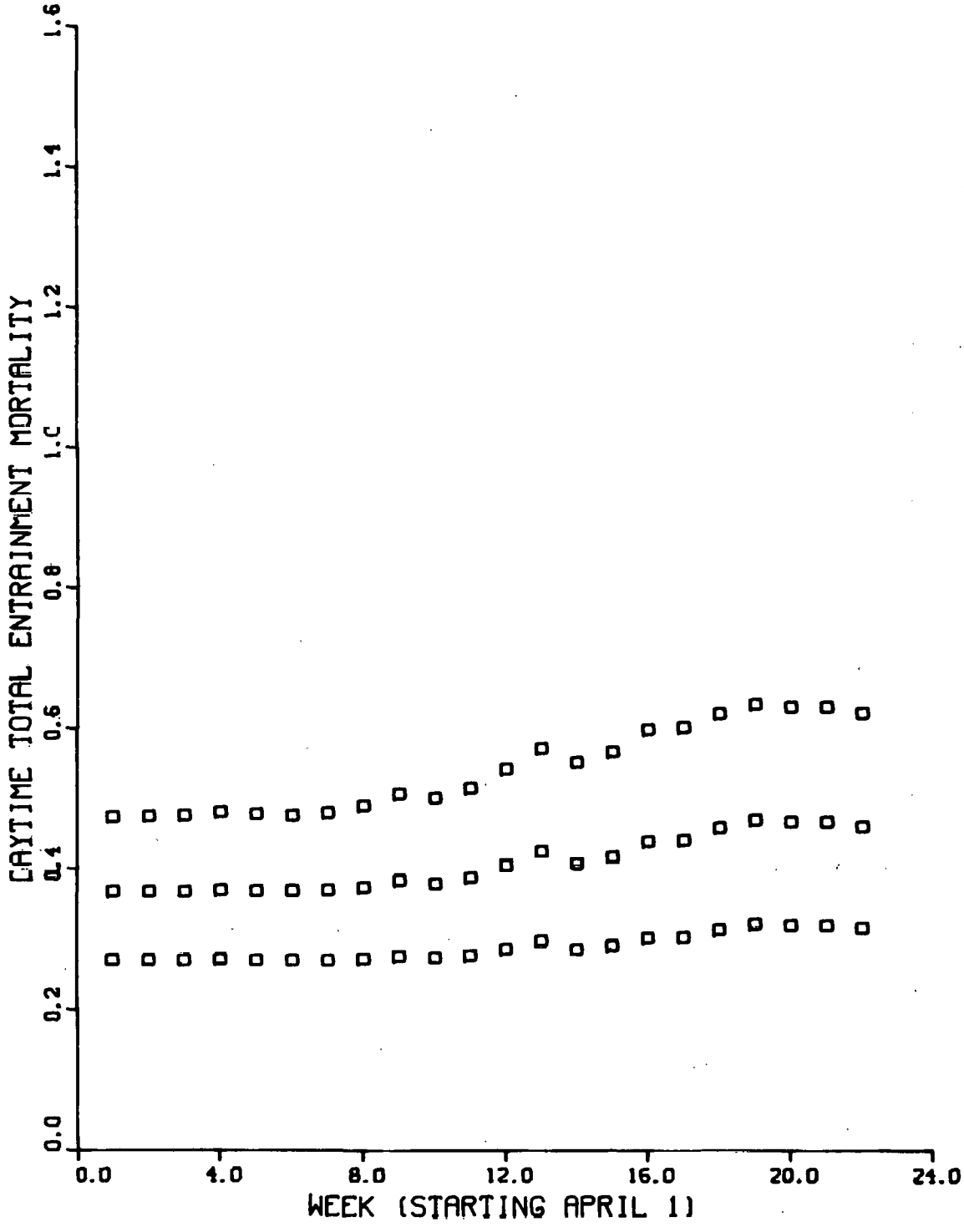

Figure F-19. Daytime total entrainment mortality of striped bass (Stage-P, Plant-3).

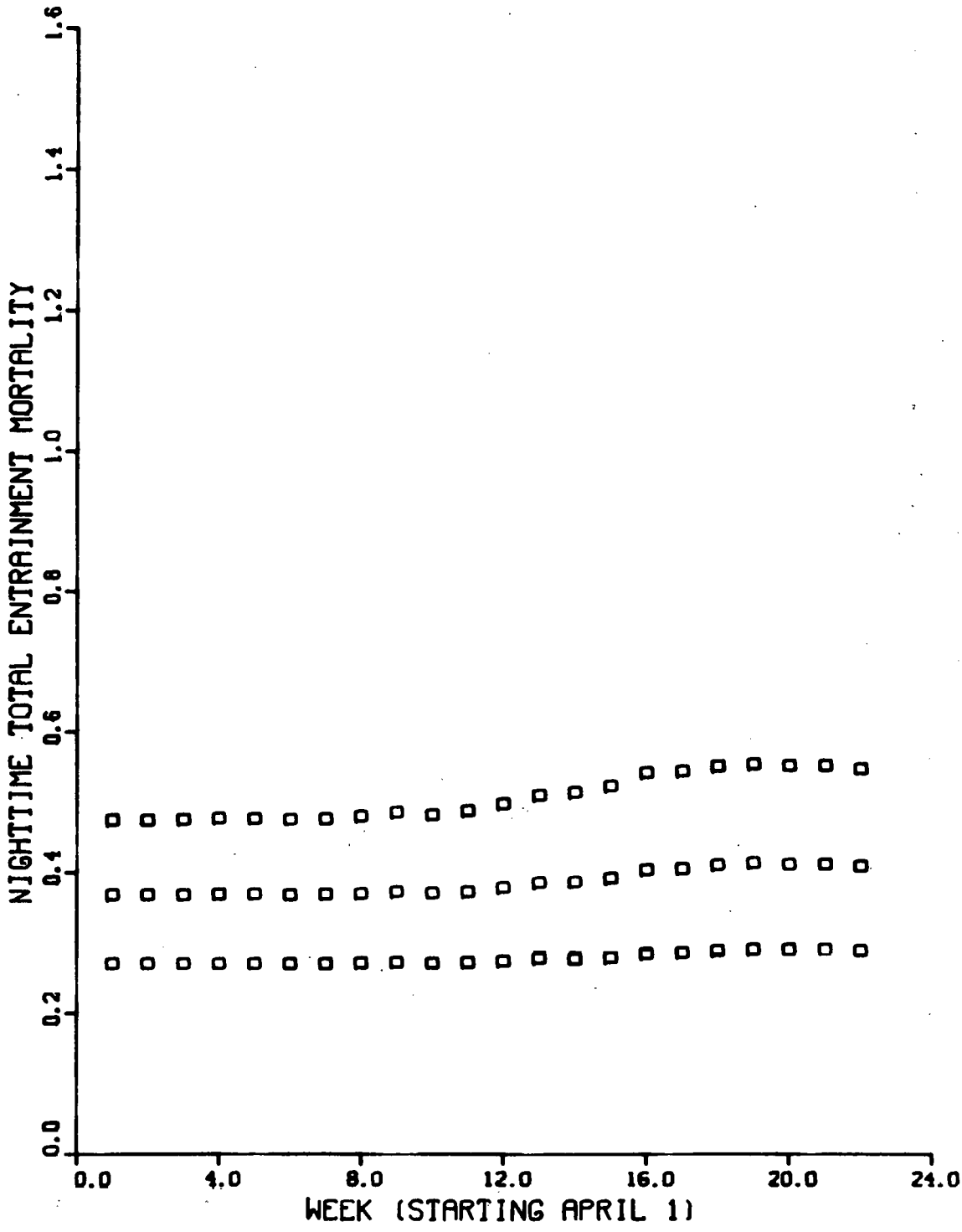

Figure F-20. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-3).

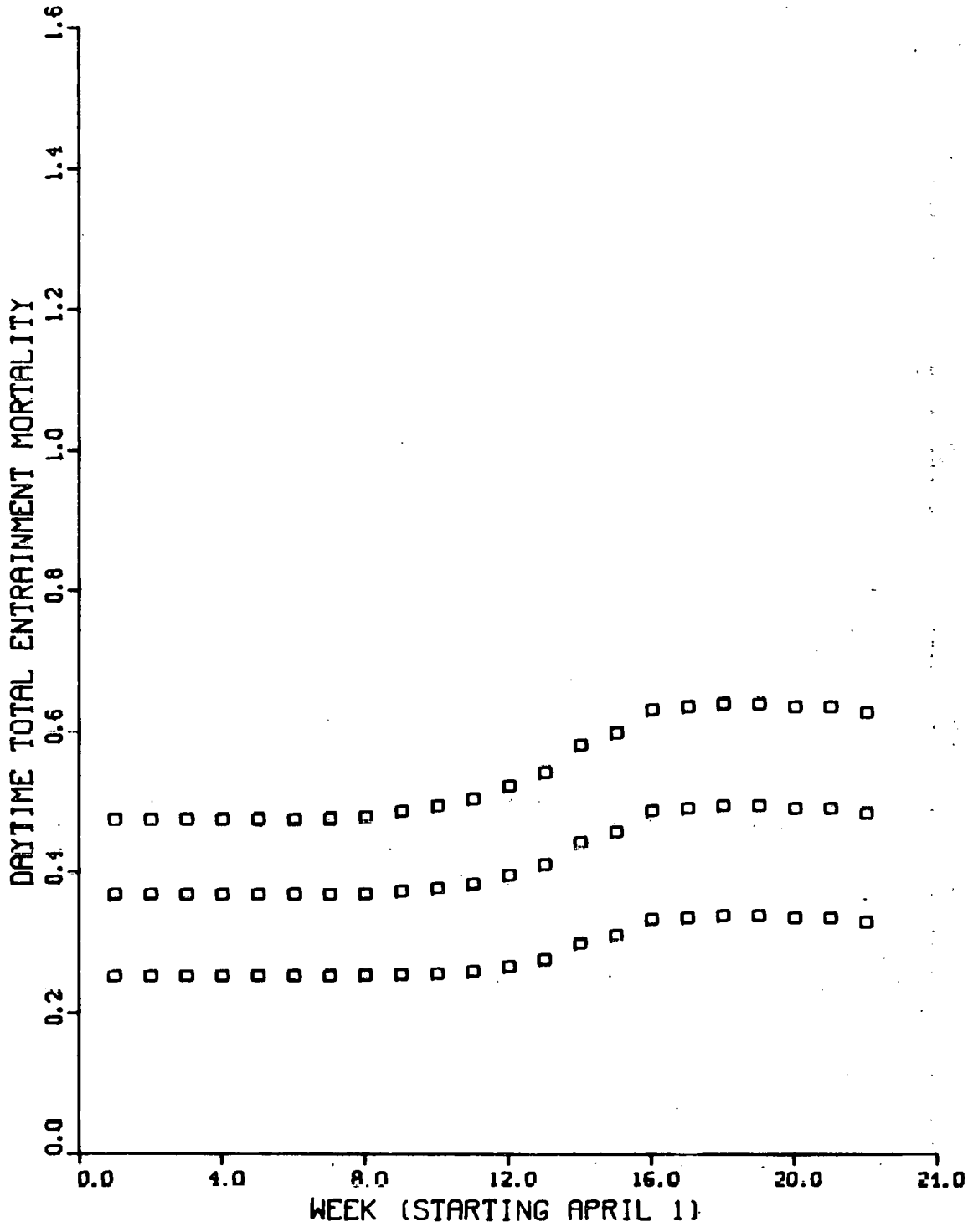

Figure F-21. Daytime total entrainment mortality of striped bass (Stage-P, Plant-4).

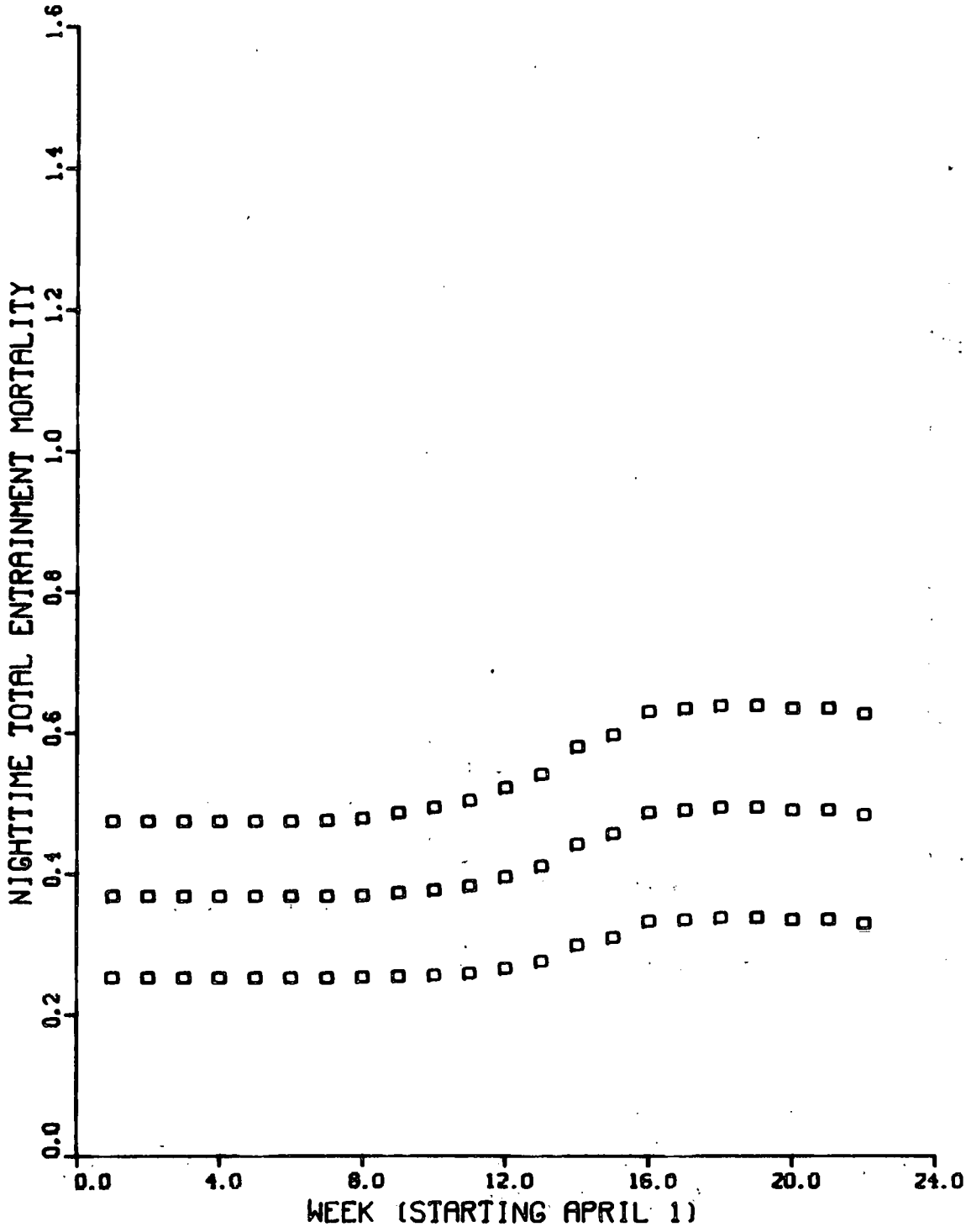

Figure F-22. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-4).

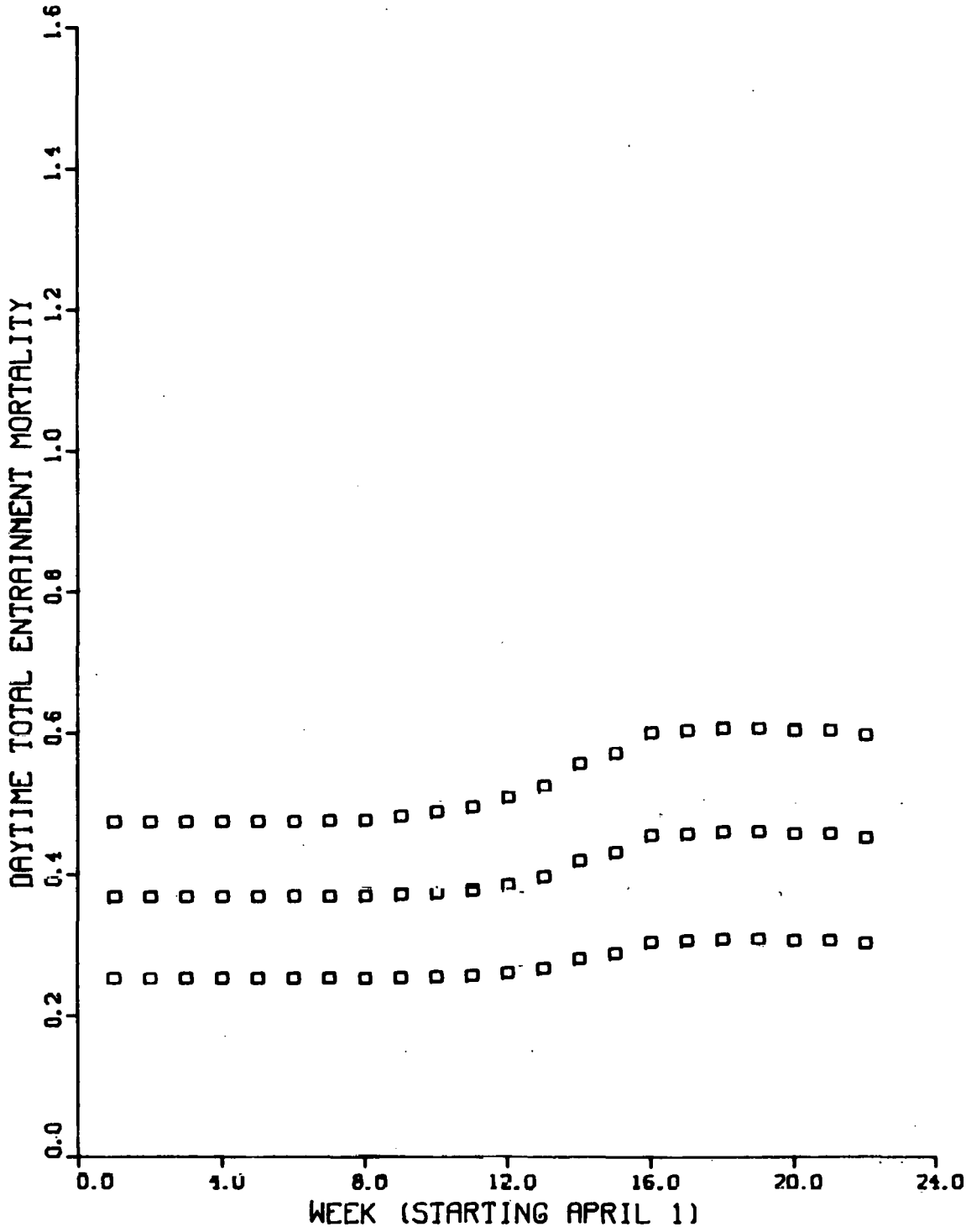

Figure F-23. Daytime total entrainment mortality of striped bass (Stage-P, Plant-5).

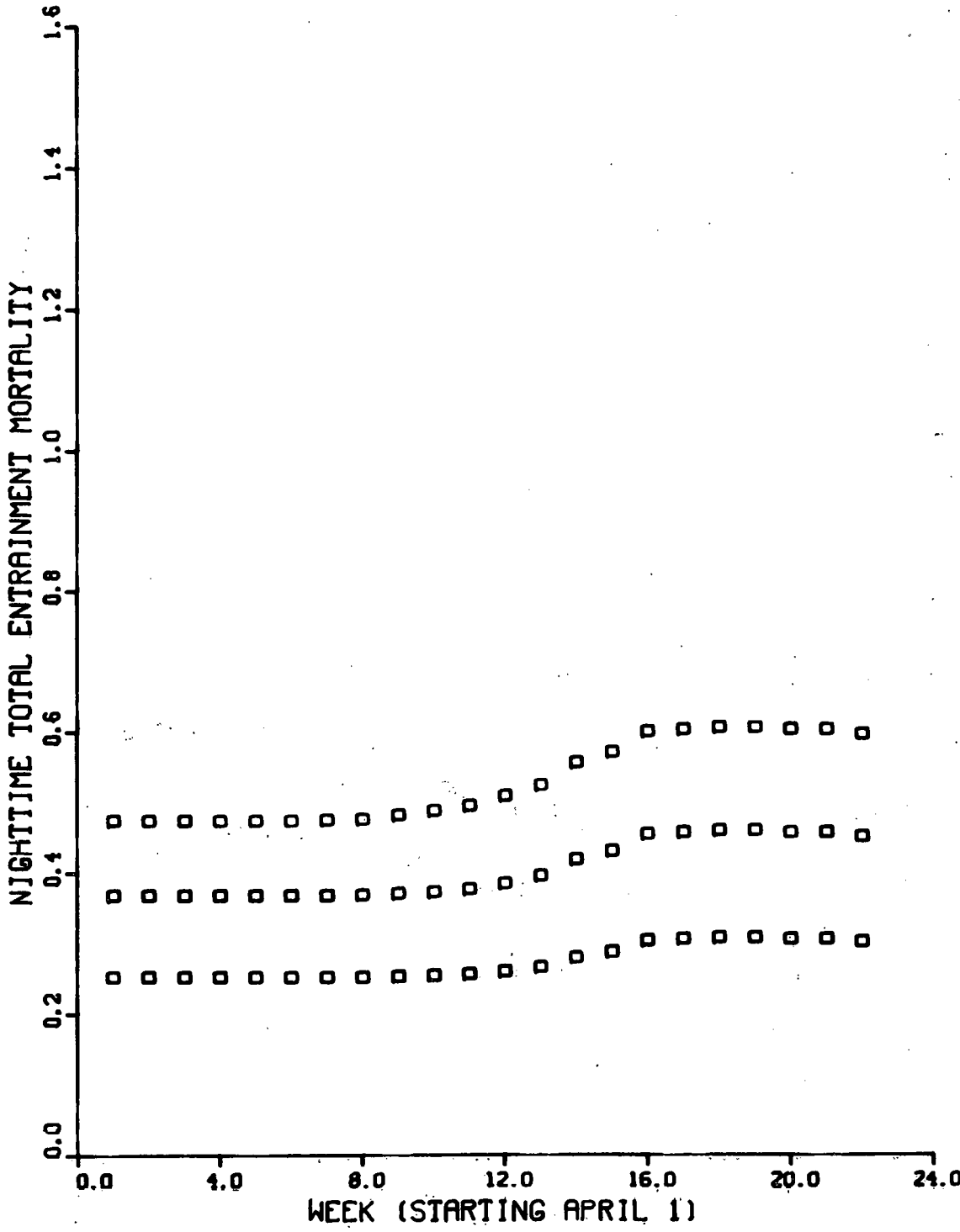

Figure F-24. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-5).

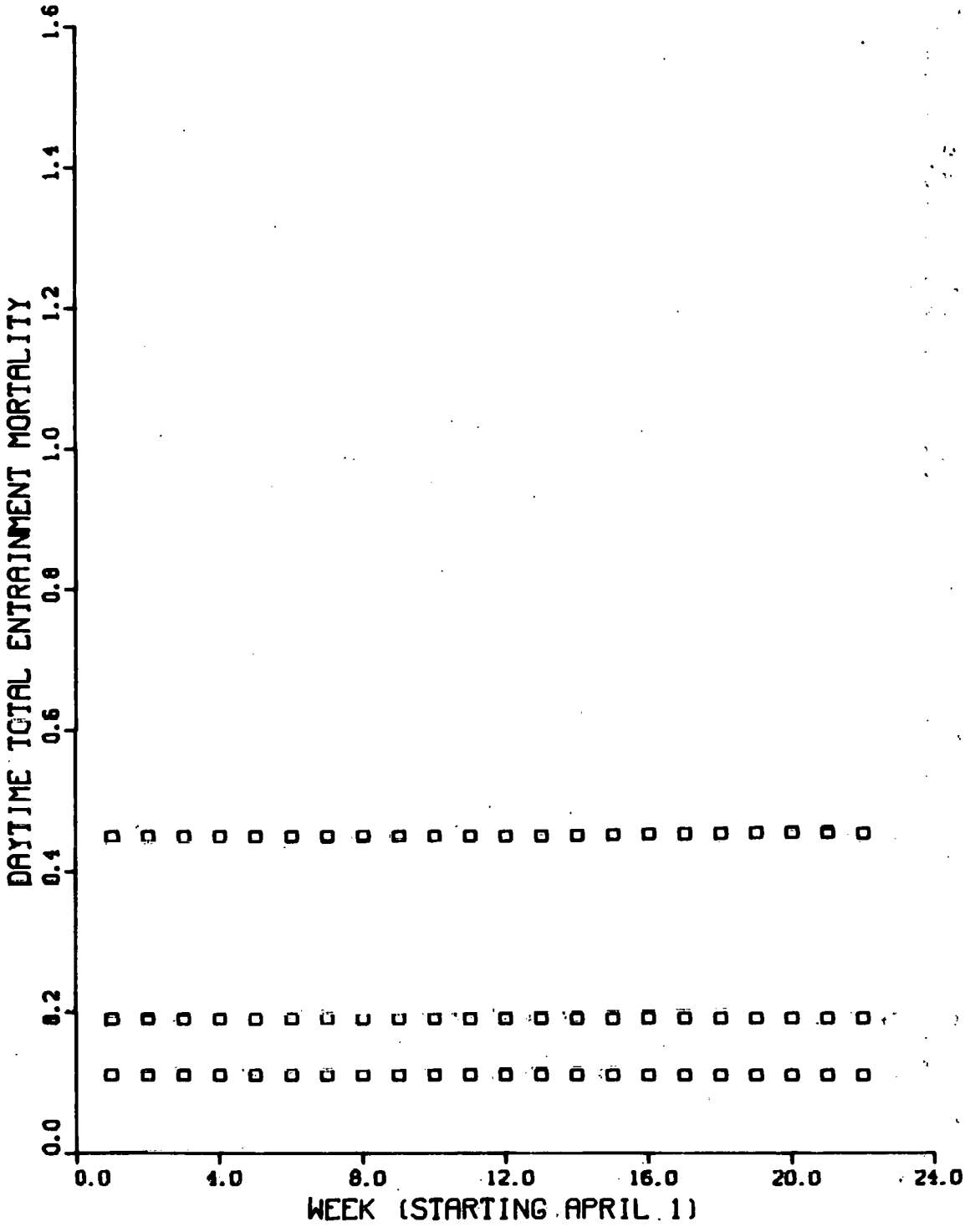

Figure F-25. Daytime total entrainment mortality of striped bass (Stage-P, Plant-6).

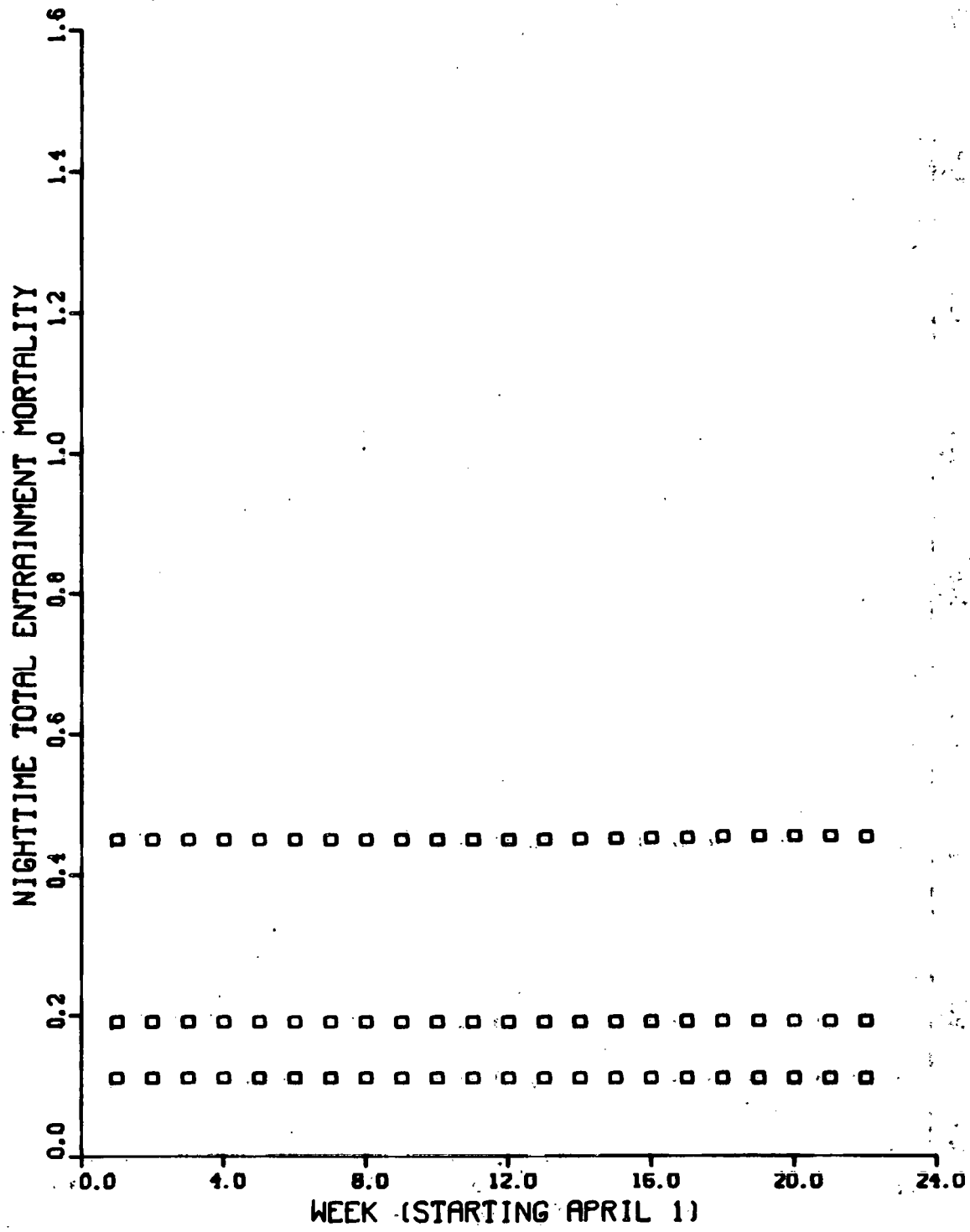

Figure F-26. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-6).

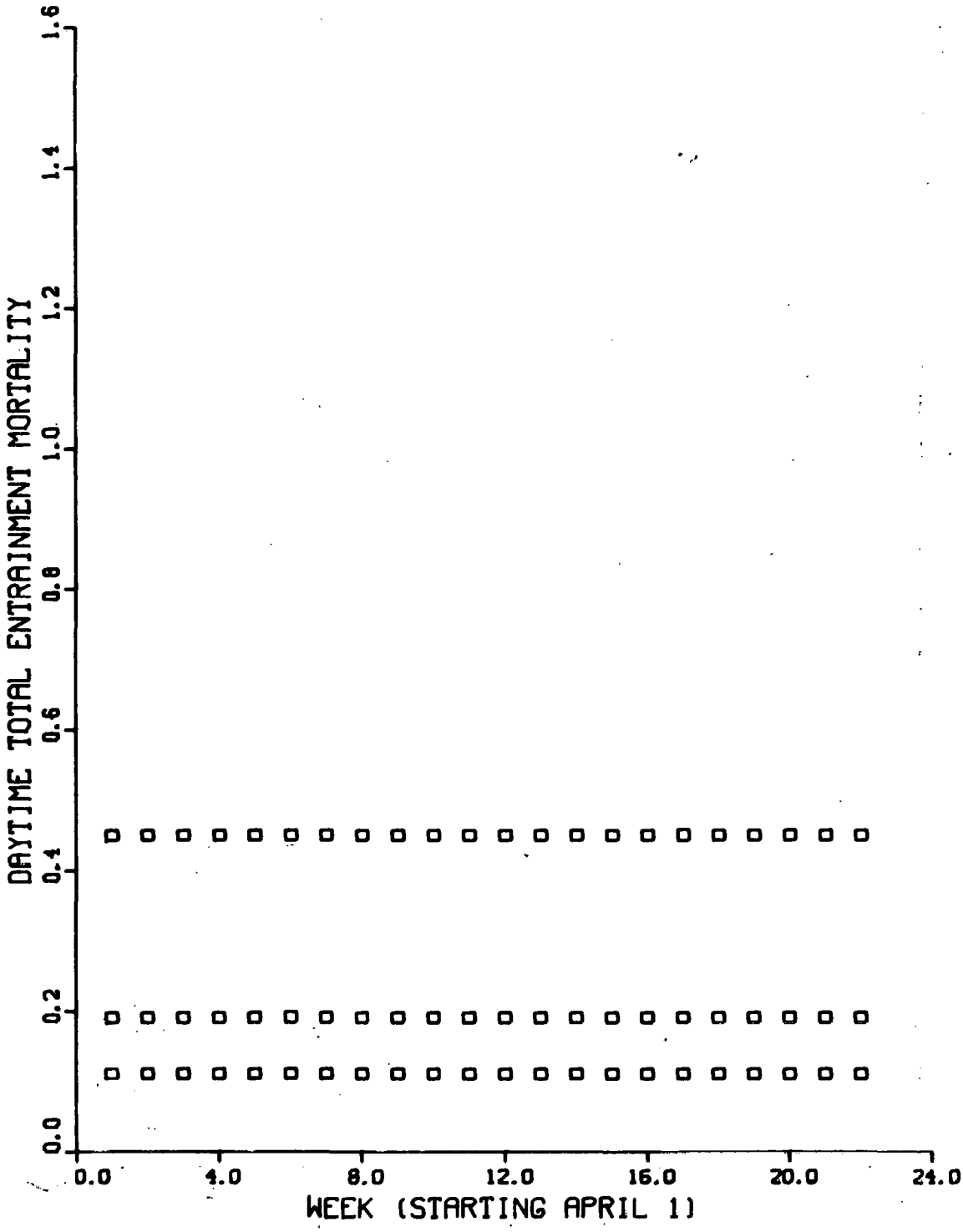

Figure F-27. Daytime total entrainment mortality of striped bass (Stage-P, Plant-7).

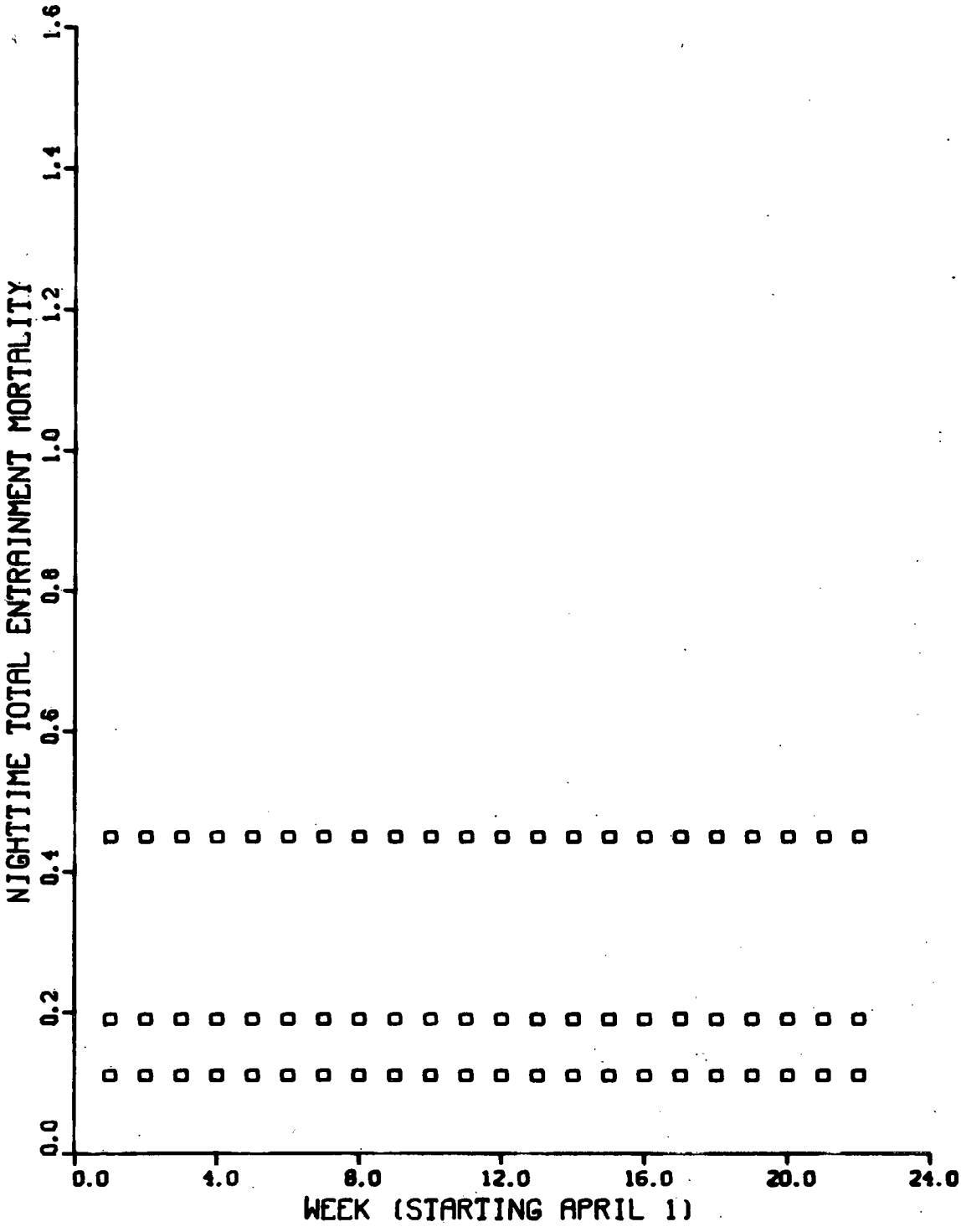

Figure F-28. Nighttime total entrainment mortality of striped bass (Stage-P, Plant-7).

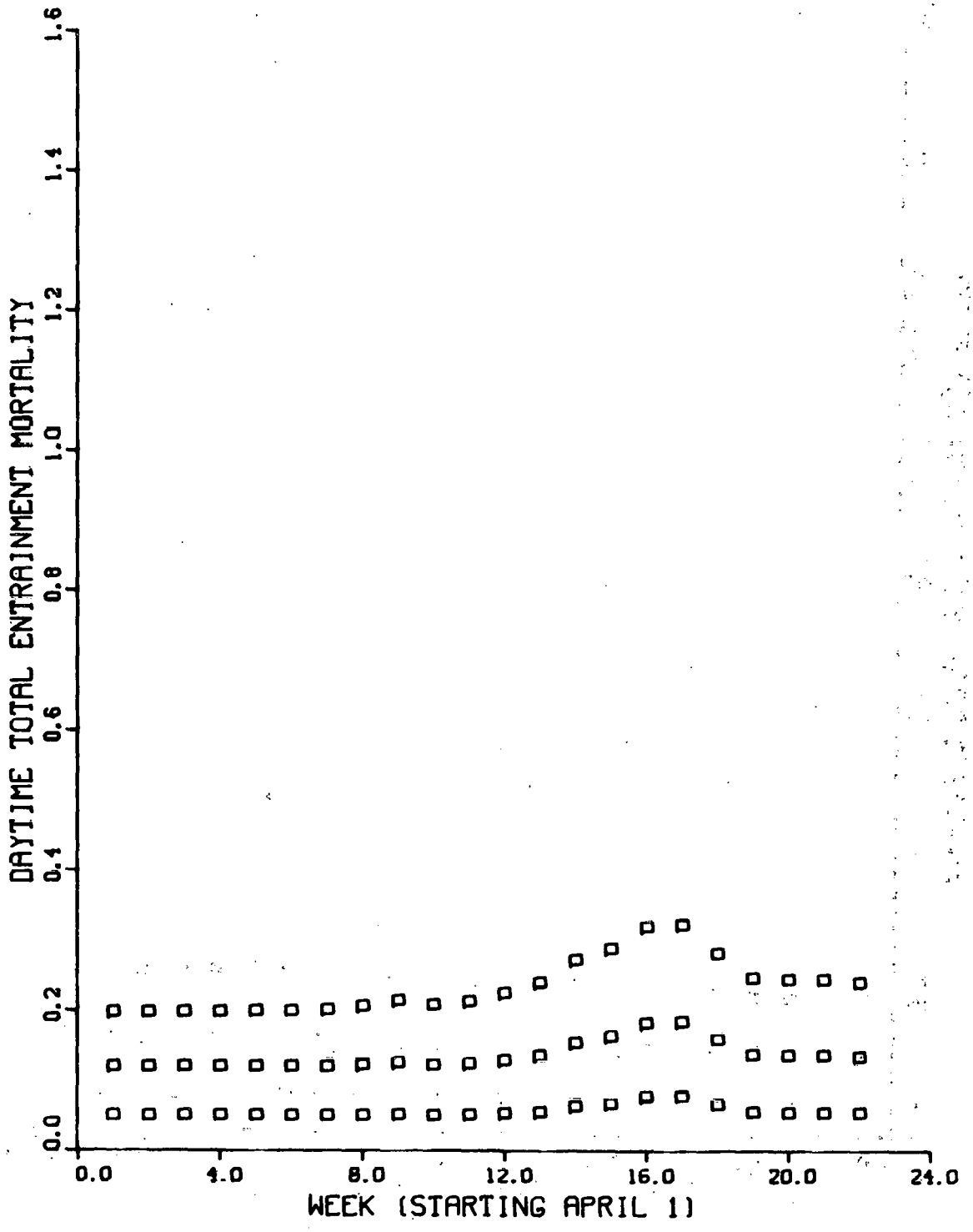

Figure F-29. Daytime total entrainment mortality of striped bass (Stage-J, Plant-1).

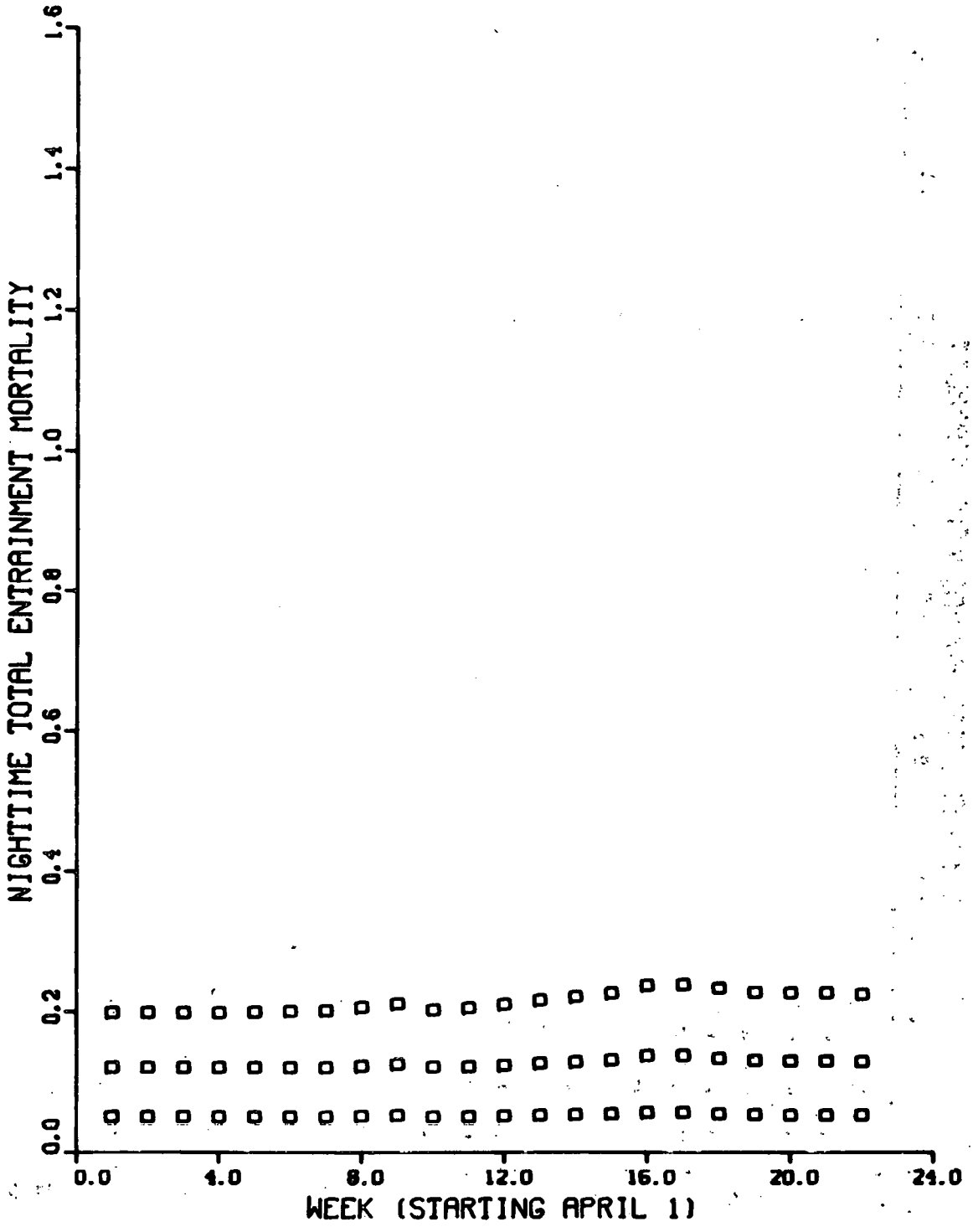

Figure F-30. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-1).

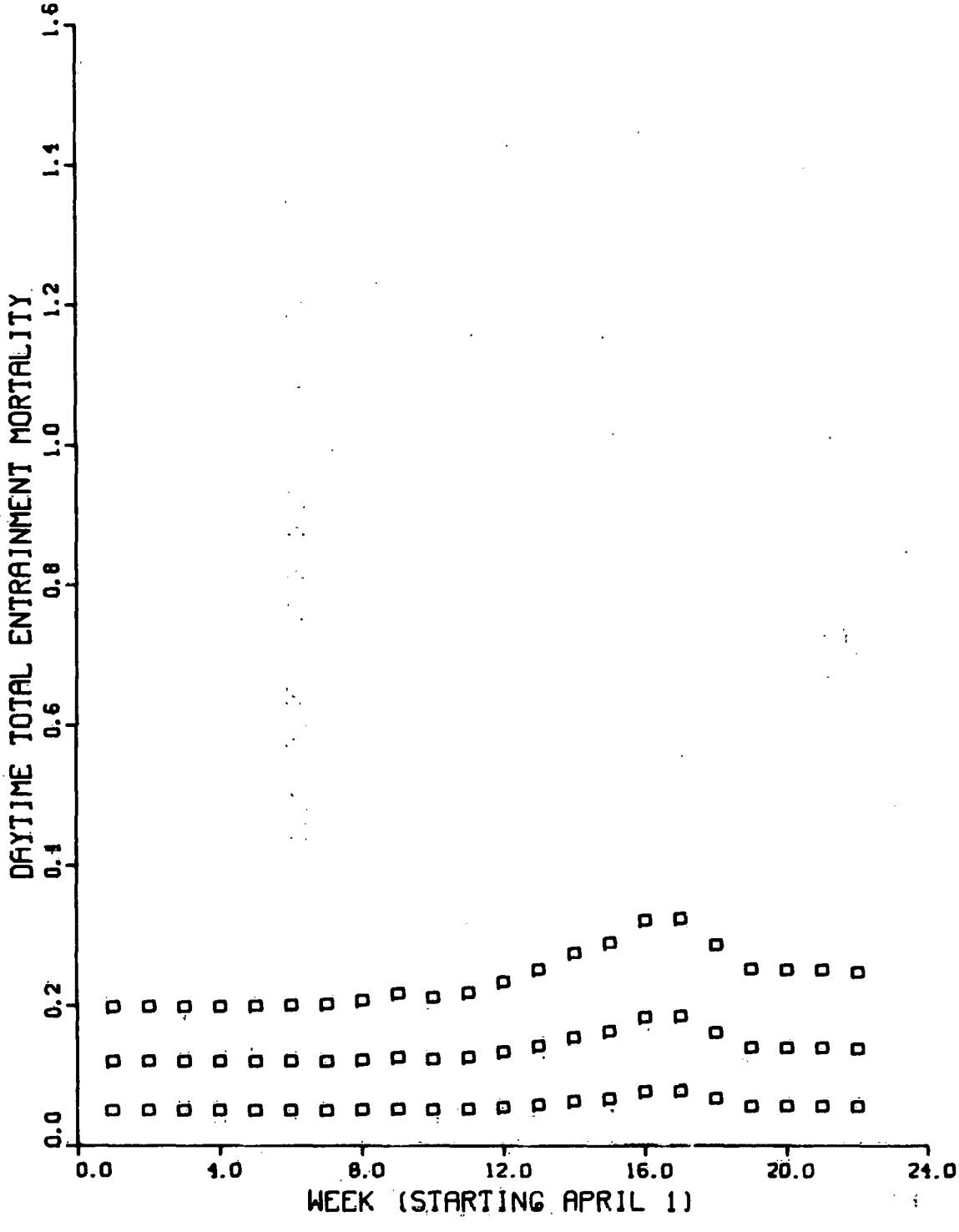

Figure F-31. Daytime total entrainment mortality of striped bass (Stage-J, Plant-2).

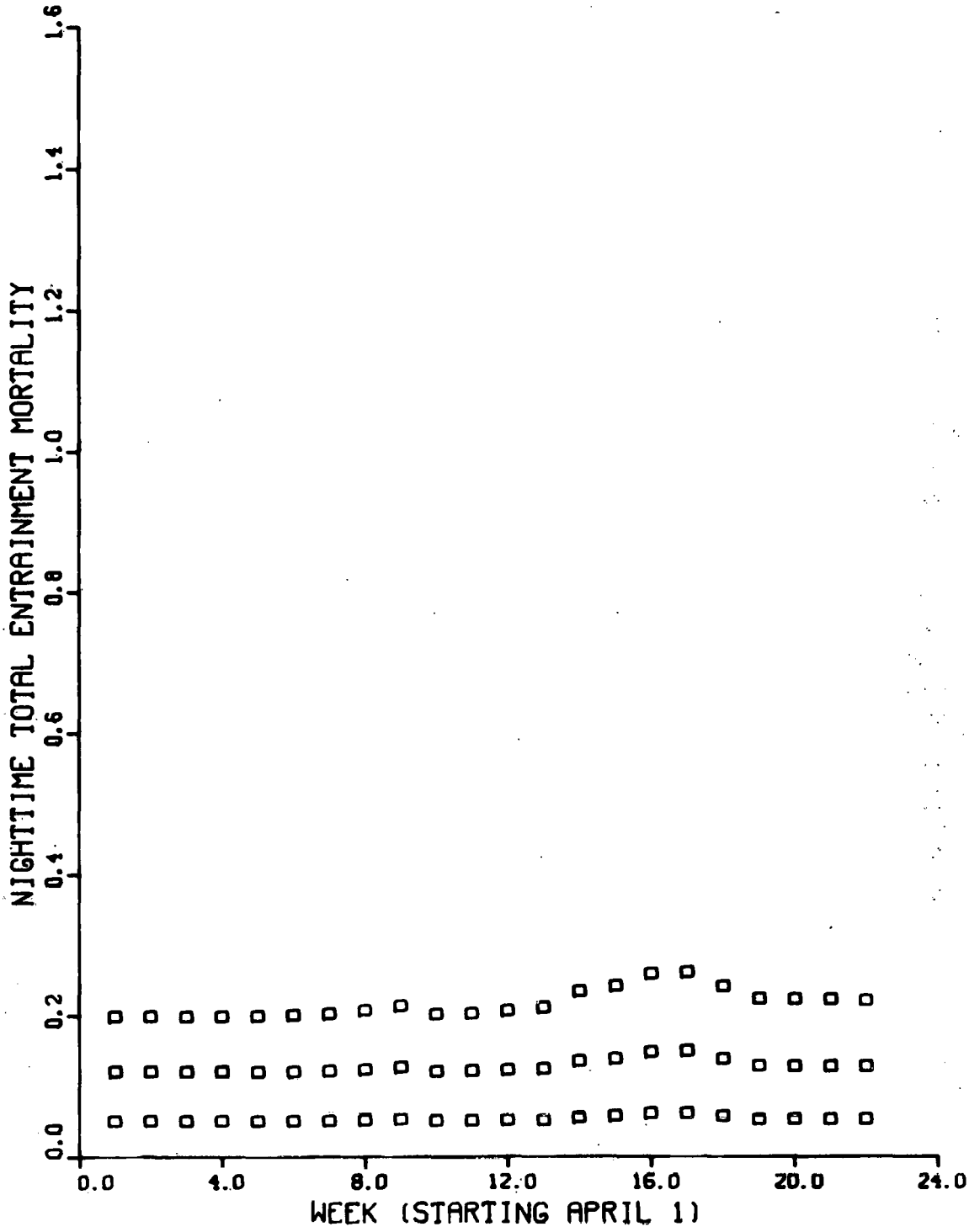

Figure F-32. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-2).

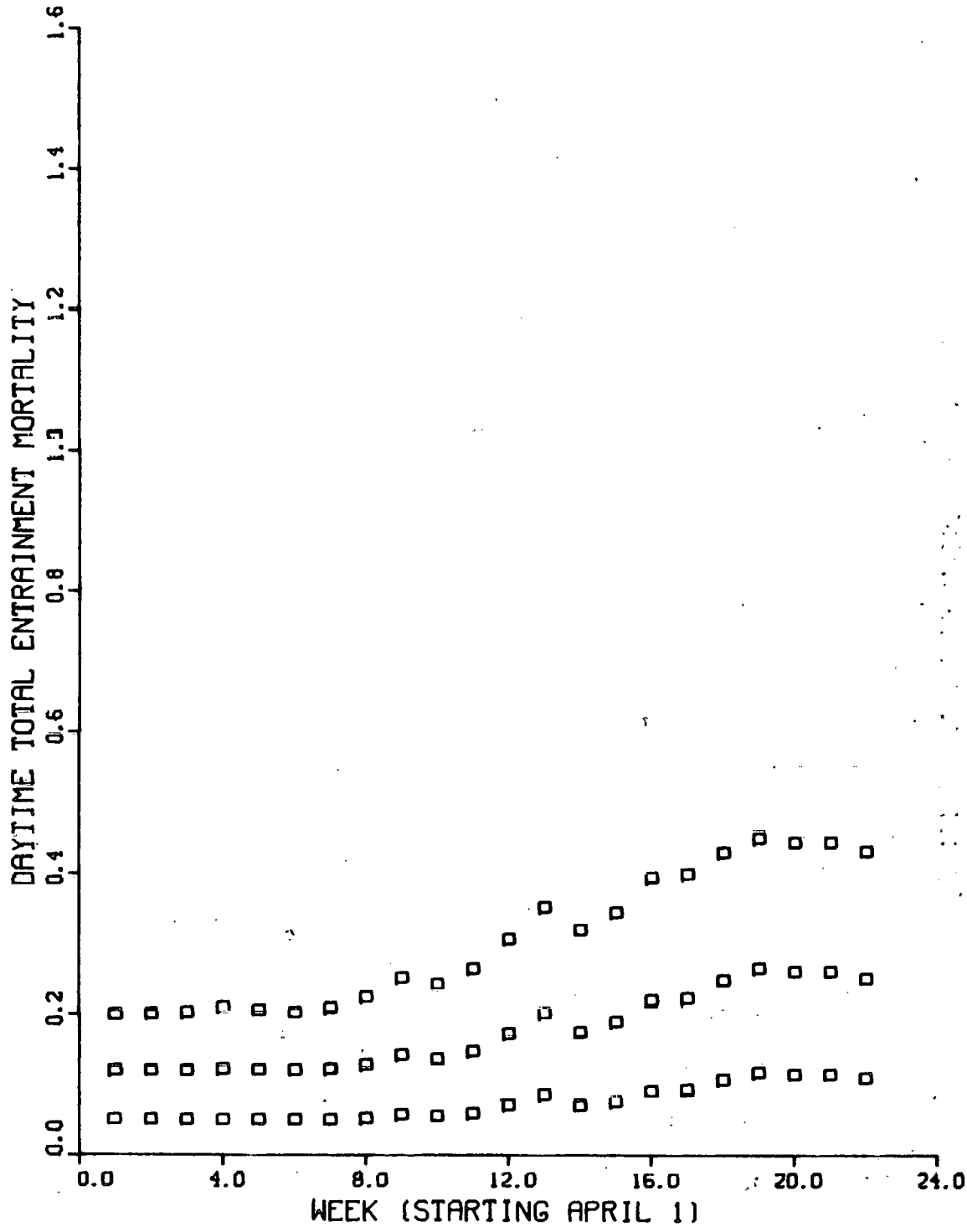

Figure F-33. Daytime total entrainment mortality of striped bass (Stage-J, Plant-3).

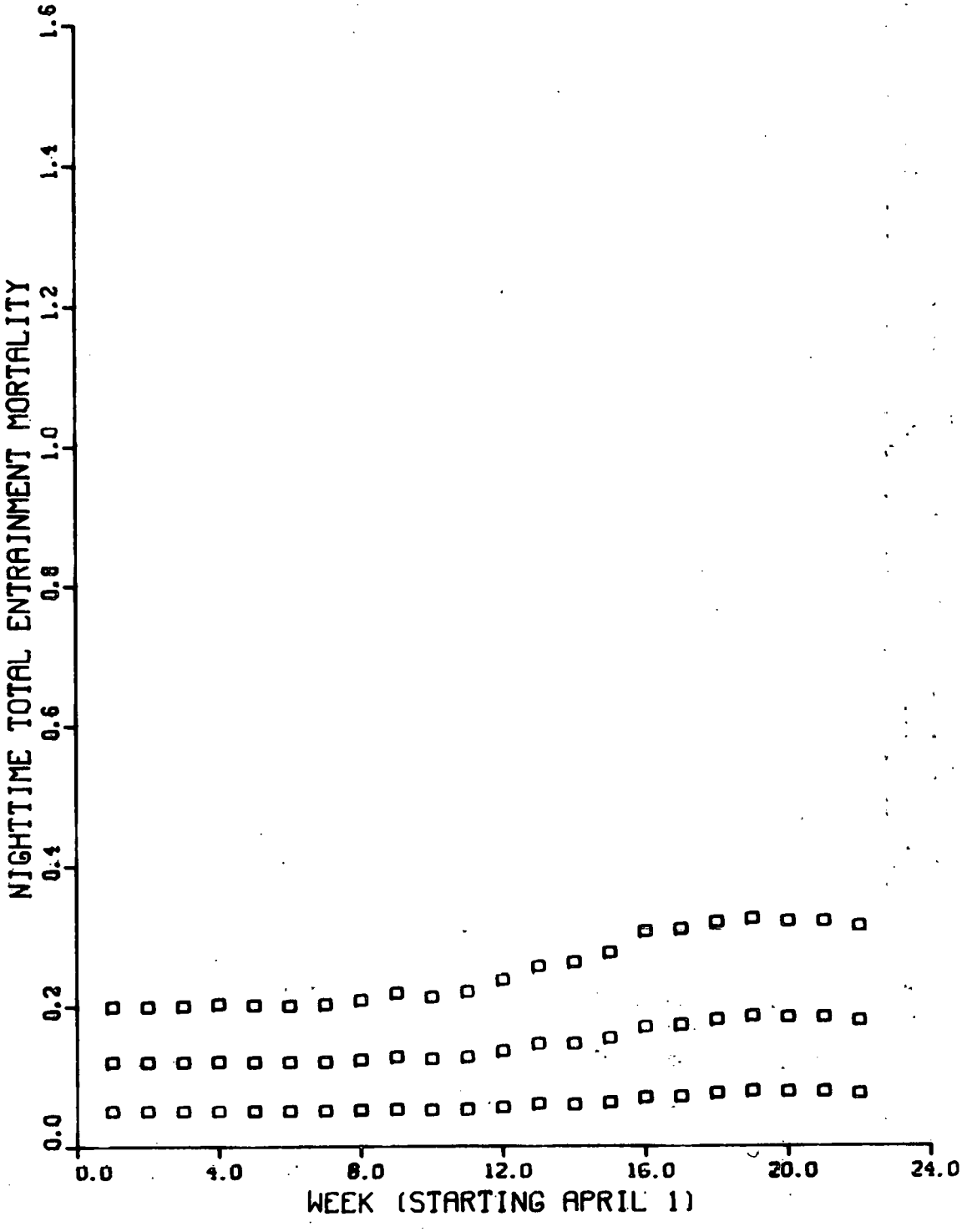

Figure F-34. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-3).

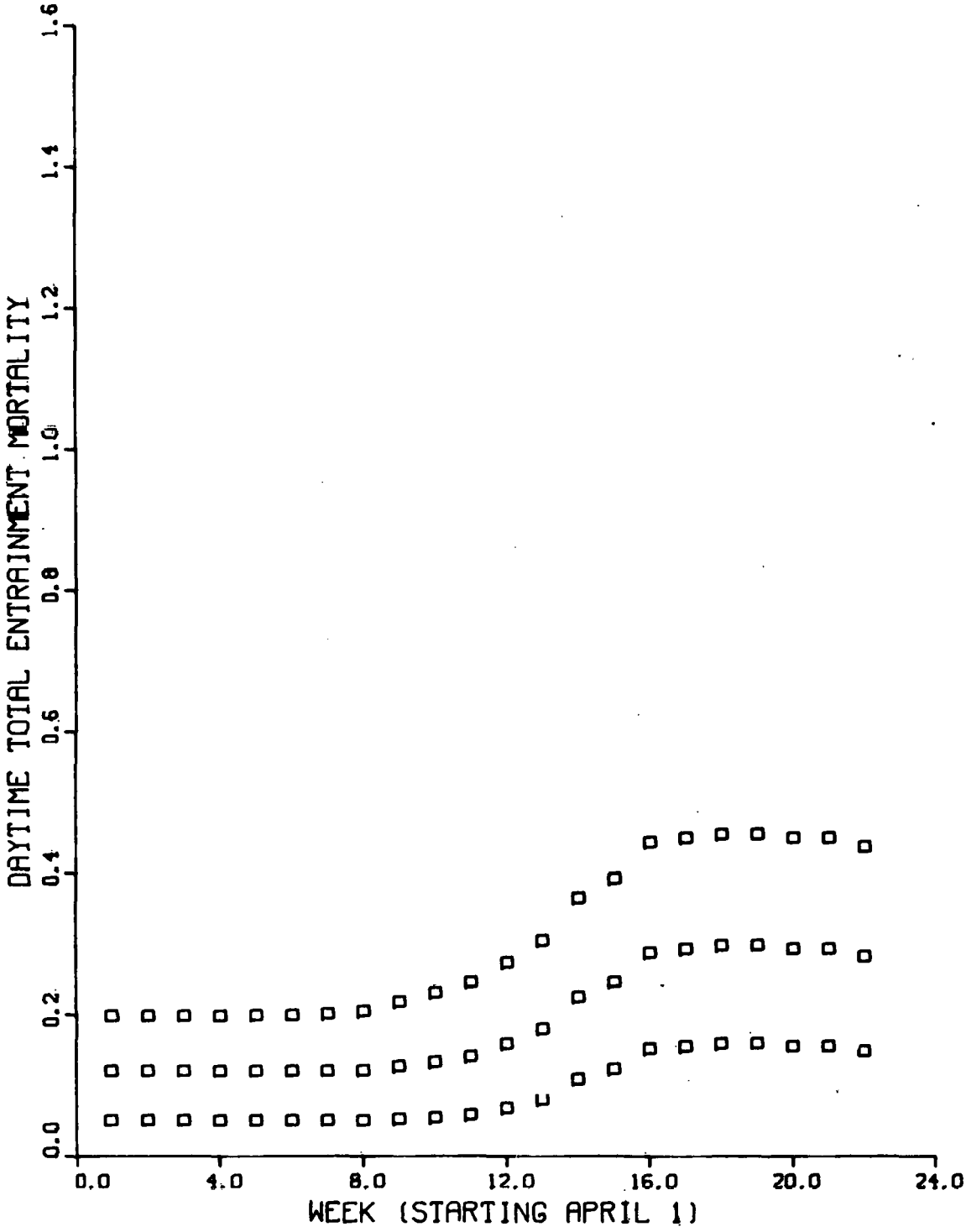

Figure F-35. Daytime total entrainment mortality of striped bass (Stage-J, Plant-4).

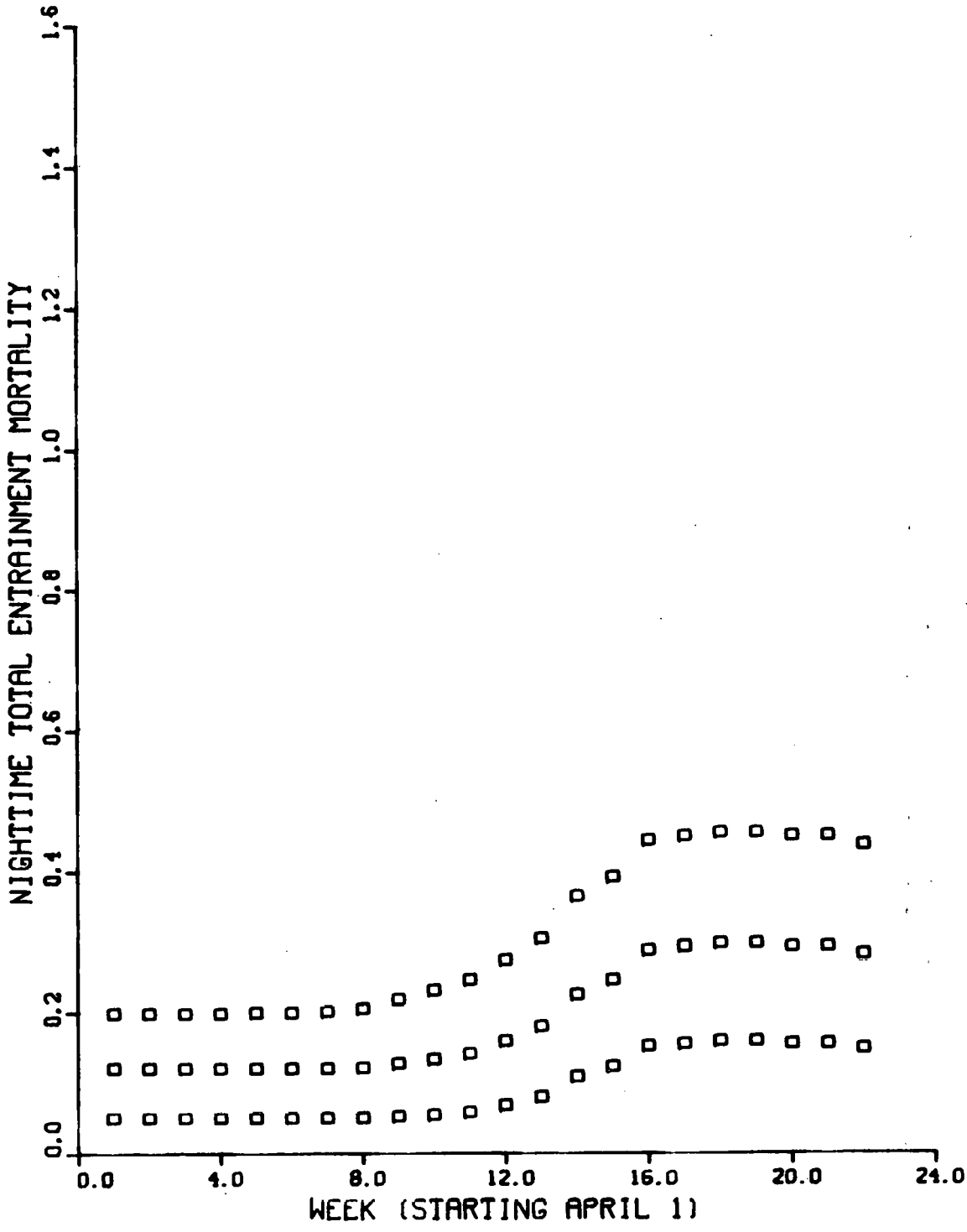

Figure F-36. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-4).

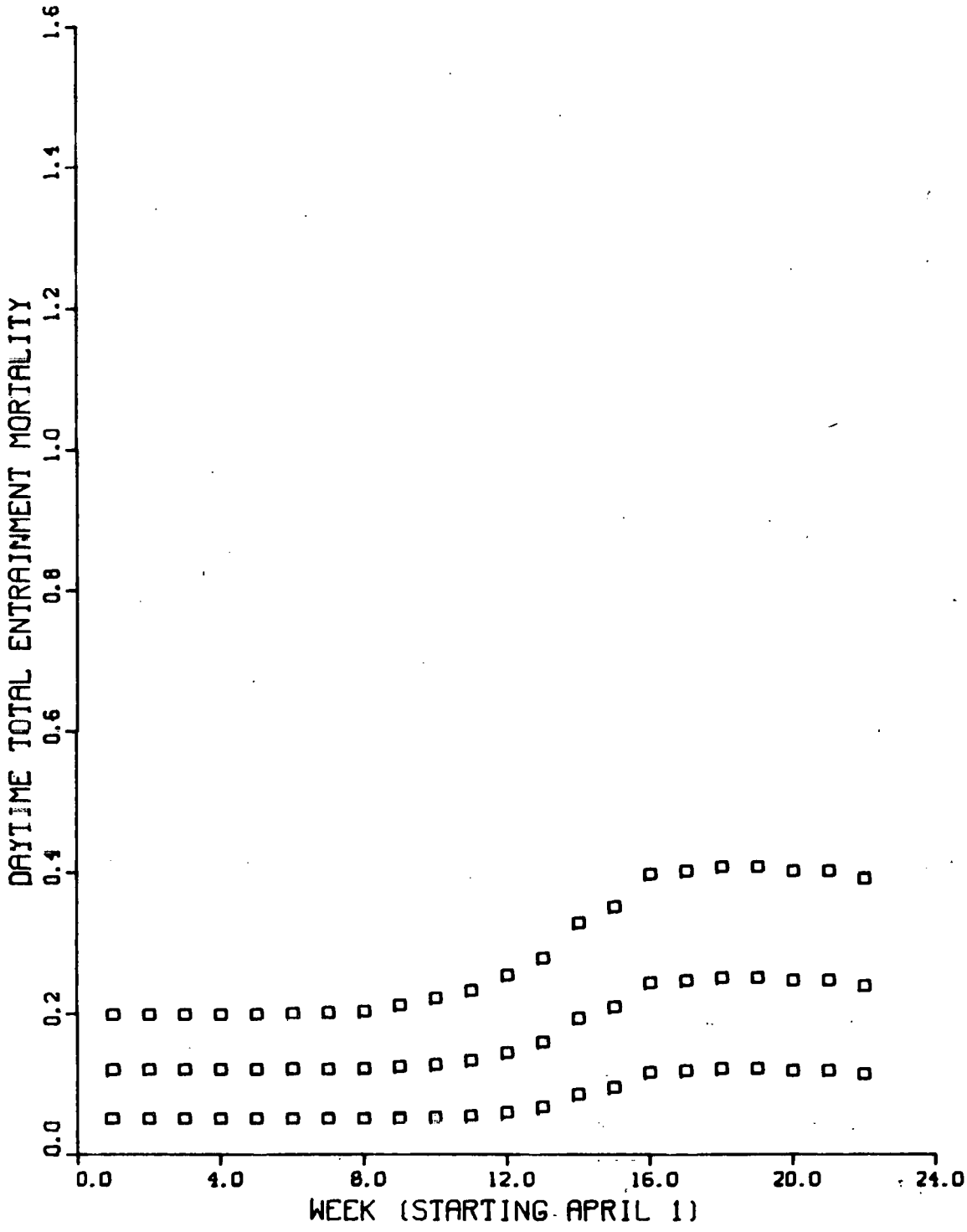

Figure F-37. Daytime total entrainment mortality of striped bass (Stage-J, Plant-5).

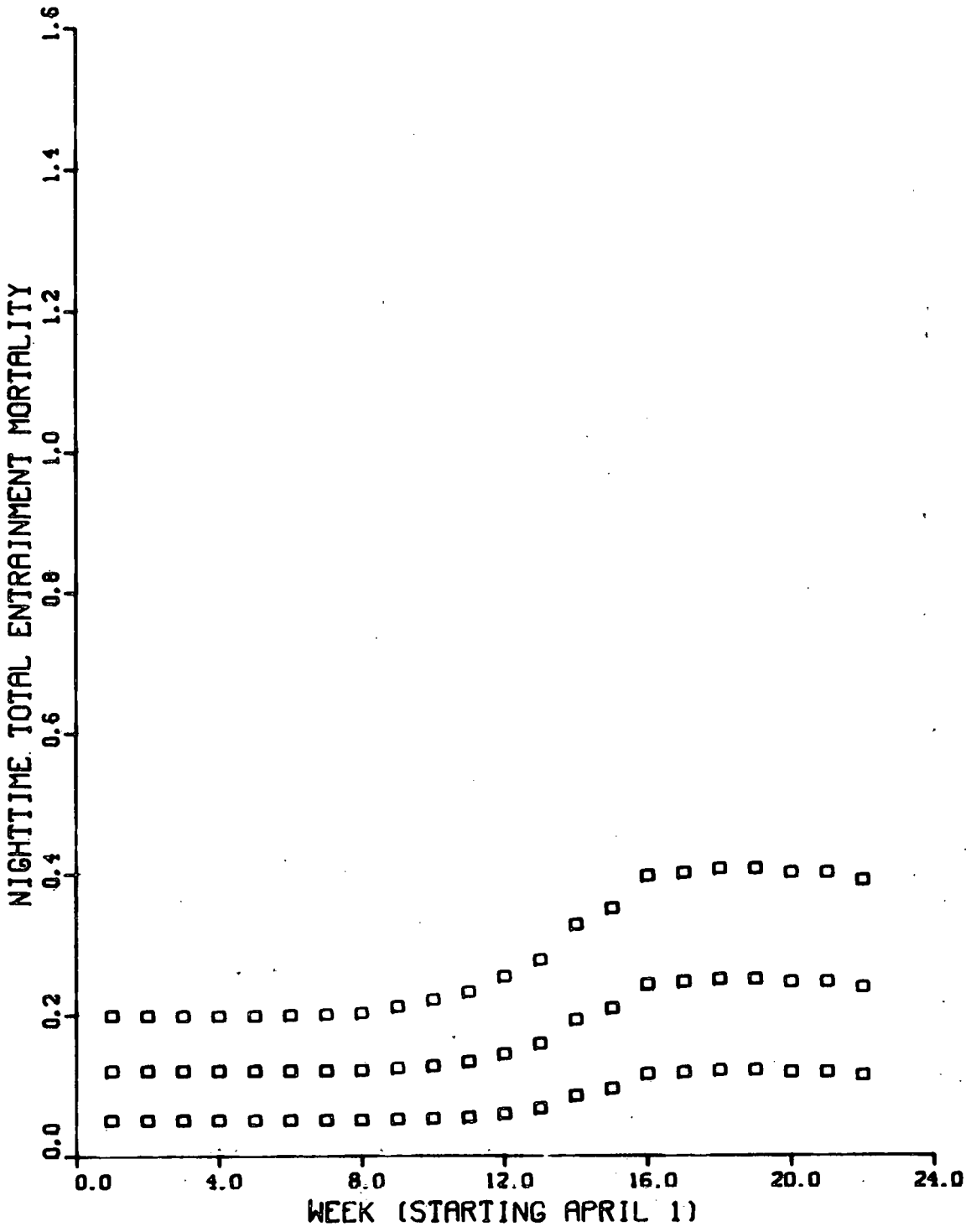

Figure F-38. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-5).

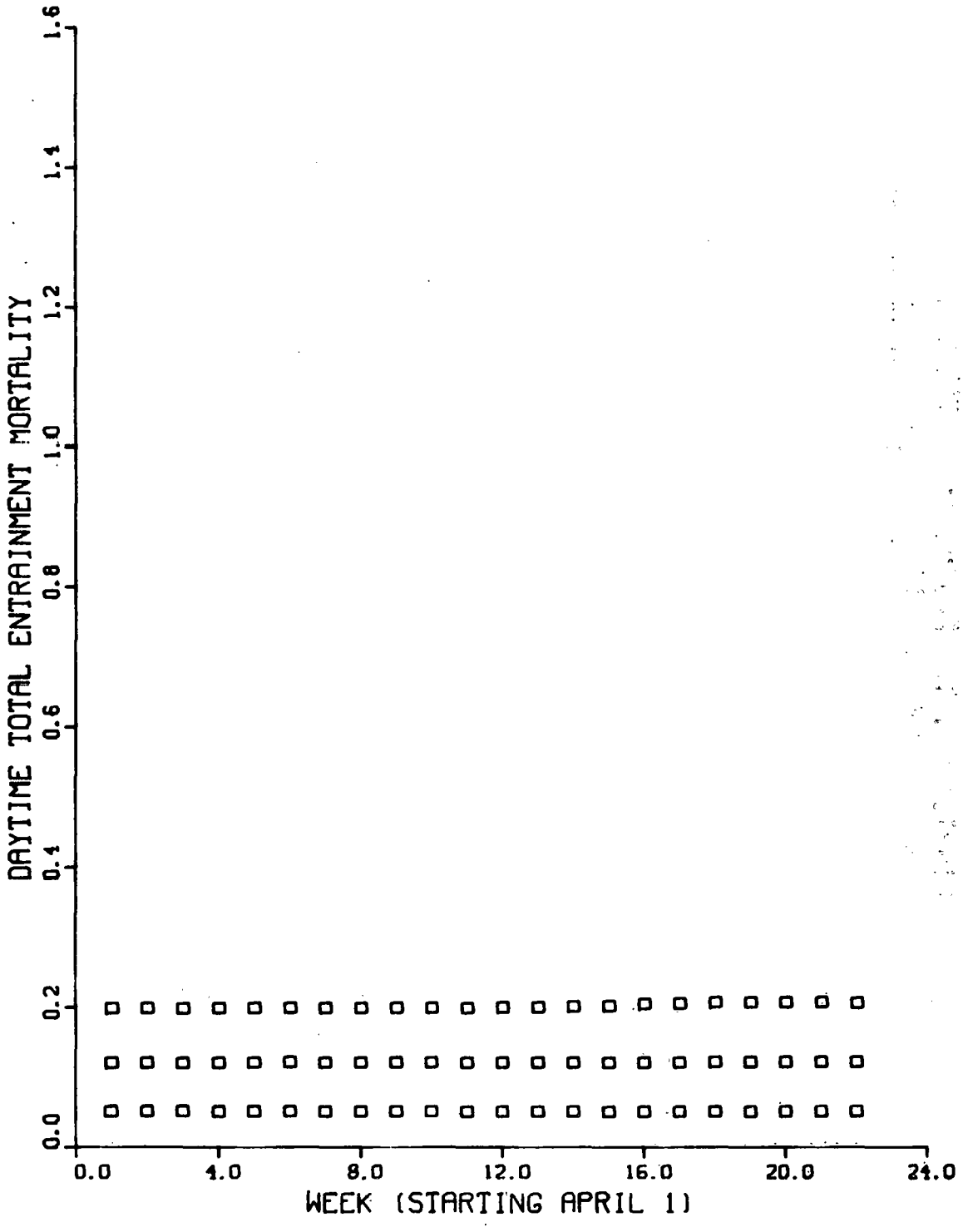

Figure F-39. Daytime total entrainment mortality of striped bass (Stage-J, Plant-6).

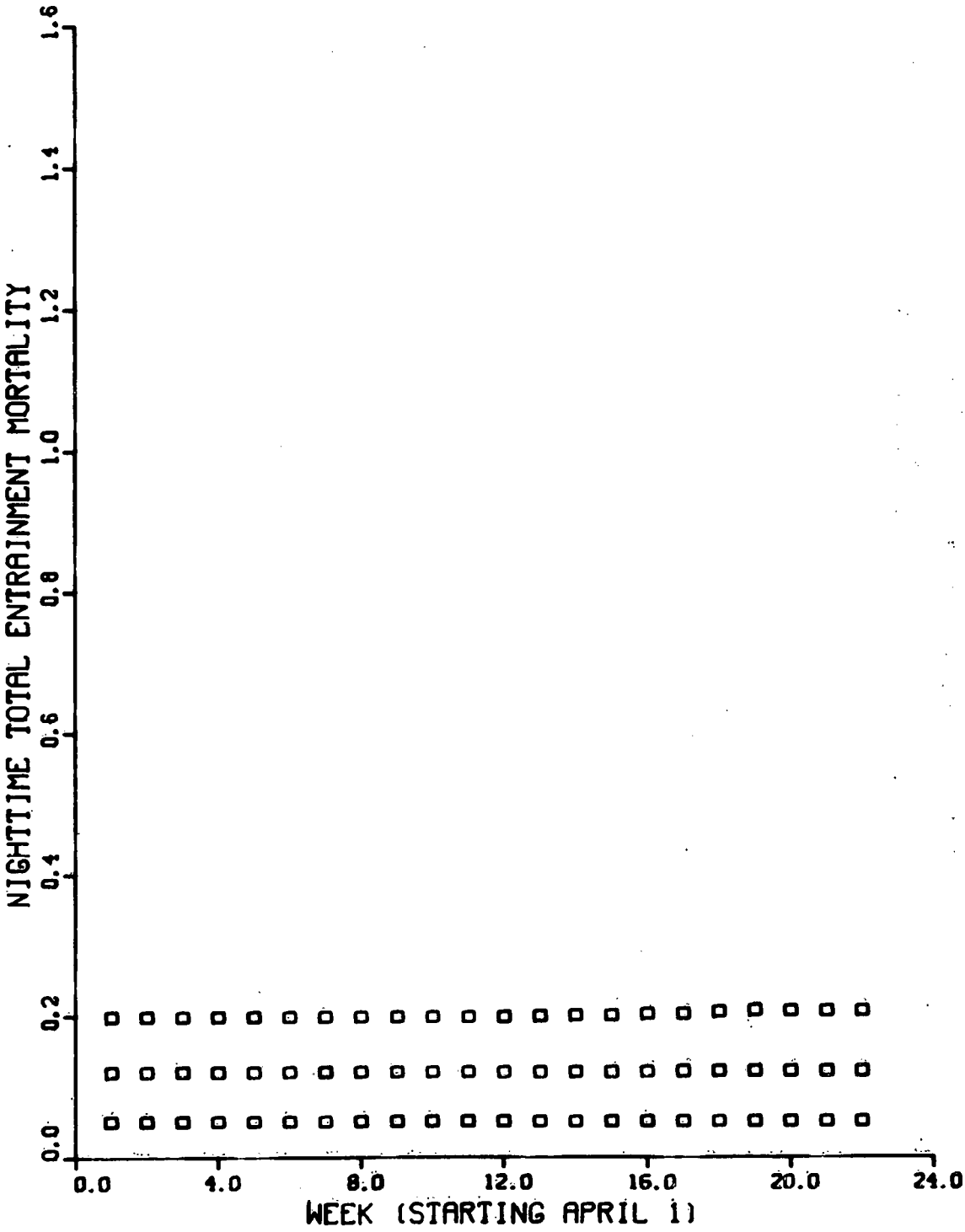

Figure F-40. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-6).

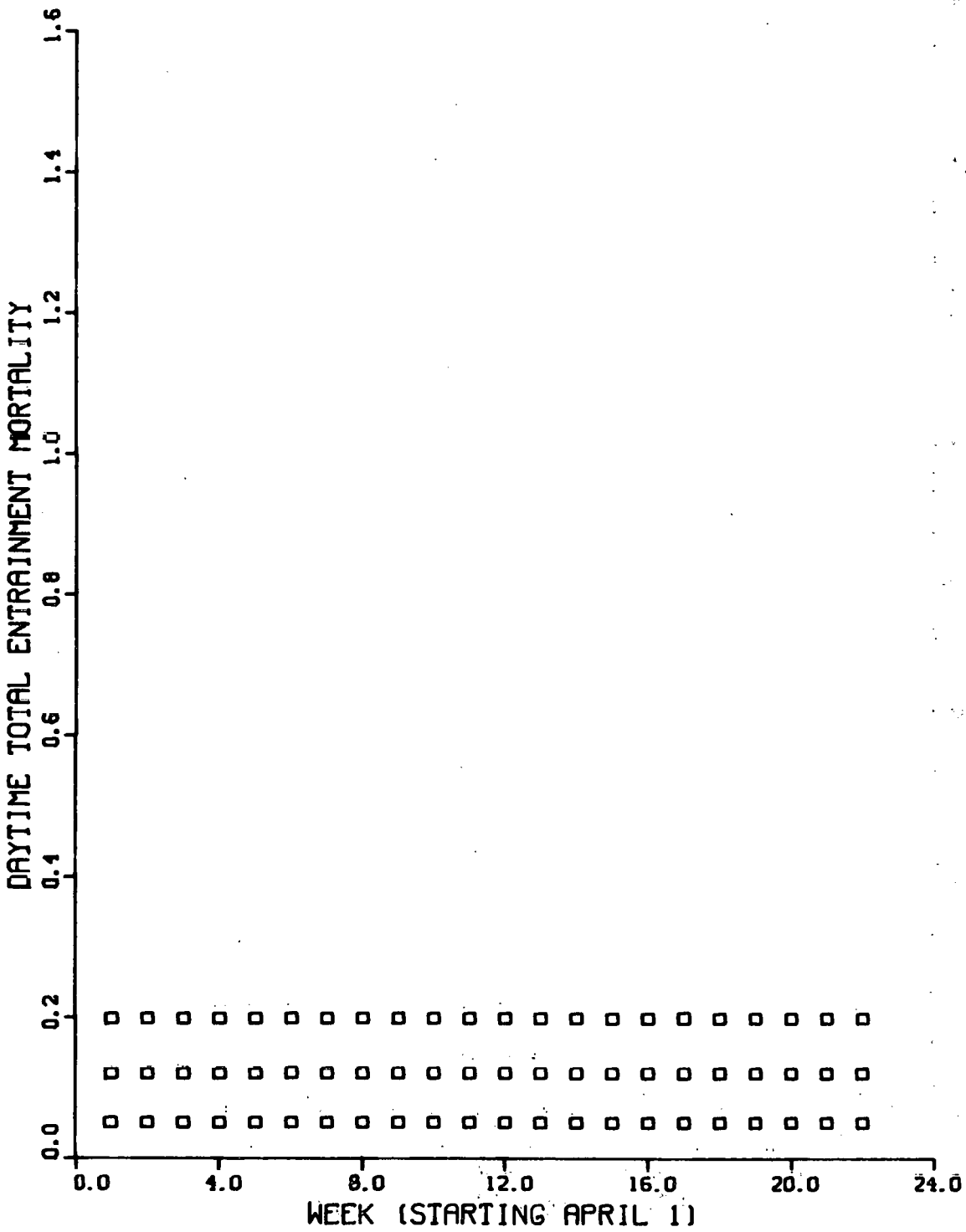

Figure F-41. Daytime total entrainment mortality of striped bass (Stage-J, Plant-7).

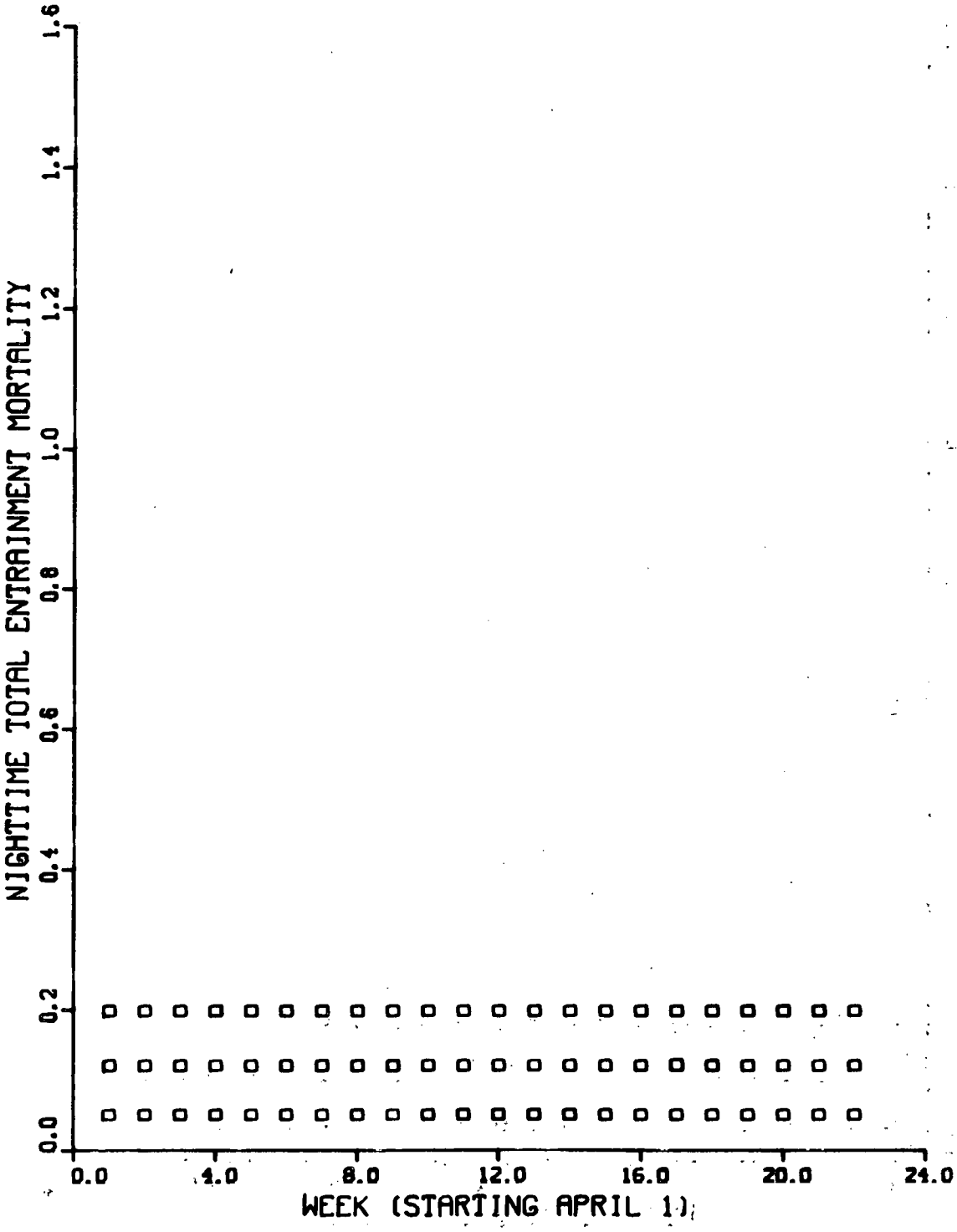

Figure F-42. Nighttime total entrainment mortality of striped bass (Stage-J, Plant-7).

Table F-1. Week number versus date of the week (key to ordinate axis of Figs. F-1 through F-42)

Week number	Date
1	April 1 - April 7
2	April 8 - April 14
3	April 15 - April 21
4	April 22 - April 28
5	April 29 - May 5
6	May 6 - May 12
7	May 13 - May 19
8	May 20 - May 26
9	May 27 - June 2
10	June 3 - June 9
11	June 10 - June 16
12	June 17 - June 23
13	June 24 - June 30
14	July 1 - July 7
15	July 8 - July 14
16	July 15 - July 21
17	July 22 - July 28
18	July 29 - August 4
19	August 5 - August 11
20	August 12 - August 18
21	August 19 - August 25
22	August 26 - August 31[a]

[a]This "week" contains six days.

APPENDICES G THRU O

JOHN BOREMAN, PhD.

NATIONAL POWER PLANT TEAM
UNITED STATES FISH AND WILDLIFE SERVICE
ANN ARBOR, MICHIGAN

APPENDICES G-L

ETM RUN RESULTS
INCORPORATING POOLED f-FACTORS

PREFACE TO APPENDICES G TO L

These appendices contain tabulations of ETM run results for six Hudson River fish populations incorporating pooled larval table f-factors:

Appendix	Population
G	Striped bass
H	White perch
I	Alosa spp. (blueback herring and alewife)
J	American shad
K	Atlantic tomcod
L	Bay anchovy

For each population, nine tables are presented:

Tables	Contents
1-3	Historical flow conditions
4-6	Projected (once-through) flow conditions
7-9	Projected (closed-cycle) flow conditions

Numbers in the tables are conditional entrainment mortality rate estimates expressed as percentages. Within each table, ETM run results are presented for the 1974 and/or 1975 data base year. For each year, ETM run results are tabulated by the W-factor estimation technique used (GBC, MU, or RDM) and by immediate and 24-hr latent f-factor values.

Appendix G-1.

Historical

Population: Striped bass

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.3	0.5	2.0	3.4
	I	0.3	0.4	1.4	2.5
Indian Pt 2	L	6.0	4.7	8.6	8.0
	I	4.2	3.4	6.1	5.6
Bowline	L	1.7	1.7	2.3	2.3
	I	0.9	0.9	1.3	1.3
Lovett	L	3.7	1.2	4.8	4.3
	I	2.7	0.8	3.4	3.2
Indian Pt 1	L	2.4	1.8	0.9	0.8
	I	1.7	1.3	0.6	0.6
Danskammer	L	1.2	1.6	1.0	0.8
	I	0.9	1.2	0.7	0.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-2.

Historical - All Plants

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.6	1.4	0.7	1.2
	I	0.6	1.4	0.7	1.2
Yolksac larvae	L	1.7	1.8	2.0	1.9
	I	1.5	1.6	1.7	1.6
Post yolksac larvae	L	9.7	5.2	12.6	12.3
	I	7.1	3.8	9.3	9.1
Juveniles	L	3.3	3.0	4.0	3.8
	I	1.2	1.2	1.5	1.6
Combined	L	14.5	11.1	18.4	18.2
	I	10.2	7.8	12.8	13.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-3.

Historical - Bowline, Indian Pt 2, Roseton

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.4	0.9	0.6	0.9
	I	0.4	0.9	0.6	0.9
Yolksac larvae	L	0.8	0.8	1.4	1.2
	I	0.7	0.7	1.2	1.0
Post yolksac larvae	L	4.8	3.0	7.9	8.6
	I	3.5	2.2	5.8	6.3
Juveniles	L	2.2	2.2	3.1	3.1
	I	0.9	0.9	1.2	1.2
Combined	L	8.0	6.8	12.5	13.2
	I	5.3	4.6	8.6	9.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-4.

Projected
(Once - through)

Population: Striped bass

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	3.1	4.0	2.1	2.8
	I	2.3	3.0	1.4	2.0
Indian Pt 2&3	L	10.1	8.5	13.1	10.7
	I	7.2	6.0	9.2	7.4
Bowline	L	2.3	2.3	3.0	3.0
	I	1.2	1.2	1.6	1.6
Lovett	L	3.4	1.1	4.6	1.4
	I	2.4	0.7	3.3	0.9
Danskammer	L	0.9	1.1	0.6	0.8
	I	0.6	0.8	0.4	0.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-5.

Projected - All Plants
(Once - through)

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.0	1.6	0.9	1.4
	I	1.0	1.6	0.9	1.4
Yolksac larvae	L	2.9	2.8	2.5	1.9
	I	2.5	2.4	2.1	1.6
Post yolksac larvae	L	11.3	8.3	14.2	9.9
	I	8.4	6.1	10.6	7.3
Juveniles	L	4.3	4.3	5.5	5.5
	I	1.7	1.7	2.2	2.2
Combined	L	18.4	16.0	21.7	17.6
	I	13.1	11.3	15.2	12.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.9	1.4	0.8	1.3
	I	0.9	1.4	0.8	1.3
Yolksac larvae	L	2.5	2.3	2.1	1.6
	I	2.1	2.0	1.8	1.3
Post yolksac larvae	L	8.4	7.3	10.5	8.8
	I	6.2	5.3	7.8	6.4
Juveniles	L	3.9	3.9	5.0	5.0
	I	1.5	1.5	2.0	2.0
Combined	L	14.9	14.1	17.4	15.8
	I	10.4	9.9	12.0	10.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-7.

Projected
(Closed - cycle)

Population: Striped bass

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.2	0.2	0.1	0.2
	I	0.2	0.2	0.1	0.2
Indian Pt 2&3	L	2.1	1.7	2.7	2.3
	I	2.1	1.7	2.7	2.3
Bowline	L	0.2	0.2	0.3	0.3
	I	0.2	0.2	0.3	0.3
Lovett	L	3.4	1.1	4.6	1.4
	I	2.4	0.7	3.3	0.9
Danskammer	L	0.9	1.1	0.6	0.8
	I	0.6	0.8	0.4	0.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-8

Projected - All Plants
(Closed - cycle)

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.2	0.2	0.2	0.2
	I	0.2	0.2	0.2	0.2
Yolksac larvae	L	0.7	0.7	0.6	0.5
	I	0.6	0.6	0.6	0.4
Post yolksac larvae	L	4.4	2.1	5.7	2.5
	I	3.5	1.8	4.6	2.1
Juveniles	L	1.4	1.4	1.9	1.8
	I	1.1	1.1	1.6	1.4
Combined	L	6.6	4.4	8.3	4.9
	I	5.4	3.7	6.9	4.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix G-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: Striped bass

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Yolksac larvae	L	0.2	0.2	0.2	0.1
	I	0.2	0.2	0.2	0.1
Post yolksac larvae	L	1.2	1.0	1.6	1.2
	I	1.2	1.0	1.6	1.2
Juveniles	L	1.0	0.9	1.4	1.2
	I	1.0	0.9	1.4	1.2
Combined	L	2.5	2.2	3.3	2.7
	I	2.5	2.2	3.3	2.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-1.

Historical

Population: White perch

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.6	0.6	3.7	4.2
	I	0.5	0.9	3.3	3.6
Indian Pt 2	L	3.9	4.9	4.5	3.3
	I	3.8	4.7	4.2	3.1
Bowline	L	2.5	2.5	1.9	1.9
	I	2.4	2.4	1.8	1.8
Lovett	L	1.3	0.4	1.4	1.4
	I	1.3	0.4	1.4	1.4
Indian Pt 1	L	1.5	1.9	0.4	0.3
	I	1.4	1.8	0.4	0.3
Danskammer	L	1.6	1.9	1.9	3.5
	I	1.3	1.7	1.6	3.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-2.

Historical - All Plants

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	2.7	3.9	1.0	2.5
	I	2.7	3.9	1.0	2.5
Yolksac larvae	L	0.7	0.6	0.8	0.7
	I	0.6	0.5	0.7	0.6
Post yolksac larvae	L	6.2	6.0	8.3	7.5
	I	6.2	6.0	8.3	7.5
Juveniles	L	1.6	1.6	3.5	3.5
	I	1.0	1.0	2.3	2.2
Combined	L	10.9	11.7	13.0	13.6
	I	10.2	11.1	11.9	12.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-3.

Historical - Bowline, Indian Pt 2, Roseton

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	2.3	3.0	0.9	1.6
	I	2.3	3.0	0.9	1.6
Yolksac larvae	L	0.5	0.4	0.6	0.6
	I	0.4	0.3	0.5	0.5
Post yolksac larvae	L	3.4	3.8	6.0	4.5
	I	3.4	3.8	6.0	4.5
Juveniles	L	0.8	0.8	2.5	2.5
	I	0.5	0.5	1.6	1.6
Combined	L	6.9	7.8	9.6	8.7
	I	6.6	7.5	8.8	8.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-4.

Projected
(Once - through)

Population: White perch

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	4.1	4.2	4.4	5.2
	I	3.7	3.8	3.8	4.6
Indian Pt 2&3	L	7.0	7.2	7.4	6.8
	I	6.7	6.9	6.9	6.2
Bowline	L	4.8	4.8	2.1	2.1
	I	4.6	4.6	1.9	1.9
Lovett	L	1.2	0.4	1.4	0.5
	I	1.1	0.4	1.3	0.4
Danskammer	L	1.2	1.5	1.3	2.2
	I	1.0	1.3	1.1	2.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-5.

Projected - All Plants
(Once - through)

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.0	6.3	0.8	2.8
	I	5.0	6.3	0.8	2.8
Yolksac larvae	L	1.0	0.9	1.0	0.8
	I	0.8	0.7	0.8	0.7
Post yolksac larvae	L	9.4	8.0	10.1	8.5
	I	9.4	8.0	10.1	8.5
Juveniles	L	2.7	2.7	4.5	4.5
	I	1.7	1.7	2.9	2.9
Combined	L	17.1	16.9	15.7	15.7
	I	16.1	16.0	14.2	14.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	4.8	6.0	0.8	1.8
	I	4.7	6.0	0.8	1.8
Yolksac larvae	L	0.8	0.8	0.8	0.8
	I	0.8	0.7	0.7	0.7
Post yolksac larvae	L	7.9	7.1	8.6	7.6
	I	7.8	7.1	8.6	7.6
Juveniles	L	2.2	2.2	3.8	3.8
	I	1.4	1.4	2.4	2.4
Combined	L	15.1	15.3	13.4	13.5
	I	14.3	14.5	12.1	12.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-7.

Projected
(Closed - cycle)

Population: White perch

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.2	0.2	0.3	0.3
	I	0.2	0.2	0.3	0.3
Indian Pt 2&3	L	1.0	1.0	1.1	1.0
	I	1.0	1.0	1.1	1.0
Bowline	L	0.2	0.2	0.1	0.1
	I	0.2	0.2	0.1	0.1
Lovett	L	1.2	0.4	1.4	0.5
	I	1.1	0.4	1.3	0.4
Danskammer	L	1.2	1.5	1.3	2.2
	I	1.0	1.3	1.1	2.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-8.

Projected - All Plants
(Closed - cycle)

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.4	0.8	0.1	1.0
	I	0.4	0.8	0.1	1.0
Yolksac larvae	L	0.2	0.1	0.2	0.1
	I	0.2	0.1	0.2	0.1
Post yolksac larvae	L	2.5	1.7	2.7	1.8
	I	2.5	1 7	2.7	1.8
Juveniles	L	0.7	0.7	1.1	1.1
	I	0.5	0.5	0.8	0.8
Combined	L	3.7	3.2	4.1	4.0
	I	3.5	3.1	3.8	3.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix H-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: White perch

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.3	0.4	0.0	0.1
	I	0.3	0.4	0.0	0.1
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	0.8	0.7	1.0	0.8
	I	0.8	0.7	1.0	0.8
Juveniles	L	0.2	0.2	0.4	0.4
	I	0.2	0.2	0.4	0.4
Combined	L	1.4	1.4	1.4	1.3
	I	1.4	1.4	1.4	1.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-1.

Historical

Population: Alosa spp.

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.4	0.5	3.1	4.8
	I	0.3	0.4	2.7	4.3
Indian Pt 2	L	1.0	1.1	0.8	1.0
	I	0.9	1.0	0.7	0.9
Bowline	L	0.4	0.4	0.1	0.1
	I	0.3	0.3	0.1	0.1
Lovett	L	0.3	0.3	0.2	0.3
	I	0.2	0.2	0.2	0.3
Indian Pt 1	L	0.4	0.4	0.1	0.1
	I	0.3	0.3	0.1	0.1
Danskammer	L	1.7	0.9	2.0	5.7
	I	1.5	0.8	1.7	5.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-2.

Historical - All Plants

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.3	6.2
	I	0.0	0.1	0.3	6.2
Yolksac larvae	L	0.1	0.1	0.1	0.2
	I	0.1	0.1	0.1	0.2
Post yolksac larvae	L	1.5	1.3	2.7	2.3
	I	1.5	1.3	2.7	2.3
Juveniles	L	2.5	2.1	3.1	3.0
	I	1.9	1.6	2.3	2.2
Combined	L	4.1	3.5	6.1	11.2
	I	3.5	3.0	5.4	10.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-3.

Historical - Bowline, Indian Pt 2, Roseton

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.2	2.0
	I	0.0	0.0	0.2	2.0
Yolksac larvae	L	0.0	0.0	0.1	0.1
	I	0.0	0.0	0.1	0.1
Post yolksac larvae	L	0.7	0.7	1.9	1.5
	I	0.7	0.6	1.9	1.5
Juveniles	L	1.1	1.3	1.8	2.4
	I	0.8	1.0	1.4	1.8
Combined	L	1.8	2.0	4.0	5.9
	I	1.5	1.7	3.5	5.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-4.

Projected
(Once - through)

Population: Alosa spp.

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	3.1	4.3	3.4	6.4
	I	2.7	3.5	2.9	5.6
Indian Pt 2&3	L	1.9	2.1	1.3	1.5
	I	1.6	1.8	1.1	1.4
Bowline	L	0.5	0.5	0.1	0.1
	I	0.4	0.4	0.1	0.1
Lovett	L	0.3	0.2	0.2	0.1
	I	0.2	0.2	0.1	0.1
Danskammer	L	1.3	0.7	1.4	3.6
	I	1.1	0.6	1.1	3.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-5.

Projected - All Plants
(Once - through)

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.3	4.9
	I	0.0	0.1	0.3	4.9
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	2.6	2.0	2.7	2.1
	I	2.6	2.0	2.7	2.1
Juveniles	L	4.3	5.6	3.2	4.5
	I	3.2	4.2	2.4	3.4
Combined	L	6.9	7.6	6.2	11.1
	I	5.9	6.3	5.4	10.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.2	2.1
	I	0.0	0.0	0.2	2.1
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	2.1	1.6	2.2	1.7
	I	2.1	1.6	2.2	1.7
Juveniles	L	3.3	5.1	2.3	4.1
	I	2.5	3.9	1.7	3.1
Combined	L	5.4	6.8	4.7	7.9
	I	4.6	5.6	4.2	7.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-7.

Projected
(Closed - cycle)

Population: Alosa spp.

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.1	0.1	0.1	0.2
	I	0.1	0.1	0.1	0.2
Indian Pt 2&3	L	0.2	0.2	0.1	0.2
	I	0.2	0.2	0.1	0.2
Bowline	L	0.0	0.0	0.0	0.0
	I	0.0	0.0	0.0	0.0
Lovett	L	0.2	0.2	0.2	0.1
	I	0.2	0.2	0.1	0.1
Danskammer	L	1.3	0.7	1.4	3.6
	I	1.1	0.6	1.2	3.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-8.

Projected - All Plants
(Closed - cycle)

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.1	3.1
	I	0.0	0.0	0.1	3.1
Yolksac larvae	L	0.0	0.0	0.0	0.0
	I	0.0	0.0	0.0	0.0
Post yolksac larvae	L	0.7	0.5	0.7	0.5
	I	0.7	0.5	0.7	0.5
Juveniles	L	1.1	0.7	1.0	0.5
	I	0.9	0.6	0.8	0.4
Combined	L	1.9	1.3	1.8	4.2
	I	1.6	1.1	1.6	4.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix I-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: Alosa spp.

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.0	0.1
	I	0.0	0.0	0.0	0.1
Yolksac larvae	L	0.0	0.0	0.0	0.0
	I	0.0	0.0	0.0	0.0
Post yolksac larvae	L	0.1	0.1	0.2	0.1
	I	0.1	0.1	0.2	0.1
Juveniles	L	0.1	0.2	0.1	0.1
	I	0.1	0.2	0.1	0.1
Combined	L	0.3	0.3	0.3	0.4
	I	0.3	0.3	0.3	0.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-1.

Historical

Population: American shad

Plant	f	1974
Roseton	L	0.7
	I	0.6
Indian Pt 2	L	4.9
	I	3.7
Bowline	L	3.2
	I	2.4
Lovett	L	1.5
	I	1.1
Indian Pt 1	L	1.8
	I	1.3
Danskammer	L	2.4
	I	1.9

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-2.

Historical - All Plants

Population: American shad

Life stage	f	1974
Eggs	L	0.0
	I	0.0
Yolksac larvae	L	0.1
	I	0.1
Post yolksac larvae	L	0.5
	I	0.5
Juveniles	L	13.0
	I	10.0
Combined	L	13.6
	I	10.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-3.
Historical - Bowline, Indian Pt 2, Roseton

Population: American shad

Life stage	f	1974
Eggs	L	0.0
	I	0.0
Yolksac larvae	L	0.0
	I	0.0
Post yolksac larvae	L	0.2
	I	0.2
Juveniles	L	8.3
	I	6.4
Combined	L	8.6
	I	6.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-4.

Projected
(Once - through)

Population: American shad

Plant	f	1974
Roseton	L	5.9
	I	4.2
Indian Pt 283	L	9.0
	I	6.9
Bowline	L	4.3
	I	3.2
Lovett	L	1.4
	I	1.0
Danskammer	L	1.9
	I	1.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-5.

Projected - All Plants
(Once - through)

Population: American shad

Life stage	f	1974
Eggs	L	0.1
	I	0.1
Yolksac larvae	L	0.2
	I	0.2
Post yolksac larvae	L	0.9
	I	0.9
Juveniles	L	19.5
	I	15.1
Combined	L	20.5
	I	16.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: American shad

Life stage	f	1974
Eggs	L	0.1
	I	0.1
Yolksac larvae	L	0.2
	I	0.2
Post yolksac larvae	L	0.7
	I	0.7
Juveniles	L	17.1
	I	13.2
Combined	L	17.9
	I	14.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-7.

Projected
(Closed - cycle)

Population: American shad

Plant	f	1974
Roseton	L	0.2
	I	0.2
Indian Pt 2&3	L	0.7
	I	0.7
Bowline	L	0.1
	I	0.1
Lovett	L	1.4
	I	1.0
Danskammer	L	1.9
	I	1.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-8.

Projected - All Plants
(Closed - cycle)

Population: American shad

Life stage	f	1974
Eggs	L	0.0
	I	0.0
Yolksac larvae	L	0.1
	I	0.1
Post yolksac larvae	L	0.2
	I	0.2
Juveniles	L	3.8
	I	3.1
Combined	L	4.1
	I	3.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix J-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: American shad

Life stage	f	1974
Eggs	L	0.0
	I	0.0
Yolksac larvae	L	0.0
	I	0.0
Post yolksac larvae	L	0.0
	I	0.0
Juveniles	L	0.9
	I	0.9
Combined	L	0.9
	I	0.9

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-1.

Historical

Population: Atlantic tomcod

Plant	f	1975 GBC	1975 MU
Roseton	L	0.2	0.2
	I	0.2	0.2
Indian Pt 2	L	2.1	5.0
	I	2.1	5.0
Bowline	L	2.0	2.0
	I	2.0	2.0
Lovett	L	0.5	0.5
	I	0.5	0.5
Indian Pt 1	L	0.4	0.7
	I	0.4	0.7
Danskammer	L	0.1	0.1
	I	0.1	0.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-2.

Historical - All Plants

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	0.5	0.4
	I	0.5	0.4
Post yolksac larvae	L	3.4	3.6
	I	3.4	3.6
Juveniles	L	1.4	4.6
	I	1.4	4.6
Combined	L	5.2	8.4
	I	5.2	8.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-3.

Historical - Bowline, Indian Pt 2, Roseton

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	0.3	0.3
	I	0.3	0.3
Post yolksac larvae	L	2.9	2.9
	I	2.9	2.9
Juveniles	L	1.1	4.1
	I	1.1	4.1
Combined	L	4.3	7.1
	I	4.3	7.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-4.

Projected
(Once - through)

Population: Atlantic tomcod

Plant	f	1975 GBC	1975 MU
Roseton	L	0.2	0.2
	I	0.2	0.2
Indian Pt 2&3	L	4.8	5.7
	I	4.8	5.7
Bowline	L	1.1	1.1
	I	1.1	1.1
Lovett	L	0.6	0.4
	I	0.6	0.4
Danskammer	L	0.0	0.1
	I	0.0	0.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-5.

Projected - All Plants
(Once - through)

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	1.1	1.1
	I	1.1	1.1
Post yolksac larvae	L	4.0	3.1
	I	4.0	3.1
Juveniles	L	1.7	3.3
	I	1.7	3.3
Combined	L	6.6	7.3
	I	6.6	7.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	0.9	0.9
	I	0.9	0.9
Post yolksac larvae	L	3.6	2.9
	I	3.6	2.9
Juveniles	L	1.6	3.3
	I	1.6	3.3
Combined	L	6.0	7.0
	I	6.0	7.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-7.

Projected
(Closed - cycle)

Population: Atlantic tomcod

Plant	f	1975 GBC	1975 MU
Roseton	L	0.0	0.0
	I	0.0	0.0
Indian Pt 2&3	L	1.6	1.7
	I	1.6	1.7
Bowline	L	1.6	1.6
	I	1.6	1.6
Lovett	L	0.6	0.4
	I	0.6	0.4
Danskammer	L	0.0	0.0
	I	0.0	0.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-8.

Projected - All Plants
(Closed - cycle)

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	1.5	1.5
	I	1.5	1.5
Post yolksac larvae	L	0.7	0.5
	I	0.7	0.5
Juveniles	L	0.2	0.4
	I	0.2	0.4
Combined	L	2.4	2.4
	I	2.4	2.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix K-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: Atlantic tomcod

Life stage	f	1975 GBC	1975 MU
Eggs	L	0.0	0.0
	I	0.0	0.0
Yolksac larvae	L	1.3	1.3
	I	1.3	1.3
Post yolksac larvae	L	0.3	0.2
	I	0.3	0.2
Juveniles	L	0.2	0.3
	I	0.2	0.3
Combined	L	1.8	1.9
	I	1.8	1.9

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-1.

Historical

Population: Bay anchovy

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.5	0.5	2.1	2.1
	I	0.4	0.4	1.6	1.6
Indian Pt 2	L	14.3	53.7	11.2	24.3
	I	12.1	44.7	9.7	20.3
Bowline	L	25.4	25.4	14.9	14.9
	I	20.3	20.3	12.5	12.5
Lovett	L	24.0	15.4	10.6	12.5
	I	19.0	13.5	8.6	11.9
Indian Pt 1	L	6.0	28.5	1.2	2.5
	I	5.0	22.5	1.0	2.0
Danskammer	L	0.5	0.5	1.0	1.0
	I	0.3	0.3	0.7	0.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-2.

Historical - All Plants

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.0	0.2
	I	0.0	0.1	0.0	0.2
Yolksac larvae	L	0.4	2.2	0.3	5.5
	I	0.4	2.2	0.3	5.5
Post yolksac larvae	L	20.1	26.0	18.5	24.0
	I	18.7	24.2	17.2	22.3
Juveniles	L	42.3	69.2	19.5	24.5
	I	33.4	58.6	14.9	19.0
Combined	L	54.1	77.8	34.8	46.0
	I	46.0	69.4	29.8	40.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-3.

Historical - Bowline, Indian Pt 2, Roseton

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.0	0.1
	I	0.0	0.0	0.0	0.1
Yolksac larvae	L	0.3	0.3	0.2	0.2
	I	0.3	0.3	0.2	0.2
Post yolksac larvae	L	13.8	15.9	14.8	17.5
	I	12.7	14.7	13.7	16.2
Juveniles	L	25.8	58.3	12.7	22.9
	I	19.7	47.9	9.5	17.6
Combined	L	36.2	65.1	25.9	38.6
	I	30.1	55.7	22.1	31.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-4.

Projected
(Once - through)

Population: Bay anchovy

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	1.3	1.3	2.7	2.7
	I	0.9	0.9	2.1	2.1
Indian Pt 2&3	L	33.7	65.7	21.8	39.1
	I	28.4	56.7	19.1	33.5
Bowline	L	28.9	28.9	19.0	19.0
	I	23.3	23.3	15.3	15.3
Lovett	L	22.3	14.3	10.1	13.4
	I	17.6	12.6	8.2	12.5
Danskammer	L	0.3	0.3	0.7	0.7
	I	0.3	0.3	0.6	0.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-5.

Projected - All Plants
(Once - through)

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.2	0.1	0.3
	I	0.0	0.2	0.1	0.3
Yolksac larvae	L	0.3	2.1	0.7	5.8
	I	0.3	2.1	0.7	5.8
Post yolksac larvae	L	25.3	30.9	22.6	27.7
	I	23.5	28.9	21.0	25.9
Juveniles	L	50.5	68.3	27.4	37.8
	I	40.5	57.6	21.1	29.9
Combined	L	63.1	78.6	44.3	57.8
	I	54.7	70.6	38.2	51.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-6.

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.1	0.2
	I	0.0	0.1	0.1	0.2
Yolksac larvae	L	0.3	0.2	0.6	0.6
	I	0.3	0.2	0.6	0.6
Post yolksac larvae	L	22.2	25.3	20.0	22.9
	I	20.7	23.5	18.6	21.3
Juveniles	L	39.5	66.8	22.1	36.5
	I	30.9	56.1	16.8	28.9
Combined	L	53.0	75.3	38.1	51.4
	I	45.4	66.6	32.7	44.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-7.

Projected
(Closed - cycle)

Population: Bay anchovy

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	0.0	0.0	0.1	0.1
	I	0.0	0.0	0.1	0.1
Indian Pt 2&3	L	2.7	7.2	1.6	3.4
	I	2.7	7.2	1.6	3.4
Bowline	L	0.8	0.8	0.5	0.5
	I	0.8	0.8	0.5	0.5
Lovett	L	22.3	14.3	10.1	13.4
	I	17.6	12.6	8.2	12.5
Danskammer	L	0.3	0.3	0.7	0.7
	I	0.3	0.3	0.6	0.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-8.

Projected - All Plants
(Closed - cycle)

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.0	0.1
	I	0.0	0.1	0.0	0.1
Yolksac larvae	L	0.0	1.9	0.1	5.4
	I	0.0	1.9	0.1	5.4
Post yolksac larvae	L	5.4	9.6	4.6	8.1
	I	5.1	9.0	4.4	7.6
Juveniles	L	20.9	11.1	8.3	4.7
	I	16.3	9.9	6.4	4.1
Combined	L	25.2	21.3	12.7	17.3
	I	20.6	19.6	10.6	16.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix L-9.

Projected - Bowline, Indian Pt 2&3, Roseton
(Closed - cycle)

Population: Bay anchovy

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.0	0.0
	I	0.0	0.0	0.0	0.0
Yolksac larvae	L	0.0	0.0	0.0	0.0
	I	0.0	0.0	0.0	0.0
Post yolksac larvae	L	1.3	1.6	1.2	1.4
	I	1.3	1.6	1.2	1.4
Juveniles	L	2.2	6.4	1.0	2.5
	I	2.2	6.4	1.0	2.5
Combined	L	3.5	7.9	2.2	3.9
	I	3.5	7.9	2.2	3.9

L = 24-hr latent f-factors
I = Immediate f-factors

APPENDICES M-O

ETM RUN RESULTS
INCORPORATING THERMAL MODEL f-FACTORS

PREFACE TO APPENDICES M TO O

These appendices contain tabulations of ETM run results incorporating projected once-through power plant flow conditions and thermal model f-factors for three Hudson River fish populations:

Appendix	Population
M	Striped bass
N	White perch
O	*Alosa* spp. (blueback herring and alewife)

For each population, three tables are presented, each representing a different level of component thermal model f-factors used in the ETM runs:

Table	Contents
1	Component thermal model f-factors minus one standard error
2	Component thermal model f-factors
3	Component thermal model f-factors plus one standard error

ETM run results are presented for the 1974 and 1975 data base years in each table. For each data base year, the ETM run results are tabulated by GBC and MU W-factors, and immediate and 24-hr latent f-factors.

Appendix M-1.1

Projected
(Once - through)

Striped bass - LOWER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	1.3	1.9	1.1	1.6
	I	1.0	1.5	0.7	1.1
Indian Pt 2&3	L	7.8	6.5	10.2	8.3
	I	5.6	4.7	7.3	6.0
Bowline	L	1.1	1.1	1.5	1.5
	I	0.5	0.5	0.7	0.7
Lovett	L	3.4	0.6	4.6	0.8
	I	2.8	0.5	3.8	0.6
Danskammer	L	0.3	0.5	0.2	0.4
	I	0.2	0.3	0.1	0.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-1.2

Projected - All Plants
(Once - through)

Striped bass - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.4	1.7	1.2	1.5
	I	1.4	1.7	1.2	1.5
Yolksac larvae	L	1.5	1.4	1.5	1.1
	I	1.5	1.4	1.5	1.1
Post yolksac larvae	L	9.0	5.7	12.0	7.2
	I	6.3	3.6	8.5	4.7
Juveniles	L	2.0	2.0	2.8	2.8
	I	0.8	0.8	1.3	1.3
Combined	L	13.4	10.4	16.8	12.2
	I	9.8	7.3	12.2	8.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-1.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Striped bass - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.3	1.6	1.1	1.4
	I	1.3	1.6	1.1	1.4
Yolksac larvae	L	1.2	1.1	1.2	0.9
	I	1.2	1.1	1.2	0.9
Post yolksac larvae	L	6.0	5.1	8.0	6.5
	I	3.9	3.3	5.2	4.3
Juveniles	L	1.9	1.9	2.7	2.7
	I	0.8	0.8	1.3	1.3
Combined	L	10.0	9.3	12.5	11.1
	I	7.0	6.6	8.6	7.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-2.1

Projected
(Once - through)

Striped bass - MIDDLE f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	2.1	2.9	1.7	2.4
	I	1.5	2.1	1.1	1.6
Indian Pt 2&3	L	11.6	9.6	15.3	12.6
	I	8.2	6.8	11.0	9.0
Bowline	L	2.0	2.0	2.7	2.7
	I	0.8	0.8	1.1	1.1
Lovett	L	4.4	1.0	6.0	1.3
	I	3.6	0.7	4.9	0.9
Danskammer	L	0.6	0.9	0.4	0.6
	I	0.3	0.4	0.1	0.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-2.2

Projected - All Plants
(Once - through)

Striped bass - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.4	1.7	1.2	1.5
	I	1.4	1.7	1.2	1.5
Yolksac larvae	L	2.5	2.3	2.4	1.8
	I	2.1	2.0	2.1	1.6
Post yolksac larvae	L	12.3	8.1	16.3	10.3
	I	8.9	5.5	12.1	7.1
Juveniles	L	4.5	4.5	6.2	6.2
	I	1.8	1.8	2.9	2.9
Combined	L	19.5	15.7	24.4	18.7
	I	13.8	10.5	17.4	12.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-2.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Striped bass - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.3	1.6	1.1	1.4
	I	1.3	1.6	1.1	1.4
Yolksac larvae	L	2.0	1.8	2.0	1.5
	I	1.7	1.5	1.7	1.3
Post yolksac larvae	L	8.6	7.3	11.4	9.4
	I	5.9	5.0	8.0	6.6
Juveniles	L	4.1	4.1	5.7	5.7
	I	1.7	1.7	2.7	2.7
Combined	L	15.2	14.0	19.1	17.0
	I	10.3	9.5	13.0	11.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-3.1

Projected
(Once - through)

Striped bass - UPPER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	3.0	4.1	2.5	3.3
	I	2.1	3.0	1.7	2.4
Indian Pt 2&3	L	15.5	12.9	20.6	17.1
	I	11.2	9.2	15.2	12.5
Bowline	L	3.1	3.1	4.2	4.2
	I	1.3	1.3	1.9	1.9
Lovett	L	5.5	1.4	7.4	1.8
	I	4.4	1.0	6.0	1.2
Danskammer	L	1.1	1.6	0.8	1.1
	I	0.7	1.0	0.4	0.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-3.2

Projected - All Plants
(Once - through)

Striped bass - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.4	1.7	1.2	1.5
	I	1.4	1.7	1.2	1.5
Yolksac larvae	L	3.5	3.2	3.4	2.6
	I	2.7	2.5	2.7	2.0
Post yolksac larvae	L	15.7	10.9	20.7	13.6
	I	12.0	8.0	16.0	10.1
Juveniles	L	7.5	7.5	10.2	10.2
	I	3.6	3.6	5.3	5.3
Combined	L	25.9	21.6	32.1	25.6
	I	18.6	14.9	23.6	17.9

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix M-3.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Striped bass - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	1.3	1.6	1.1	1.4
	I	1.3	1.6	1.1	1.4
Yolksac larvae	L	2.8	2.5	2.8	2.1
	I	2.2	1.9	2.2	1.6
Post yolksac larvae	L	11.1	9.5	14.8	12.3
	I	8.1	6.9	11.0	9.1
Juveniles	L	6.9	6.9	9.4	9.4
	I	3.3	3.3	5.0	5.0
Combined	L	20.6	19.1	25.9	23.3
	I	14.2	13.1	18.2	16.2

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-1.1

Projected
(Once - through)

White perch - LOWER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	2.1	2.3	1.8	2.4
	I	1.8	2.0	1.3	1.8
Indian Pt 2&3	L	8.5	8.9	7.0	6.4
	I	8.3	8.7	6.5	5.9
Bowline	L	4.1	4.1	1.0	1.0
	I	4.0	4.0	0.8	0.8
Lovett	L	0.9	0.3	0.9	0.3
	I	0.9	0.3	0.8	0.3
Danskammer	L	0.1	0.4	0.3	1.2
	I	0.0	0.3	0.1	1.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-1.2

Projected - All Plants
(Once - through)

White perch - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.5	7.3	0.9	2.6
	I	5.5	7.3	0.9	2.6
Yolksac larvae	L	0.7	0.6	0.6	0.6
	I	0.7	0.6	0.6	0.6
Post yolksac larvae	L	8.7	7.5	7.7	6.5
	I	8.7	7.5	7.7	6.5
Juveniles	L	0.8	0.8	1.7	1.7
	I	0.1	0.1	0.2	0.2
Combined	L	15.0	15.4	10.7	11.0
	I	14.5	14.8	9.3	9.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-1.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

White perch - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.4	6.9	0.8	1.6
	I	5.4	6.9	0.8	1.6
Yolksac larvae	L	0.6	0.6	0.5	0.5
	I	0.6	0.6	0.5	0.5
Post yolksac larvae	L	8.1	7.3	7.1	6.4
	I	8.1	7.3	7.1	6.4
Juveniles	L	0.6	0.6	1.4	1.4
	I	0.0	0.0	0.1	0.1
Combined	L	14.1	14.7	9.6	9.6
	I	13.6	14.2	8.5	8.4

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-2.1

Projected
(Once - through)

White perch - MIDDLE f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	3.1	3.3	2.9	3.5
	I	2.5	2.7	1.9	2.5
Indian Pt 2&3	L	11.2	11.3	10.0	9.1
	I	10.8	10.9	9.1	8.2
Bowline	L	4.3	4.3	1.3	1.3
	I	4.1	4.1	0.9	0.9
Lovett	L	1.2	0.4	1.2	0.5
	I	1.2	0.4	1.1	0.4
Danskammer	L	0.3	0.6	0.5	1.5
	I	0.1	0.4	0.2	1.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-2.2

Projected - All Plants
(Once - through)

White perch - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.5	7.3	0.9	2.6
	I	5.5	7.3	0.9	2.6
Yolksac larvae	L	1.1	1.0	1.0	0.9
	I	0.9	0.8	0.9	0.8
Post yolksac larvae	L	11.7	10.0	10.4	8.8
	I	11.7	10.0	10.4	8.8
Juveniles	L	1.7	1.7	3.6	3.6
	I	0.5	0.5	0.9	0.9
Combined	L	18.9	18.8	15.3	15.2
	I	17.8	17.7	12.8	12.7

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-2.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

White perch - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.4	6.9	0.8	1.6
	I	5.4	6.9	0.8	1.6
Yolksac larvae	L	0.9	0.9	0.9	0.9
	I	0.8	0.8	0.8	0.8
Post yolksac larvae	L	10.9	9.8	9.6	8.6
	I	10.9	9.8	9.6	8.6
Juveniles	L	1.4	1.4	3.0	3.0
	I	0.3	0.3	0.7	0.7
Combined	L	17.7	18.0	13.8	13.5
	I	16.7	17.0	11.7	11.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-3.1

Projected
(Once - through)

White perch - UPPER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	4.2	4.4	4.3	4.8
	I	3.5	3.7	3.0	3.6
Indian Pt 2&3	L	13.7	13.5	12.8	11.7
	I	13.1	12.9	11.6	10.5
Bowline	L	4.5	4.5	1.8	1.8
	I	4.2	4.2	1.2	1.2
Lovett	L	1.5	0.5	1.6	0.6
	I	1.5	0.5	1.5	0.5
Danskammer	L	0.8	1.1	1.0	2.0
	I	0.5	0.8	0.6	1.5

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-3.2

Projected - All Plants
(Once - through)

White perch - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.5	7.3	0.9	2.6
	I	5.5	7.3	0.9	2.6
Yolksac larvae	L	1.5	1.4	1.5	1.3
	I	1.2	1.1	1.1	1.0
Post yolksac larvae	L	14.8	12.7	13.1	11.1
	I	14.8	12.7	13.1	11.1
Juveniles	L	2.9	2.9	6.1	6.1
	I	1.3	1.3	2.7	2.7
Combined	L	23.1	22.5	20.3	19.7
	I	21.5	21.0	17.1	16.6

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix N-3.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

White perch - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	5.4	6.9	0.8	1.6
	I	5.4	6.9	0.8	1.6
Yolksac larvae	L	1.3	1.3	1.3	1.3
	I	1.0	1.0	1.0	1.0
Post yolksac larvae	L	13.5	12.2	11.9	10.6
	I	13.5	12.2	11.9	10.6
Juveniles	L	2.4	2.4	5.1	5.1
	I	1.1	1.1	2.2	2.2
Combined	L	21.2	21.2	18.1	17.5
	I	19.8	19.9	15.4	14.8

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix 0-1.1

Projected
(Once - through)

Alosa spp. - LOWER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	1.7	2.2	1.9	3.7
	I	1.7	2.2	1.9	3.7
Indian Pt 2&3	L	0.9	0.9	0.5	0.6
	I	0.9	0.9	0.5	0.6
Bowline	L	0.2	0.2	0.0	0.0
	I	0.2	0.2	0.0	0.0
Lovett	L	0.1	0.1	0.0	0.1
	I	0.1	0.1	0.0	0.1
Danskammer	L	0.7	0.5	0.8	3.8
	I	0.7	0.5	0.8	3.8

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-1.2

Projected - All Plants
(Once - through)

Alosa spp. - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.2	4.9
	I	0.0	0.1	0.2	4.9
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	1.1	0.7	1.2	0.8
	I	1.1	0.7	1.2	0.8
Juveniles	L	2.4	3.0	1.8	2.4
	I	2.4	3.0	1.8	2.4
Combined	L	3.6	3.8	3.2	8.0
	I	3.6	3.8	3.2	8.0

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-1.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Alosa spp. - LOWER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.1	1.6
	I	0.0	0.0	0.1	1.6
Yolksac larvae	L	0.0	0.0	0.0	0.1
	I	0.0	0.0	0.0	0.1
Post yolksac larvae	L	0.9	0.6	0.9	0.6
	I	0.9	0.6	0.9	0.6
Juveniles	L	1.9	2.7	1.3	2.1
	I	1.9	2.7	1.3	2.1
Combined	L	2.8	3.3	2.4	4.3
	I	2.8	3.3	2.4	4.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-2.1

Projected
(Once - through)

Alosa spp. - MIDDLE f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	2.6	3.7	2.8	5.2
	I	2.0	2.6	2.2	4.1
Indian Pt 2&3	L	1.9	2.0	1.2	1.4
	I	1.4	1.6	1.0	1.2
Bowline	L	0.4	0.4	0.1	0.1
	I	0.3	0.3	0.1	0.1
Lovett	L	0.2	0.2	0.1	0.1
	I	0.1	0.1	0.1	0.1
Danskammer	L	1.2	0.7	1.3	4.0
	I	0.9	0.6	1.0	3.8

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-2.2

Projected - All Plants
(Once - through)

Alosa spp. - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.2	4.9
	I	0.0	0.1	0.2	4.9
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	1.8	1.5	1.9	1.6
	I	1.8	1.5	1.9	1.6
Juveniles	L	4.4	5.4	3.2	4.3
	I	2.8	3.5	2.1	2.8
Combined	L	6.2	6.9	5.3	10.5
	I	4.7	5.1	4.2	9.1

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-2.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Alosa spp. - MIDDLE f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.1	1.6
	I	0.0	0.0	0.1	1.6
Yolksac larvae	L	0.0	0.0	0.1	0.1
	I	0.0	0.0	0.1	0.1
Post yolksac larvae	L	1.4	1.2	1.5	1.3
	I	1.4	1.2	1.5	1.3
Juveniles	L	3.4	4.8	2.4	3.8
	I	2.2	3.2	1.5	2.5
Combined	L	4.8	6.0	4.0	6.6
	I	3.6	4.4	3.2	5.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-3.1

Projected
(Once - through)

Alosa spp. - UPPER f-factor values

Plant	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Roseton	L	2.9	4.1	3.1	5.7
	I	2.3	3.0	2.5	4.5
Indian Pt 2&3	L	2.4	2.7	1.8	2.1
	I	2.0	2.2	1.6	1.9
Bowline	L	0.5	0.5	0.1	0.1
	I	0.4	0.4	0.1	0.1
Lovett	L	0.2	0.2	0.1	0.1
	I	0.2	0.2	0.1	0.1
Danskammer	L	1.4	0.8	1.5	4.1
	I	1.1	0.7	1.1	3.9

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-3.2

Projected - All Plants
(Once - through)

Alosa spp. - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.1	0.2	4.9
	I	0.0	0.1	0.2	4.9
Yolksac larvae	L	0.1	0.1	0.1	0.1
	I	0.1	0.1	0.1	0.1
Post yolksac larvae	L	2.5	2.2	2.7	2.4
	I	2.5	2.2	2.7	2.4
Juveniles	L	4.9	6.0	3.6	4.8
	I	3.2	4.1	2.4	3.3
Combined	L	7.4	8.2	6.5	11.7
	I	5.8	6.3	5.3	10.3

L = 24-hr latent f-factors
I = Immediate f-factors

Appendix O-3.3

Projected - Bowline, Indian Pt 2&3, Roseton
(Once - through)

Alosa spp. - UPPER f-factor values

Life stage	f	1974 GBC	1974 MU	1975 GBC	1975 MU
Eggs	L	0.0	0.0	0.1	1.6
	I	0.0	0.0	0.1	1.6
Yolksac larvae	L	0.0	0.0	0.1	0.1
	I	0.0	0.0	0.1	0.1
Post yolksac larvae	L	2.0	1.9	2.2	2.0
	I	2.0	1.9	2.2	2.0
Juveniles	L	3.8	5.4	2.6	4.3
	I	2.6	3.7	1.8	2.9
Combined	L	5.8	7.2	4.9	7.8
	I	4.6	5.5	4.1	6.5

L = 24-hr latent f-factors
I = Immediate f-factors

APPENDIX P

INCORPORATION OF SUBLETHAL EFFECTS AND INDIRECT MORTALITY IN MODELING POPULATION-LEVEL IMPACTS OF POWER-PLANT ENTRAINMENT

Joint Testimony of

Webster Van Winkle, Ph.D.

and

Sigurd W. Christensen, Ph.D.

Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

APPENDIX P

INCORPORATION OF SUBLETHAL EFFECTS AND INDIRECT MORTALITY IN MODELING POPULATION-LEVEL IMPACTS OF POWER-PLANT ENTRAINMENT

This testimony is submitted by Dr. Webster Van Winkle and Dr. Sigurd W. Christensen. The objectives of the testimony are (1) to summarize the principal findings and conclusions contained in a report prepared for the U.S. Nuclear Regulatory Commission entitled "Incorporation of Sublethal Effects and Indirect Mortality in Modeling Population-Level Impacts of a Stress, with an Example Involving Power-plant Entrainment and Striped Bass" (ORNL/NUREG/TM-228); (2) to review the utilities' position with respect to the incorporation of sublethal effects and indirect mortality in estimating the cropping factor (f_c) and in modeling population-level impacts of entrainment; and (3) to present an alternative to the utilities' position, which better reflects the results of research in the area of sublethal effects and indirect mortality, and which has been used in EPA's direct testimony in estimating f_c for all species and in modeling the population-level impacts of entrainment on the Hudson River American shad, Atlantic tomcod, bay anchovy, striped bass, and white perch populations.

PRINCIPAL FINDINGS AND CONCLUSIONS FROM ORNL/NUREG/TM-288

ORNL/NUREG/TM-288 was prepared jointly by Drs. Van Winkle and Christensen. The experiments on sublethal effects of heat shock on feeding of striped bass larvae were performed jointly by Drs. Van Winkle and Christensen, with the assistance of Dr. J. Samuel Suffern, at Oak Ridge National Laboratory during May and June of 1977. ORNL/NUREG/TM-288 indicates the following:

(1) When direct mortality due to entrainment is less than 100%, it is important to estimate indirect mortality.

(2) An equation is derived for the conditional mortality rate due to a stress, with power plant entrainment as the example, that incorporates both direct and indirect mortality.

(3) Preliminary experiments to test for sublethal effects of heat shock on the feeding of striped bass (Morone saxatilis) larvae suggest that striped bass larvae are less likely to feed following heat shocks of the type used in these experiments. However, the results also suggest that once they do start feeding, the amount eaten is not substantially influenced by the preceding heat shock.

(4) Although the results from these experiments are preliminary, the methodology of estimating a conditional mortality rate from such results is clear, as are some of the problems of extrapolating from sublethal effects to indirect mortality.

(5) A conceptual framework is diagramed for considering interactions between stressed individuals at one trophic level with those at the next lower and higher trophic levels, particularly with reference to power plant entrainment as the source of stress. The diagram requires modification in going from uncontrolled field studies to controlled experimental studies designed to test hypotheses and estimate conditional mortality rates associated with a stress.

(6) The use of application factors in modeling population-level impacts is recommended, based on the same rationale that justifies the use of application factors in setting effluent and water-quality standards.

REVIEW OF UTILITIES' POSITION

The utilities' direct case with respect to consideration of sublethal effects and indirect mortality in estimating cropping factors (f_c) and in modeling population-level impacts of entrainment is almost nonexistent. This is evident from an examination of the following two documents, which are the two most logical and appropriate documents in which this topic should be considered.

(1) Exhibit UT-11, entitled "Survival of Entrained Ichthyoplankton and Macroinvertebrates at Hudson River Power Plants." There is no mention of sublethal effects or indirect mortality due to entrainment for any species in this recent (July 1977) report by Ecological Analysts.

(2) Exhibit UT-3, Section 3-IV-D-2-d, entitled "Entrainment mortality, the f_c factor." It is indicated (p. 3-IV-58) that hatching success of striped bass eggs collected at the discharge stations was significantly lower than at the intake stations at Indian Point in 1974, but not in 1975. This indirect mortality is included in estimating f_c for striped bass eggs for 1974. However, there is no mention of indirect entrainment mortality for striped bass larvae and early juveniles. By omission the implications are that indirect entrainment mortality for these life stages is negligible, and that thus, it can be ignored in modeling population-level impacts of entrainment using the real-time life-cycle model.

In summary, with the one exception of considering hatching success of striped bass eggs in 1974, the utilities' direct case completely ignores sublethal effects and indirect mortality in estimating f_c and in modeling population-level impacts of entrainment.

During EPA's cross examination of the utilities' panel of expert witnesses on the cropping factor, consisting of Drs. Englert, Jinks, Lauer, and O'Connor, the following points were established:

(1) If entrained organisms have a competitive disadvantage in feeding, if they then become smaller than their congeners (i.e., other young-of-the-year organisms of the same age and species), and if consequently, they have a lower survival than their congeners, then a measure of power plant mortality which was limited to direct mortality would understate actual power plant-induced mortality. (Transcript p. 8788)

(2) Accelerated rates of predation on entrained organisms, if they occur, represent an indirect effect of entrainment that would not occur but for the power plant. (Transcript p. 8791)

(3) If there is a tendency of entrained organisms to have a higher susceptibility to bacterial, fungal, and parasitic diseases, and if those effects either take longer than 96 hours to show up, or require reentry into the river environment to occur, then whatever the magnitude of that effect, it would not be reflected by the utilities' assessment of the mortality caused by the power plants. (Transcript p. 8794)

(4) If organisms subject to entrainment were more vulnerable in the sense of survival potential to certain environmental stresses (e.g., pollutants (Transcript p. 8796), oxygen (Transcript p. 8797), temperature (Transcript p. 8800), and salinity (Transcript p. 8800), then the utilities' method of calculating entrainment mortality caused by the power plant would fail to reflect this source of mortality, whatever its magnitude. (Transcript p. 8795)

EPA'S POSITION

Based on the information in ORNL/NUREG/TM-288 and a careful review of recent open-literature publications dealing with sublethal effects and indirect mortality due to environmental stresses Coutant et al., 1979; Deacutis, 1978; Ginn et al., 1978 , EPA's position with respect to including indirect mortality in estimating the cropping factor (f_c) and in modeling population-level impacts of entrainment is as follows:

(1) The conditional rate of indirect entrainment mortality (m_I) is almost certainly greater than 0.0. The question is, how much greater than 0.0 is it?

(2) As indicated in numerous other places in EPA's direct case, when faced with uncertainty we feel that the most scientifically justifiable course of action is to select a range of values, based on professional judgment, which has a reasonably high probability of including the true value of a parameter.

(3) For all entrainable life stages of all species at all power plants, we have assumed that m_I is proportional to m_D, that is, $m_I = k\ m_D$, where k is the proportionality constant. In keeping with Item (2) above, we have selected the following values of k: lower estimate = 0.0; upper estimate = 0.2; and best estimate = 0.1. The best estimate value of 0.1 means that m_I is assumed to be 10% of m_D.

(4) These calculated values for m_I have been used in models to estimate the conditional mortality rate due to entrainment (m_E) and entrainment and impingement combined (m_T) and to estimate long-term population-level impacts of power plant operation.

REFERENCES CITED

Coutant, C. C., R. B. McLean, and D. L. DeAngelis. 1979. Influences of physical and chemical alterations on predator-prey interactions. pp. 57-68. IN H. Clepper (ed.)., Predator-Prey Systems in Fisheries Management, Sport Fishing Institute, Washington, D. C.

Deacutis, C. F. 1978. Effect of thermal shock on predator avoidance by larvae of two fish species. Trans. Am. Fish. Soc. 107(4):632-635.

Exhibit UT-3. McFadden, J. T., and J. P. Lawler (eds.). 1977. Supplement I to 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. Submitted to Consolidated Edison Company of New York, Inc.

Exhibit UT-11. Ecological Analysts, Inc. (EA). 1977. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc.

Ginn, T. C., G. V. Poje, and J. M. O'Connor. 1978. Survival of planktonic organisms following passage through a simulated power plant condenser tube. pp. 91-101. In L. D. Jensen (ed.), Fourth National Workshop on Entrainment and Impingement, EA Communications, A Division of Ecological Analysts, Inc., Melville, New York.

Van Winkle, W., S. W. Christensen, and J. S. Suffern. 1979. Incorporation of sublethal effects and indirect mortality in modeling population-level impacts of a stress, with an example involving power-plant entrainment and striped bass. ORNL/NUREG/TM-288. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

NUREG/CR-2220
Volume I
ORNL/NUREG/TM-385/V1
Distribution Category-RE

INTERNAL DISTRIBUTION

1. S. M. Adams
2. S. I. Auerbach
3-5. L. W. Barnthouse
6. S. M. Bartell
7. J. E. Breck
8. G. F. Cada
9. J. B. Cannon
10-12. S. W. Christensen
13. C. C. Coutant
14. D. L. DeAngelis
15. M. P. Farrell
16. S. G. Hildebrand
17. D. W. Lee
18. J. M. Loar
19. A. L. Lotts
20. R. B. McLean
21. R. M. Rush
22. D. E. Reichle
23. J. A. Solomon
24. W. Van Winkle
25-26. D. S. Vaughan
27. N. D. Vaughan
28. G. T. Yeh
29. H. E. Zittel
30. Central Research Library
31-41. ESD Library
42-43. Laboratory Records Dept.
44. Laboratory Records, ORNL-RC
45. ORNL Y-12 Technical Library
46. ORNL Patent Office

EXTERNAL DISTRIBUTION

47. P. Reed, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555
48. Office of Assistant Manager for Energy Research and Development, DOE-ORO
49-50. Technical Information Center, Oak Ridge, TN 37830
51-265. NRC distribution - RE (Environmental Research)

SPECIAL DISTRIBUTION BY NRC

266. J. H. Balletto, Licensing and Environment Department, Public Service Electric and Gas Company, 80 Park Plaza, Newark, NJ 07101
267. H. L. Bergman, Department of Zoology and Physiology, The University of Wyoming, University Station, P.O. Box 3166, Laramie, WY 82071
268. K. E. Biesinger, Environmental Research Laboratory - Duluth, 6201 Congdon Blvd., Duluth, MN 55804
269. C. W. Billups, U.S. Nuclear Regulatory Commission, Washington, DC 20555
270-280. J. G. Boreman, Northeast Fisheries Center, National Marine Fisheries Service, Woods Hole, MA 02543
281. W. H. Bossert, Harvard University, Cambridge, MA 02138
282. R. W. Brocksen, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303
283. H. W. Brown, American Electric Power Service Corporation, P.O. Box 487, Canton, OH 44701

284. E. J. Carpenter, Marine Sciences Research Center, State University of New York, Stony Brook, NY 11794
285. H. K. Chadwick, California Department of Fish and Game, 3900 N. Wilson Way, Stockton, CA 95204
286. C. Chen, Tetra Tech, Inc., 3700 Mt. Diablo Blvd., LaFayette, CA 94549
287. B. Cohen, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, Room 845, New York, NY 10278
288. William J. Coppoc, Texaco, Inc., P.O. Box 509, Beacon, NY 12508
289. M. J. Dadswell, Biological Station, Fisheries and Oceans Canada, St. Andrews, New Brunswick, CANADA
290. R. Deriso, International Pacific Halibut Commission, P.O. Box 5009, University Station, Seattle, WA 98105
291. D. J. Dunning, Power Authority of the State of New York, 10 Columbus Circle, New York, NY 10019
292. Ecological Analysts, Inc., Library, R.D. 2, Goshen Turnpike, Middletown, NY 10940
293. C. Edwards, International Joint Commission, Regional Office, 100 Ouellette Avenue, Windsor, Ontario N9A 6T3, CANADA
294. T. Englert, Lawler, Matusky, and Skelly Engineers, 415 Route 303, Tappan, NY 10983
295. T. K. Fikslin, U.S. Environmental Protection Agency, Woodbridge Avenue, Edison, NJ 08817
296. R. I. Fletcher, Center for Quantitative Science, University of Washington, Seattle, WA 98195
297. T. D. Fontaine, III, Savannah River Ecology Laboratory, Drawer E, Aiken, SC 29801
298. A. A. Galli, U.S. Environmental Protection Agency, Mail Code R.D. 682, Washington, DC 20460
299. H. Gluckstern, Regional Counsel and Enforcement Division, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, Room 441, New York, NY 10278
300. R. A. Goldstein, Electric Power Research Institute, P.O. Box 10412, Palo Alto, CA 94303
301. J. Golumbek, Energy and Thermal Wastes Section, Water Division, U.S. Environmental Protection Agency, Region II, New York, NY 10278
302. C. P. Goodyear, National Fish Center-Leetown, U.S. Fish and Wildlife Service, Route 3, P.O. Box 41, Kearnysville, WV 25430
303. P. A. Hackney, Division of Forestry, Fisheries, and Wildlife Development, Tennessee Valley Authority, Norris, TN 37828
304. D. H. Hamilton, Office of Health and Environmental Research, Department of Energy, Germantown, MD 20767
305. R. Henshaw, Bureau of Environmental Protection, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233
306. C. Hickey, U.S. Nuclear Regulatory Commission, Washington, DC 20555
307. E. G. Horn, Chief, Bureau of Environmental Protection, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233

308. T. Horst, Environmental Engineering Division, Stone and Webster Engineering Corp., 225 Franklin St., Boston, MA 02107
309. T. Huggins, Central Hudson Gas and Electric Corporation, 284 South Avenue, Poughkeepsie, NY 12602
310. J. B. Hutchison, Jr., Orange and Rockland Utilities, Inc., 75 West Rt. 59, Spring Valley, NY 10977
311. W. L. Kirk, Consolidated Edison, 4 Irving Place, New York, NY 10003
312. R. J. Klauda, Applied Physics Laboratory, The Johns Hopkins University, Johns Hopkins Road, Laurel, MD 20810
313. L. C. Kohlenstein, Applied Physics Laboratory, The Johns Hopkins University, Johns Hopkins Road, Laurel, MD 20810
314. G. J. Lauer, Ecological Analysts, Inc., R.D. 2, Goshen Turnpike, Middletown, NY 10940
315. S. A. Levin, Section of Ecology and Systematics, Bldg. No. 6, Langmuir Laboratory, Cornell University, Ithaca, NY 14850
316. R. Levins, Harvard School of Public Health, Harvard University, Boston, MA 02115
317. S. Lewis, U.S. Nuclear Regulatory Commission, Office of the Executive Legal Director, Washington, DC 20555
318. F. Locicero, Technical Resources Branch, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, New York, NY 10278
319. Helen McCammon, Director, Division of Ecological Research, Office of Health and Environmental Research, Department of Energy, Washington, DC 20545
320. D. McKenzie, Ecosystems Dept., Battelle Pacific Northwest Laboratory, Richland, WA 99352
321. G. Milburn, U.S. Environmental Protection Agency, Region V, Enforcement Division, 230 S. Dearborn St., Chicago, IL 60604
322. S. Moore, Resources Management Associates, 3706 Mt. Diablo Blvd., LaFayette, CA 94549
323. M. Mulkey, Office of the General Counsel, U.S. Environmental Protection Agency, 4th and M Street, SW, Washington, DC 20460
324. W. Muller, New York Institute of Technology, Old Westbury, NY 11568
325. Haydn H. Murray, Director, Department of Geology, Indiana University, Bloomington, IN 47405
326. J. V. Nabholz, Office of Toxic Substances, Environmental Review Division, Environmental Protection Agency, 401 M Street, SW, Washington, DC 20545
327. William S. Osburn, Jr., Division of Ecological Research, Office of Health and Environmental Research, Department of Energy, Washington, DC 20545
328. C. H. Pennington, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39180
329. T. T. Polgar, Martin Marietta Laboratories, 1450 S. Rolling Rd., Baltimore, MD 21227
330. D. Policansky, University of Massachusetts, Boston, MA 02125
331. E. M. Portner, The Johns Hopkins University, Applied Physics Laboratory, Johns Hopkins Rd., Laurel, MD 20810

332. E. Radle, Bureau of Environmental Protection, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, NY 12233
333. P. Rago, School of Natural Resources, University of Michigan, Ann Arbor, MI 48109
334. W. E. Ricker, Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, British Columbia V9R 5K6, CANADA
335. Paul G. Risser, Office of the Chief, Illinois Natural History Survey, Natural Resources Building, 607 E. Peabody Ave., Champaign, IL 61820
336. D. S. Robson, Biometrics Unit, Cornell University, Ithaca, NY 14850
337. F. J. Rohlf, State University of New York, Stony Brook, NY 11790
338. Q. E. Ross, Power Authority of the State of New York, 10 Columbus Circle, New York, NY 10019
339. S. Saila, Department of Zoology, University of Rhode Island, Kingston, RI 02881
340. E. Santoro, Technical Resources Branch, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, New York, NY 10278
341. W. E. Schaaf, Atlantic Estuarine Fisheries Center, National Marine Fisheries Service, Beaufort, NC 28516
342. C. N. Shuster, Jr., Office of Energy Systems, Federal Energy Regulatory Commission, 825 N. Capitol St., Washington, DC 20426
343. M. P. Sissenwine, National Marine Fisheries Service, Woods Hole, MA 02543
344. P. N. Skinner, New York State Law Department, Two World Trade Center, New York, NY 10047
345. L. B. Slobodkin, State University of New York, Stony Brook, NY 11790
346. J. Strong, Regional Counsel and Enforcement Division, U.S. Environmental Protection Agency, Region II, 26 Federal Plaza, Room 441, New York, NY 10278
347. J. S. Suffern, 15 Loveton Circle, Sparks, MD 21152
348. G. Swartzman, Center for Quantitative Science, University of Washington, Seattle, WA 98195
349. L. Tebo, U.S. Environmental Protection Agency, Southeast Environmental Research Laboratory, College Station Road, Athens, GA 30601
350. K. W. Thornton, Environmental Laboratory, United States Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS 39180
351. C. J. Walton, Maine Department of Marine Resources, Fisheries Research Laboratory, West Boothbay Harbor, ME 04575
352. R. L. Watters, Division of Ecological Research, Office of Health and Environmental Research, Department of Energy, Washington, DC 20546
353. A. W. Wells, Ichthyological Associates, Inc., Delaware River Ecological Study, 100 South Cass St., Middletown, DE 19709

354. Frank J. Wobber, Division of Ecological Research, Office of Health and Environmental Research, Department of Energy, Mail Stop E201, Washington, DC 20545
355. Robert W. Wood, Director, Division of Pollutant Characterization and Safety Research, Department of Energy, Washington, DC 20545

* U.S. GOVERNMENT PRINTING OFFICE: 1981-548-067/367