**A Computer Simulation Model for the
STRIPED BASS YOUNG-OF-THE-YEAR POPULATION
in the
HUDSON RIVER**

**A. H. Eraslan, W. Van Winkle, R. D. Sharp, S. W. Christensen,
C. P. Goodyear, R. M. Rush, and W. Fulkerson**

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ENERGY DIVISION
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A COMPUTER SIMULATION MODEL FOR THE STRIPED BASS YOUNG-OF-THE-YEAR POPULATION IN THE HUDSON RIVER

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ABSTRACT

This report presents a daily transient (tidal-averaged), longitudinally one-dimensional (cross-section-averaged) computer simulation model for the assessment of the entrainment and impingement impacts of power plant operations on young-of-the-year populations of the striped bass, *Morone saxatilis*, in the Hudson River.

The model considers six life-stage populations (i.e., egg, yolk-sac larva, post-yolk-sac larva, Juvenile I, Juvenile II, and Juvenile III). The choice of the particular life stages and their associated durations is based on information from the literature and from sampling programs in the Hudson River relating to the morphological, physiological, and behavioral characteristics of the striped bass young-of-the-year. The transfer of populations from earlier to later life stages is formulated in terms of apparent survival probabilities of life-stage populations and timewise continuous coefficients for growth and mortality rates. The continuous property of the formulation enables the model to represent realistically the simultaneous existence of different life-stage populations in the river.

To incorporate the existence of various mechanisms for biological compensation which might in part affect the young-of-the-year populations in the river, the formulation includes multiplicative factors which can separately vary the apparent survival probabilities, growth rate coefficients, and mortality rate coefficients of each life stage as a function of the population density of that life stage.

The dependence of various biological characteristics of the life stages on temperature and salinity is also considered in the model. The necessary information for the physical conditions is included as input data in the form of daily transient, longitudinal distributions along the river.

The model considers 152 river miles of the estuary from the Troy Dam to the Battery. This length is longitudinally segmented into 76 discrete elements, each 2 miles in length. The high spatial resolution assures the necessary accuracy in specifying the existing morphological characteristics and the flow conditions in the river which can affect the distributions of the life-stage populations and hence the conditions of entrainment and impingement at the power plants. The input data for the important geometric properties of the discrete elements (i.e., area, volume, depth, and surface width) are realistically determined using appropriate transect profiles obtained from maps of the Hudson River.

The mathematical system governing the model is based on the tidal-averaged and cross-section-averaged forms of the conservation principles for the water mass and the population number of each life stage in each discrete element. Consistent with the tidal-averaged assumption of the model, the longitudinal convective transfer of the life-stage populations is formulated in terms of the local net freshwater flow in the river. The necessary input data for the freshwater flow are determined from the daily flow rates observed at the Troy Dam, with appropriate modifications to approximately simulate the longitudinal distributions of freshwater flow resulting from the additional runoff in the Hudson River Basin.

Based on the physical conditions in the river and the biological characteristics of the striped bass young-of-the-year populations, the overall longitudinal transport phenomenon is rigorously formulated by considering three fundamental contributions: (a) tidal dispersion transport, (b) convective defect transport, and (c) migratory transport.

The tidal dispersion transport is formulated as though the organisms were passive. This approach determines the tidal-averaged longitudinal transport fluxes resulting from the vertical turbulent eddy diffusion phenomenon under periodic tidal flow conditions in an estuary. The ultimate longitudinal effects of the actual nonuniform distributions in the vertical and lateral directions of the axial velocity component and of the life-stage population densities result in a decreased net rate of movement downstream of the early life-stage populations. To simulate this aspect of reality, convective defect transport fluxes were included in the model. The associated coefficients were determined for each age group, based on a parametric study to obtain the best simulations of the observed 1973 longitudinal distributions of the life-stage populations in the river.

The longitudinal transport due to the migration of the juvenile life stages to the shoal areas along the estuary is modeled according to a formulation that represents a balance between the effects of shoaling preference and overcrowding. The representative geometric parameter for indicating the relative abundance of shoaling areas in a discrete element is defined as the ratio of the surface width to the maximum depth averaged over the 2-mile length of the element. This parameter is calculated from the detailed transect cross-sectional data for the estuary. The longitudinal migratory transport flux of a life stage is formulated as a linear combination of the gradient of shoal parameter and the gradient of the population density of the life stage.

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The rates of reduction of the life-stage populations by entrainment and impingement at the power plants are formulated by considering (a) the differences between the population densities entering the intakes and the average densities in the discrete elements, (b) avoidance factors (for Juveniles) based on temperature- and salinity-dependent mobility characteristics, (c) geometric factors for the intakes and the discharges, and (d) temperature-dependent survival probabilities of the life stages upon passage through the cooling water system of the power plants.

The general mathematical formulation of the model is a semidiscrete system of moderately coupled, quasi-linear, ordinary differential equations for the densities of the life-stage populations in the discrete elements. The system is numerically integrated by a fourth-order Runge-Kutta-Gill scheme with a time-step size based on a rigorous stability criterion for explicit finite difference methods. The initial conditions for the model are specified either as (a) no young-of-the-year population in the estuary, corresponding to the conditions at the start of the spawning period, or (b) for restart computational runs, life-stage population densities in all discrete elements, corresponding to longitudinal distributions in the river after spawning. The numerical solutions are obtained as extensions of the initial conditions to represent the daily averaged population densities for all life stages in all the discrete elements.

The model was employed to simulate the striped bass young-of-the-year populations from May through October 1973. Sufficient data for 1973 are available to represent the physical and biological conditions in the Hudson River; the May-October period was selected, since the entrainment impact, which is of greater magnitude and concern than the impingement impact, is confined to this period. The comparisons of numerical solutions from the model with summaries of the 1973 data indicate that the model is acceptable both from qualitative and quantitative considerations for simulating temporal and longitudinal distributions of the life-stage population densities in the estuary. The discrepancies between the computer simulations and the observed data for temporal variations of the net standing crops of the life stages in the river suggest inadequacies and inconsistencies in the sampling and reduction of the 1973 data.

FORTRAN listing of the associated computer code STRIPE is presented in the Appendix. Sample outputs are included to illustrate the various available forms of presentation of the numerical solutions.

1. INTRODUCTION

The Hudson River serves as one of the major estuarine systems along the eastern coast of North America for the spawning of striped bass. Under typical freshwater flow conditions in the Hudson during the spawning period in May and June, the spawning region extends approximately 30 to 100 miles upstream of the battery at New York City.

Existing and proposed electric power generating stations along the river circulate the river water at substantial flow rates through their condenser cooling systems. Since the early life stages of the striped bass do not have the ability to effectively avoid the intakes, the young-of-the-year populations become vulnerable to destruction at the power plants. Entrainment of the organisms exposes them to combined mechanical, thermal, and chemical stresses during passage through the cooling systems. Impingement of the larger young-of-the-year striped bass at the intake screens results in mechanical destruction. Hence the power plant operations impose an additional and man-made source of mortality on the young-of-the-year striped bass in the Hudson River.

Successive yearly reductions in the striped bass young-of-the-year populations could subsequently affect the adult population and probably result in an impact on the overall striped bass fishery. The assessment of the long-term (longer than one year) damage to the adult population requires a model for the entire striped bass life cycle. All adult life-cycle models (e.g., Lawler [1,2,3] and Van Winkle et al. [4]) require values for the yearly reduction in the young-of-the-year populations in order to estimate the ultimate impact of the power plant operations on the striped bass population and fishery. Hence, although the striped bass life-cycle models determine the long-term biological and economic impact on the fishery, it is also necessary to employ reliable models that can predict the short-term impact of the power plant operations on the young-of-the-year populations in the Hudson River.

The quantitative assessment of the entrainment and impingement impact of the power plants on the young-of-the-year populations requires mathematical models that incorporate in their general formulations both the biological characteristics of the striped bass life stages and the physical transport conditions which affect the movement of the populations in the estuary. A mathematical model which complies with these criteria was developed by Lawler [1,2,3] for the assessment of the impact of the Indian Point Station. The model was based on the daily transport (tidal-period-averaged), longitudinally one-dimensional (cross-section-averaged), freshwater flow convective (tidal-flow-averaged), and mesoscale transportive (tidal-dispersive) system of partial differential equations for constituent mass concentrations. An earlier version of this model was originally used by Lawler in his previous studies of the water quality conditions in the Hudson River [5,6]. A recruitment model was proposed by Goodyear [7] based on daily cohort populations for the life stages in segments of specified lengths along the estuary. The model included the standard formulation of the downstream, freshwater convection (tidal-flow-averaged). It also approximated the overall effects of the vertical and lateral variations of population densities and the mesoscale longitudinal transport (tidal dispersion) as a combined phenomenon based on a daily averaged two-layer flow concept for partially mixed estuaries.

The basic mathematical systems of the aforementioned models, which were developed specifically for the striped bass young-of-the-year populations in the Hudson River, possess certain properties that are common to more extensive models for biological species in general. The population transport phenomenon associated with the two-dimensional distributions of biological species was first considered by Skellum [8] based on a random dispersal hypothesis. Further studies by Landahl [9,10], Barakat [11], and Thompson and Weiss [12] extended the population dispersal formulations to incorporate the nonlinear effects of population growth functions (e.g., Pearl-Verhulst logistic law [13]) and nonlinear dispersion coefficients in the general biological models. The population convection

phenomenon was first introduced by Kerner [14,15,16] in a model based on the adaption of the concepts of classical statistical mechanics to interacting biological species. These studies established that, starting with Volterra-Lotka [17,18] population kinetics equations without spatial dependence, the proper statistical averaging of the mathematical system would lead to a continuity equation for population density which includes both convection and spatial variation terms in its formulation. A general ecological model for biological species (including human populations) was proposed by Eranslan [19,20] based on the assumption of continuous media and plausible conservation principles for the populations. The mathematical formulation of the model considers temporal and spatial variations, associated with convection and transport phenomena, migration, and states of existence of the populations according to the sustenance of their environment.

In theory, the majority of these general biological population models can be applied, with proper modifications, to the striped bass young-of-the-year populations in the Hudson River. However, the actual formulations of the terms for the convective and diffusive transport phenomena in the general models would require extensive effort in the preparation of the necessary input information about the flow and physical conditions in the particular estuary and about the particular physiological and behavioral characteristics of the striped bass life stages. Furthermore, the associated mathematical systems, resulting from the particular applications of the general models, would consist of nonlinear partial differential equations which cannot be solved by simple analytical methods. Consequently, they would require computational solutions based on modern numerical techniques. Hence, modified and simplified applications of the general theoretical models would not necessarily be advantageous to the development of a specific computational model, having the desired level of accuracy and based on the same concepts as the general models.

This report presents the development of a daily transport (tidal-averaged), longitudinally one-dimensional (cross-section-averaged) simulation model for young-of-the-year striped bass based on the discrete-element formulation [21,22,23] which leads directly to mathematical systems amenable to computational solutions.

The model employs a temporal resolution of 24-hr. daily variations (tidal-averaged) for two reasons: (1) to avoid the necessity of inclusion of tidal flow conditions and (2) to guarantee sufficient accuracy for the simulation of the life-stage populations with short durations. A finer temporal resolution, particularly within the tidal cycle variation (e.g., 3 hr), would require inclusion of the periodic tidal velocity field as the fundamental convective phenomenon in the model, since the tidal flow rates are significantly higher than the net freshwater flow rates in the Hudson River. Because the accuracy of the available data for striped bass young-of-the-year distributions (which are used for verification of the simulations) is limited to weekly averages [24], the additional complexities in model development and the inevitable increases in computation times associated with short-time, tidal-transient (high temporal resolution) formulations cannot be justified. A coarser resolution, such as weekly variations (which are consistent with the available reduced data [24] for the striped bass young-of-the-year populations), would introduce errors in the modeling due to the short durations of the early life stages. The approximate life-stage duration is 1.2 days for eggs and six days for yolk-sac larvae.

The longitudinally one-dimensional (cross-section-averaged) model considers a spatial resolution of 2-mile segments along the estuary. This spatial resolution is sufficient to specify the locations of the intakes and the discharges relative to the existing morphological characteristics and the flow conditions in the river. Although it is theoretically possible to develop three-dimensional, high-spatial-resolution models, there are two reasons why such formations would result in the introduction of additional uncertainties rather than the improvement of the simulations. First, the inclusion of three-dimensional phenomena would require the necessary information about the vertical and, to a lesser extent, the lateral

variations in the flow conditions resulting from turbulent velocity profiles during tidal cycles and stratification conditions due to temperature and salinity distributions over the cross sections. Considering the limited accuracy of the available three-dimensional data about the velocity, temperature, and salinity conditions in the Hudson River, it is unrealistic to undertake such an effort to improve the accuracy of the biological population models. Second, the ultimate verification of a mathematical model depends on its capability to simulate the observed data in the estuary. Considering the inaccuracies involved in the sampling of the three-dimensional distributions of striped bass young-of-the-year populations [25] and also considering that the ichthyoplankton and beach seine data have been reduced to weekly averaged and ten-mile-averaged population numbers [24], it would seem inappropriate to consider sophisticated, three-dimensional formulations.

2. FUNDAMENTAL EQUATIONS OF THE COMPUTER SIMULATION MODEL

The formulation of the present striped bass young-of-the-year model is based on the discrete-element, control volume approach, which highlights the direct numerical simulation procedure without necessitating continuum limit partial differential equations for conservation principles. The applications of this approach to the modeling of the physical phenomena associated with the hydrodynamic, thermal, and water quality conditions in estuaries and coastal regions are discussed in refs. 21-23 and 29.

In the present formulation of the model, a general discrete-element "i" of the estuary is defined as the control volume between two specified transect cross sections as shown in Fig. 2.1. Since the simulation model considers daily transient conditions in the estuary, all the variables associated with the physical conditions and the striped bass young-of-the-year populations are defined as being temporally averaged over the tidal cycle and spatially averaged over the volume of the discrete elements. In the subsequent definitions, the bar notation over a variable is employed to represent the temporally and spatially averaged property of that variable.

The geometrical properties of the discrete elements are as follows:

- x_i = representative location of the discrete element "i" corresponding to the distance from the Troy Dam to the midpoint between its enclosure transects (ft).
 - $x_{i-1/2}$ = locations of the upstream and downstream transect cross sections of the discrete element "i" (ft).
 - Δx_i = longitudinal length of the discrete element "i" (ft).
 - A_i = representative cross-sectional area of the discrete element "i" (ft²).
 - $A_{i-1/2}$ = areas of the upstream and downstream transect cross sections of the discrete element "i" (ft²).
- (2.1)

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Fig. 2.1 Schematic representation of a discrete element for the conceptual development of the computer simulation model.

D_i = representative maximum depth in the discrete element "i" (ft).

$D_{i,1,2}$ = maximum depths at the upstream and downstream transect cross sections of the discrete element "i" (ft).

B_i = representative surface width of the estuary in the discrete element "i" (ft).

L_i = representative length of the estuary bed contour in the discrete element "i" (ft).

The variables associated with the flow conditions in the discrete elements are defined as:

$\bar{Q}_i$ = net freshwater flow rate across the representative cross-sectional area A_i of the discrete element "i" (ft^3/hr).

$\bar{Q}_{i,1,2}$ = net freshwater flow rates across the upstream and downstream transect cross-sectional areas of the discrete element "i" (ft^3/hr).

$g_{s,i}$ = flow rate per unit area (normal velocity component) on the estuary surface in the discrete element "i" (e.g., rainfall) (ft/hr).

$g_{r,i}$ = flow rate per unit area (normal velocity component) on the estuary bed contour in the discrete element "i" (e.g., seepage, runoff) (ft/hr). (2.2)

V_i = maximum tidal speed in the discrete element "i" (ft/hr).

$V_{i,1,2}$ = maximum tidal speed at the upstream and downstream transect cross sections of the discrete element "i" (ft/hr).

$\bar{Q}_{t,i}$ = net nontidal flow rate into the discrete element "i" from tributary "i" (ft^3/hr).

$(\bar{Q}_{\text{INT}})_m$ = net flow rate of the intake of the power plant "m" in the discrete element "i" (ft^3/hr).

$(\bar{Q}_{\text{DIS}})_m$ = net flow rate of the discharge of the power plant "m" in the discrete element "i" (ft^3/hr). (Note: the intake and discharge need not be in the same discrete element "i".)

The variables associated with the life-stage populations in the discrete elements are defined as:

$p_i^{(k)}$ = population density of the life stage "k" in the discrete element "i" (number/ft³).

$p_{i,1,2}^{(k)}$ = population densities of the life stage "k" at the locations of the upstream and downstream transect cross sections of the discrete element "i" (number/ft³).

$\dot{p}_i^{(k)}$ = net local time rate of variation of population density (due to growth to the next life stage and mortality) of the life stage "k" in the discrete element "i" (number/ft³/hr).

$p_{s,i}^{(k)}$ = population density of life stage "k" in the surface flow rate $g_{s,i}$ in the discrete element "i" (number/ft³). (2.3)

$p_{r,i}^{(k)}$ = population density of life stage "k" in the estuary bed flow $g_{r,i}$ in the discrete element "i" (number/ft³).

$p_{t,i}^{(k)}$ = population density of life stage "k" in the tributary flow $\bar{Q}_{t,i}$ in the discrete element "i" (number/ft³).

$p_{\text{INT},m}^{(k)}$ = population density of life stage "k" in the intake flow $(\bar{Q}_{\text{INT}})_m$ in the discrete element "i" (number/ft³).

$p_{\text{DIS},m}^{(k)}$ = population density of life stage "k" in the discharge flow $(\bar{Q}_{\text{DIS}})_m$ in the discrete element "i" (number/ft³).

The flux terms associated with the general transport phenomena across the discrete-element enclosure surfaces for the life-stage populations are defined as:

$$\begin{aligned}
 g_{i+1/2}^{(k)} &= \text{net transport flux of the population of life stage "k" across the upstream and} \\
 &\quad \text{downstream transect cross-sectional areas } A_{i+1/2} \text{ of the discrete element "i"} \\
 &\quad \text{(number ft}^2 \text{ hr)}, \\
 g_{i+1}^{(k)} &= \text{transport flux of the population of life stage "k" from the estuary bed contour l'} \\
 &\quad \text{surface into the discrete element "i" (number ft}^2 \text{ hr)}.
 \end{aligned}
 \tag{2.4}$$

In all the definitions of the variables, Eqs. (2.1) through (2.4), the associated sign conventions are:

- the positive x axis is toward the Battery, originating at the Troy Dam,
- all estuary flow rates are positive along the downstream direction, along the x axis toward the Battery,
- all geometric dimensions and areas associated with the discrete elements are positive,
- all tidal speeds as magnitudes are positive,
- all flow rates associated with the tributaries, intakes, and discharges are positive for inflow conditions into the discrete elements,
- all flow rates per unit area (normal velocity components) are positive for inflow conditions into the discrete elements,
- all transport fluxes for life-stage populations are positive along the downstream direction, along the positive x axis toward the Battery,
- all population densities for all life stages are positive.

The governing equations of the simulation model can be developed in terms of the defined variables by applying the fundamental conservation principles to all the discrete elements that span the specified length of the estuary.

2.1 DISCRETE-ELEMENT EQUATIONS FOR WATER MASS CONSERVATION PRINCIPLE (AUXILIARY EQUATIONS)

Applying the mathematical statement for the classical mass conservation principle to the water mass in the discrete element "i", the auxiliary equation which represents the time rate of change of the cross-sectional area of the discrete element becomes

$$\begin{aligned}
 \frac{d\bar{A}}{dt} &= \frac{1}{\Delta x_i} (\bar{G}_{i+1/2} - \bar{G}_{i-1/2}) + \frac{\delta_{li}}{\Delta x_i} \bar{G}_{li} + \frac{(\delta_{lvi})_{m,i}}{\Delta x_i} (\bar{G}_{lvi})_{m,i} \\
 &\quad + \frac{(\delta_{lvi})_{m,i}}{\Delta x_i} (\bar{G}_{lvi})_{m,i} + \bar{B}_{vi} \bar{g}_{vi} + \bar{I}_i \bar{g}_{li}
 \end{aligned}
 \tag{2.5}$$

where the Kronecker deltas are defined as

$$\begin{aligned}
 \delta_{li} &= \begin{cases} 1: \text{tributary "l" in discrete element "i"} \\ 0: \text{tributary "l" not in discrete element "i"} \end{cases} \\
 (\delta_{lvi})_{m,i} &= \begin{cases} 1: \text{intake of power plant "m" in discrete element "i"} \\ 0: \text{intake of power plant "m" not in discrete element "i"} \end{cases} \\
 (\delta_{lvi})_{m,i} &= \begin{cases} 1: \text{discharge of power plant "m" in discrete element "i"} \\ 0: \text{discharge of power plant "m" not in discrete element "i"} \end{cases}
 \end{aligned}
 \tag{2.6}$$

2.2 DISCRETE-ELEMENT EQUATIONS FOR LIFE-STAGE AGE-GROUP POPULATION NUMBER CONSERVATION PRINCIPLE (PRINCIPAL EQUATIONS)

Applying the mathematical statement of the population number conservation principle (see refs. 19 and 20) to the life-stage "k" population in discrete element "i", the principal set of equations that represents the time rates of change of age-group population numbers in the discrete elements becomes

$$\begin{aligned} \frac{d}{dt}[\bar{A}\bar{p}^{(k)}] = & \bar{A}_i\hat{p}^{(k)} + \frac{1}{\Delta x_i}[\bar{G}_{i-1,i}\bar{p}^{(k)}_{i-1} - \bar{G}_{i,i+1}\bar{p}^{(k)}_i] \\ & + \frac{1}{\Delta x_i}[\bar{A}_{i-1,i}\bar{g}^{(k)}_{i-1} - \bar{A}_{i,i+1}\bar{g}^{(k)}_i] + \frac{\delta_{i,i}}{\Delta x_i}\bar{G}_i[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] \\ & + \frac{(\delta_{INT})_{m,i}}{\Delta x_i}(\bar{G}_{INT})_{m,i}[\bar{p}^{(k)}_{INT,m} - \bar{p}^{(k)}_i] + \frac{(\delta_{DIS})_{m,i}}{\Delta x_i}(\bar{G}_{DIS})_{m,i}[\bar{p}^{(k)}_{DIS,m} - \bar{p}^{(k)}_i] \\ & + \bar{B}_{i,i}\bar{g}_{i,i}[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] + \bar{\Gamma}_{i,i}\bar{g}_{i,i}[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] + \bar{\Gamma}_{i,i}[\bar{g}^{(k)}_i] \end{aligned} \quad (2.7)$$

Equation (2.7) can be directly employed to obtain the solution for the population density of life stage "k" in discrete element "i" provided that the variations of the cross-sectional areas $\bar{A}$ and $\bar{A}_{i-1,i}$ and the flow rates $\bar{G}_{i-1,i}$ can be simultaneously and correctly specified for all discrete elements along the estuary. If this input information cannot be supplied correctly, the solutions for the population densities from Eq. (2.7) could lead to appreciable errors due to the discrepancies in the fluid mass conservation in the discrete elements. To avoid the necessity for the simultaneous solution of the hydrodynamic flow field in the estuary [which is inherent to the continuum partial differential equations of the chemical constituent models (see refs. 1-3, 5,6)], the auxiliary equation (2.5) is directly employed in the general formulation of the present model.

2.3 GOVERNING DISCRETE-ELEMENT EQUATIONS OF THE COMPUTER SIMULATION MODEL

The derivative of the product term on the left-hand side of Eq. (2.7) can be expanded in the form

$$\frac{d}{dt}[\bar{A}\bar{p}^{(k)}] = \bar{A}_i \frac{d\bar{p}^{(k)}}{dt} + \bar{p}^{(k)} \frac{d\bar{A}_i}{dt} \quad (2.8)$$

where the last term in Eq. (2.8) contains the time rate of change of the cross-sectional area in the discrete element "i", which is represented by the left-hand side of the auxiliary equation (2.5). Hence multiplying Eq. (2.5) by $\bar{p}^{(k)}$, adding the resulting equation and Eq. (2.7) to eliminate the second term on the right-hand side of Eq. (2.8), and rearranging, the final form of the discreteelement equation for the population density of life stage "k" in discrete element "i" becomes

$$\begin{aligned} \frac{d\bar{p}^{(k)}}{dt} = & \hat{p}^{(k)} + \frac{1}{\Delta x_i \bar{A}_i} \left\{ \bar{G}_{i-1,i}[\bar{p}^{(k)}_{i-1} - \bar{p}^{(k)}_i] - \bar{G}_{i,i+1}[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i+1}] \right\} \\ & + \frac{1}{x_i \bar{A}_i} [\bar{A}_{i-1,i}\bar{g}^{(k)}_{i-1} - \bar{A}_{i,i+1}\bar{g}^{(k)}_i] + \frac{\delta_{i,i}}{\Delta x_i \bar{A}_i} \bar{G}_i[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] \\ & + \frac{(\delta_{INT})_{m,i}}{\Delta x_i \bar{A}_i} (\bar{G}_{INT})_{m,i}[\bar{p}^{(k)}_{INT,m} - \bar{p}^{(k)}_i] + \frac{(\delta_{DIS})_{m,i}}{\Delta x_i \bar{A}_i} (\bar{G}_{DIS})_{m,i}[\bar{p}^{(k)}_{DIS,m} - \bar{p}^{(k)}_i] \\ & + \frac{\bar{B}_{i,i}}{\bar{A}_i} \bar{g}_{i,i}[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] + \frac{\bar{\Gamma}_{i,i}}{\bar{A}_i} \bar{g}_{i,i}[\bar{p}^{(k)}_i - \bar{p}^{(k)}_{i-1}] + \frac{\bar{\Gamma}_{i,i}}{\bar{A}_i} [\bar{g}^{(k)}_i] \end{aligned} \quad (2.9)$$

Equation (2.9) is the final numerical simulation form for all population densities $p^{(i)}$ in all discrete elements, and it represents a system of coupled, first-order, ordinary differential equations. Hence, provided the terms on the right-hand side of Eq. (2.9) can be formulated in terms of the principal variables (i.e., the population densities in the discrete elements), the mathematical system of the computer simulation model can be readily integrated from a given set of initial conditions.

2.4 FORMULATION OF THE HALF-POINT VALUES

The half-point values for the areas $A_{i+1/2}$, flow rates $G_{i+1/2}$, and the age-group population densities $p^{(i)}_{i+1/2}$ at the locations of the upstream and downstream transect cross sections of the discrete elements are formulated according to "second upwind differencing" or "donor cell method" (refs. 21-23,29), which is very desirable from numerical stability considerations of the explicit finite difference methods. The standard formulations were slightly modified for the areas and the flow rates to incorporate the unequal lengths of the discrete elements of the present model in the linear averaging forms as

$$\bar{A}_{i+1/2} = (\Delta x_i \bar{A}_{i+1} + \Delta x_{i+1} \bar{A}_i) / (\Delta x_i + \Delta x_{i+1}) \quad \bar{G}_{i+1/2} = (\Delta x_i \bar{G}_{i+1} + \Delta x_{i+1} \bar{G}_i) / (\Delta x_i + \Delta x_{i+1}) \quad (2.10)$$

The standard forms for the convected properties with the fluid, that is, the population densities $p^{(i)}_{i+1/2}$, are retained as

$$\bar{p}^{(i)}_{i+1/2} = \begin{cases} p^{(i)}_i & \text{for } G_{i+1/2} < 0 \\ p^{(i)}_{i+1} & \text{for } G_{i+1/2} > 0 \end{cases} \quad (2.11)$$

$$\bar{p}^{(i+1)}_{i+1/2} = \begin{cases} p^{(i+1)}_i & \text{for } G_{i+1/2} < 0 \\ p^{(i+1)}_{i+1} & \text{for } G_{i+1/2} > 0 \end{cases}$$

It should be noted that the "second upwind differencing" or "donor cell" forms, Eqs. (2.10) and (2.11), could cause stability problems in the numerical solutions of the system due to the unequal lengths of the adjacent discrete elements. Hence, in the division of the length of the river into discrete elements, the sizes of the adjacent elements should not be excessively different from each other.

The remaining terms of the right-hand side of the discrete-element equation (2.9) cannot be eliminated in terms of the principal unknowns, population densities $p^{(i)}$, based on solely mathematical considerations. However, they need to be individually modeled based on the detailed descriptions of the hydrodynamic conditions, biological phenomena, and power plant operational conditions in the river.

3. BIOLOGICAL CHARACTERISTICS OF STRIPED BASS YOUNG-OF-THE-YEAR

The present model considers six sequential life stages in the mathematical formulations and a dummy adult spawning group for the simulation of egg deposition in the estuary. The particular life stages and their associated life-stage durations were specified based on their physiological and behavioral characteristics and on available information from sampling programs in the river. These characteristics control the levels of susceptibility to destruction by the power plants. The approximate optimum (minimum) durations of these life stages, the approximate range of lengths of the fish at each life stage, and the nature and extent of their susceptibility to destruction are indicated in Table 3.1.

Table 3.1 Physiological and behavioral characteristics of striped bass

Life-stage index (k)	Life stage	Optimum (minimum) duration (days)	Length (mm)	Destruction	
				Type	Avoidance
1	Egg	1.2	1.6-3.5	Entrainment	None
2	Yolk-sac larva	6.0	3.1-6.2	Entrainment	None
3	Post-yolk-sac larva	22.0	6.3-15	Entrainment	None
4	Juvenile I	40.0	16-50	Entrainment	Low
5	Juvenile II	123.0	>50	Impingement	Medium
6	Juvenile III	172.0		Impingement	High
7	Dummy adult				

The biological characteristics explicitly considered in the model are associated with the duration, survival, mortality, and swimming speed of each life stage of the striped bass young-of-the-year. In the mathematical development of the simulation model, it is assumed that all the biological characteristics are controlled by the local physical conditions and the population densities of the life stages in the Hudson River. This a priori assumption guarantees the necessary generality in the model to incorporate all the pertinent factors which could affect the biological characteristics according to the following five postulates:

- Every biological characteristic of a life stage has an optimum value which exists only within a range of simultaneous optimum conditions for population density, temperature, and salinity associated with the particular life stage.
- For population densities outside the optimum density range associated with the life stage, any biological characteristic of the life stage can be modified from its representative optimum value by a multiplicative correction factor that represents the effect of the nonoptimum population density conditions.
- For temperature conditions outside the optimum temperature range associated with a life stage, any biological characteristic of the life stage can be modified from its representative optimum value by a multiplicative correction factor that represents the effect on the nonoptimum temperature conditions.
- For salinity conditions outside the optimum salinity range associated with a life stage, any biological characteristic of the life stage can be modified from its representative optimum value by a multiplicative correction factor that represents the effect of the nonoptimum salinity conditions.
- Other physical and biological conditions not explicitly considered in the definition of the optimum conditions (e.g., turbidity, dissolved oxygen, and food) are assumed to be of secondary importance in terms of their effect on the biological characteristics, or they are considered to be incorporated in the effects of population density, temperature, and salinity (e.g., dependence on food is implicitly incorporated in the dependence on population density).

According to postulate (b), the mechanisms of density-dependent compensation associated with the striped bass young-of-the-year populations can be incorporated in a general manner in the present computer simulation model. This approach is not limited to the modification of the mortality rate coefficient alone, as is done in ref. 2.

The particular forms of the correction factors for the population density, temperature, and salinity effects on the biological characteristics of the life stages will be considered in detail for each biological characteristic in the subsequent development of the model.

3.1 FORMULATION OF RATE AND DISTRIBUTION OF EGG DEPOSITION IN THE HUDSON RIVER

Accurate simulation of the egg deposition in the river is difficult because definitive knowledge about the factors that control spawning does not exist. However, since the distributions of the intermediate, entrainable life stages are strongly dependent on the location and timing of egg production during the spawning period, it is important to simulate egg deposition rates and distributions that correspond reasonably well with the actual spawning in the river.

3.1.1 Longitudinal Distribution of Egg Deposition

The longitudinal distribution of egg deposition in the estuary is simulated by generating an appropriate distribution of a "dummy" population of spawning adult females throughout the observed spawning area. The general formulation of the model considers numerous adult age-groups which can contribute to spawning at different rates and with different longitudinal distributions along the estuary. Hence the population densities of spawners need to be specified as

$$p_{SPK}^{(i)} = p_{SPK}^{(i)}(t) \quad (3.1)$$

in all the discrete elements $i = 1, \dots, N$; for all time t ; and for all spawning age-groups $k = K_{SP1}, \dots, K_{SPK}$ (where K_{SP1} and K_{SPK} represent the youngest and the oldest female adult age-groups, respectively, that spawn in the estuary).

In the applications of the model to the 1973 conditions, the spawning adult age-groups were combined into a single dummy adult spawning age-group $p_{SPW}^{(i)}$, and its distribution along the estuary was assumed to remain constant during the spawning period. This distribution was established by trial and error to achieve reasonably accurate simulations of the observed weekly averaged longitudinal distributions of egg and yolk-sac larva populations in the river.

It must be emphasized that accurate data for the total number of females spawning in the Hudson River in 1973 and for the longitudinal distribution of these females are not available. A value for the total number of spawning females for 1973 was approximated as

$$P_{SPW}^{(i)}(t) = P_{EST}^{(i)} \approx 1.32 \times 10^7, \quad (3.2)$$

where the subscript EST stands for the "estimated" total number in the estuary. This number of spawners is in approximate agreement with other estimates [30].

Simulation of the rate and distribution of egg deposition in the estuary based on the observed spatial and temporal distribution of eggs poses a problem which cannot be resolved without resorting to artificial approximations. The model requires the specification of the rate of deposition and distribution of fertilized and viable eggs along the estuary to initiate the computations, since only fertilized and viable

eggs can grow to later life stages. However, in the 1973 data no distinction is made between the fertilized and viable eggs and the dead ones. Consequently, the simulated spawning rate and the longitudinal distribution of the dummy adult spawning age-group only approximate the actual spawning conditions, in the estuary, of the fertilized and viable eggs for 1973.

The longitudinal distribution of the population density of the adult spawning age-group $p_{spw}(t)$ was estimated so that it satisfied the necessary restriction that the sum of spawners in all the discrete elements was the estimated total number in the estuary; that is,

$$P_{spw}(t) = P_{TNT} = \sum_{i=1}^N \Delta x_i A_i p_{spw}(t) = \sum_{i=1}^N \Delta x_i A_i \bar{p}_{spw} \quad (3.3)$$

Note that it is assumed that the total size of the spawning adult population and their longitudinal distribution are independent of time. To obtain the necessary longitudinal population density input to the model (i.e., p_{spw} values), a fractional longitudinal distribution of the spawning adult population was defined as

$$R_{spw}^i = P_{spw} / P_{TNT} \quad (3.4)$$

The longitudinal egg distributions were obtained as weekly averaged numbers in approximately 10-mile-long segments based on the reduction of the 1973 striped bass ichthyoplankton data as presented in ref. 24. As a first approximation, the R_{spw}^i values were estimated from the observed longitudinal distributions of eggs during the first three weeks of the spawning period as the percentage of the total number of eggs in the estuary as calculated for each discrete element. This approximation was based on the assumption that the relative distribution of eggs along the estuary was a good approximation of the relative distribution of the spawning females that produced those eggs. The population densities p_{spw} of the dummy adult spawning age-group in the discrete elements were calculated by taking into account the volumes of the discrete elements as

$$p_{spw}^i = P_{spw}^i / \Delta x_i A_i = R_{spw}^i P_{TNT} / \Delta x_i A_i \quad (3.5)$$

Subsequently, the R_{spw}^i values were adjusted to improve the agreement between the observed and simulated weekly averaged longitudinal distributions of eggs in the estuary. The final R_{spw}^i values for the discrete elements are presented in Fig. 3.1.

3.1.2 Formulation of Time Rate of Deposition of Egg Population Density in a Discrete Element

According to the postulates about the biological characteristics and considering the general case of more than one spawning adult age-group, the rate of egg deposition in the discrete elements can be represented on a per unit volume basis as

$$\dot{p}_{TGO,i} = \sum_{k=1}^K \delta_{spw}^{(k)} \bar{r}_{TGO,spw}^{(k)} C_{spw}^{(k)}(\bar{p}^{(k)}) C_{Tspw}^{(k)}(\bar{T}_i) C_{Sspw}^{(k)}(\bar{S}_i) \bar{p}^{(k)} \quad (3.6)$$

where

$\dot{p}_{TGO,i}$ = time rate of deposition of egg population density in discrete element "i" (number of eggs $\text{ft}^{-3} \text{hr}$),

$$\delta_{spw}^{(k)} = \begin{cases} 1, & K_{sp1} \leq k \leq K_{spK} \text{ (spawning age-group)} \\ 0, & k < K_{sp1} \text{ or } k > K_{spK} \text{ (nonspawning age-group)}. \end{cases}$$

Fig. 3.1. Assumed relative longitudinal distribution of the adult spawning life-stage population in the discrete elements for the simulations of the 1973 data.

- $\bar{r}_{(k)sp}^{(k)}$ = optimum spawning rate of life stage "k" (eggs spawned per unit time per fish) (number fish hr). (3.7)
- $C_{p,sp}^{(k)}[\bar{p}^{(i)}]$ = correction factor for nonoptimum population density conditions for spawning age-group "k" in discrete element "i".
- $C_{T,sp}^{(k)}(\bar{T})$ = correction factor for nonoptimum temperature conditions for spawning age-group "k" in discrete element "i".
- $C_{S,sp}^{(k)}(\bar{S})$ = correction factor for nonoptimum salinity conditions for spawning age-group "k" in discrete element "i".

It should be noted that $\dot{p}_{(k)sp}^{(k)}$ strictly represents the time rate of deposition of eggs per unit volume and not the time rate of variation of egg population density $\dot{p}^{(i)}$ in the discrete element "i", since it does not contain the additional effects of egg growth and mortality in its formulation.

The particular forms of the correction factors for the nonoptimum conditions for spawning will be considered in the subsequent discussions of the population density-dependent compensatory mechanisms and the effects of temperature and salinity conditions on the biological characteristics.

3.1.3 Rate of Egg Deposition by Each Dummy Spawning Adult

According to the formulation of the model, the simulation of the local rate of egg deposition in the discrete elements along the estuary requires the specification of both the distribution of the dummy

spawning females and the rate of deposition of fertilized and viable eggs per fish per hour under optimum conditions. Since direct information about the rate of deposition of fertilized and viable eggs is not available, the necessary value for the parameter was selected based on simulations of the egg population distributions in the river.

It is assumed that each dummy female spawner deposits 1440 fertilized and viable eggs per day under optimum conditions, which corresponds to a total seasonal production of approximately 50,000 eggs per fish. The 50,000 fertilized and viable eggs per fish per season can be considered a realistic estimate, based on the assumption of 1,000,000 eggs spawned per female per season, only 5% of which are likely to be both fertilized and viable. Hence, in the applications of the model, the optimum hourly spawning rate for the dummy spawning adult age-group was specified as

$$r_{\text{opt}} = 60.0 \text{ eggs spawned per fish per hour.} \quad (3.8)$$

Since there are no available direct data for the longitudinal spatial distribution and the spawning rate for the dummy spawning age-group or for the percentage of eggs spawned that are fertilized and viable and the time (hours or days) unfertilized and unviable eggs remain in the water column, it should be realized that there is not a unique set of values which can be employed in the applications of the model. Hence different combinations of spatial distribution of population density p_{opt} and spawning rate r_{opt} for the dummy spawning adult age-group and of the percent of eggs spawned that are fertilized and viable can be employed to obtain successful simulations of the egg population density distributions in the estuary.

3.2 FORMULATION OF THE POPULATION MODEL FOR THE LIFE STAGES

The life stages of the striped bass young-of-the-year specified in the model correspond to the life stages commonly used in field and laboratory research (e.g., see Table 3.1), which in turn are selected on the basis of morphologically and physiologically distinctive characteristics.

Each life stage can be defined by a range in length (e.g., 1.6–3.5 mm for eggs, 3.1–6.2 mm for yolk-sac larvae, 6.3–15 mm for post-yolk-sac larvae, etc.). Then the duration of each life stage can be estimated from field and laboratory samples by observing the period of time it takes for the fish to grow from the lower length to the upper length (e.g., 1.2 days for eggs, 6 days for yolk-sac larvae, 22 days for post-yolk-sac larvae, etc.). Since various biotic and abiotic factors may change the rate of development, the durations of the life stages would certainly depend on the conditions of the environment during the observations.

There are two basic approaches to the formulation of a life-stage population model for the striped bass young-of-the-year. The first approach is to consider a discrete-time cohort formulation (e.g., Goodyear [7]) in which the durations of all life stages correspond to the time step of the model (e.g., 3 hr, 12 hr, 1 day, etc.). At each time step, the model computes the population number for each cohort (e.g., 3-hr-old, 6-hr-old, 9-hr-old, 12-hr-old, 24-hr-old, 36-hr-old, 1-day-old, 2-day-old, 3-day-old, etc.). Clearly, the model does not directly compute the population numbers for the morphologically and physiologically defined life stages (e.g., egg, yolk-sac larva, post-yolk-sac larva, etc.). Hence, to obtain the population number in a biologically defined life stage, the model sums the population numbers in all the cohorts within the estimated duration of the particular life stage. For example, for a 3-hr, discrete-time cohort model, the sum of the population numbers in 16 cohorts (i.e., 3-hr, 6-hr, 9-hr, ..., 48-hr) would constitute the population number of the egg life stage with a 1.2-day duration. Similarly, for a daily, discrete-time cohort model, the sum of the population numbers in six cohorts (i.e., 3-day, 4-day, 5-

day, ..., 8-day) would constitute the population number of the yolk-sac larva life stage with a 6-day duration.

The various research groups currently working on striped bass in the Hudson River measure young-of-the-year collected in samples and classify them according to the length ranges given in Table 3.1 (e.g., refs. 31-36); the actual age of the fish in the samples cannot be determined. Hence the durations of the life stages cannot be determined directly from the sampling programs. Consequently, additional information, from laboratory and other field research programs, is relied on in part to estimate the durations of the life stages. Hence, in the application of a discrete-time cohort model, although the precise age of the individual fish in each cohort is known (within the limits of accuracy of the time step), the required summation procedure for obtaining the population numbers in the biologically defined life stages could cause appreciable errors in the simulations of the actual life-stage populations, due to errors in estimates of the durations of the life stages.

The second approach is to consider a formulation in which the life stages correspond directly to the biologically defined life stages (e.g., refs. 37 and 38) with durations which are, in general, considerably longer than the time step used in the model (e.g., 40 days duration for Juvenile I and 4 hr for the time step). This class of models is usually referred to as dynamic population models (e.g., refs. 16, 19, 20, and 38), since the significantly smaller time-step size (relative to the durations of the life stages) requires the formulation of, in a sense, instantaneous and continuous (dynamic) transfer rates in a sequential order through the life stages. Although the dynamic models cannot consider the precise ages of the individuals in the age-groups, this less detailed formulation by no means indicates that a dynamic model is less accurate than its discrete-time cohort counterpart. Noting that a discrete-time cohort model has to sum the population numbers of all the cohorts within a certain life stage in order to obtain the population size of the life stage, it is no more accurate than a dynamic model which simulates the life-stage population directly. Indeed, properly formulated dynamic and cohort population models would have equivalent accuracy levels in simulating striped bass young-of-the-year populations in the Hudson River.

The present model is a dynamic population model. Considering that a typical spawning period lasts four to five weeks, which is longer than the estimated durations of the early life stages (see Table 3.1), two or more life-stage populations simultaneously exist in the system from the time eggs hatch into yolk-sac larvae in early May until winter, when there are only Juvenile III striped bass left in the estuary. Hence, to realistically formulate a dynamic population model, certain important properties of the life-stage populations must be considered:

- a. The local population of each life stage contains fish of different ages, the ages depending on the individual hatching dates and locations in the estuary. According to the biologically defined life stages, an individual fish in a life stage can have an age anywhere between the lower bound and the upper bound of the duration (e.g., between two days old and eight days old for yolk-sac larvae with a six-day duration). Hence, there exists a frequency distribution for the ages of the individual fish in the life stage.
- b. During any observable time period (e.g., 10 min, 4 hr, 1 day), a certain number of fish in a given life stage have completed their duration there and grown into the next stage. Hence, in reality, there exists a continuous transfer of individual fish in a sequential order through the life stages. The effect of this transfer is that any given life stage will (i) continuously gain individuals from the preceding life stage at a rate depending on the duration of the earlier life stage and (ii) continuously lose individuals to the next life stage at a rate depending on the duration of the given life stage.
- c. During any observable time period (e.g., 10 min, 4 hr, 1 day), a certain number of fish in a given life stage die due to natural causes. Hence, in reality, there exists a continuous rate of loss of fish from a

given life stage; these fish are permanently removed from the process of sequential growth through the life stages.

- d. An individual striped bass cannot exist in a life stage longer than the duration of that life stage. Although various biotic and abiotic environmental factors may accelerate or retard its duration in a life stage to a certain degree, an individual striped bass must either die while in the life stage or transfer to the next life stage after a time corresponding to the duration of the life stage. The sum of the growth rate to the next life stage and the mortality rate constitutes the total rate of loss from the given life stage.

The above qualitative properties of the striped bass population can be used as a basis for the development of a quantitative population model for the biologically defined life stages.

3.2.1 Formulation of the General Dynamic Population Model: Net Local Time Rate of Variation of Population Density of the Life Stage

In view of properties (a) through (d) of the striped bass life-stage populations, a general, dynamic population model can be formulated as shown schematically in Fig. 3.2. The net local time rate of variation of the population density of life stage "k" in discrete element "i" is formulated for $k = 1$ (egg) as

$$\dot{p}_i^{(1)} = \dot{p}_{EGG,i} - \dot{p}_{GRW,i}^{(1)} - \dot{p}_{MOR,i}^{(1)} \quad (3.9)$$

and for $k \geq 2$ as

$$\dot{p}_i^{(k)} = \dot{p}_{GRW,i}^{(k-1)} - \dot{p}_{GRW,i}^{(k)} - \dot{p}_{MOR,i}^{(k)} \quad (3.10)$$

where

$$\begin{aligned} \dot{p}_{EGG,i} &= \text{time rate (per unit volume) of deposition of egg population density in discrete element "i"}, \\ \dot{p}_{GRW,i}^{(k)} &= \text{growth rate (per unit volume) of life stage "k" into life stage "k + 1" in discrete element "i"}, \\ \dot{p}_{MOR,i}^{(k)} &= \text{mortality rate (per unit volume) of life stage "k" in discrete element "i"}. \end{aligned} \quad (3.11)$$

In Equation (3.10), $\dot{p}_{GRW,i}^{(k-1)}$ represents the rate of gain of population density of life stage "k" from the previous life stage "k - 1" [according to property (b)]. The sum of the terms $\dot{p}_{GRW,i}^{(k)}$ and $\dot{p}_{MOR,i}^{(k)}$ represents the total rate loss of population density [according to properties (c) and (d)] due to growth into the next life stage "k + 1" and due to mortality (see Fig. 3.2).

3.2.2 Formulation of Growth Rates into the Next Life Stage and Mortality Rates

The four properties previously discussed (Sect. 3.2.1) of the biologically defined life stages suggest the general quantitative formulation of the growth rate into the next life stage $\dot{p}_{GRW,i}^{(k)}$ (per unit volume) and the mortality rate $\dot{p}_{MOR,i}^{(k)}$ (per unit volume) as (see Fig. 3.2)

$$\dot{p}_{GRW,i}^{(k)} = \bar{r}_{GRW,i}^{(k)} \bar{R}_{SRV,i}^{(k)} \bar{p}_i^{(k)} \quad (3.12)$$

$$\dot{p}_{MOR,i}^{(k)} = \bar{r}_{MOR,i}^{(k)} [1 - \bar{R}_{SRV,i}^{(k)}] \bar{p}_i^{(k)} \quad (3.13)$$

Fig. 3.2. Schematic representation of the dynamic population model for the striped bass life stages.

where

$$\begin{aligned}\bar{r}_{GRW,i}^{(k)} &= \text{growth rate coefficient for life stage "k" in discrete element "i"}, \\ \bar{r}_{MOR,i}^{(k)} &= \text{mortality rate coefficient for life stage "k" in discrete element "i"}, \\ \bar{R}_{SRV,i}^{(k)} &= \text{apparent survival probability for life stage "k" in discrete element "i"}.\end{aligned}\quad (3.14)$$

According to the definitions of the growth rate into the next life stage $\bar{p}_{GRW,i}^{(k)}$ and the mortality rate $\bar{p}_{MOR,i}^{(k)}$, Eqs. (3.12) and (3.13), it is evident that the general formulation of the dynamic population model is based on three parameters, that is, apparent survival probability $\bar{R}_{SRV,i}^{(k)}$, growth rate coefficient $\bar{r}_{GRW,i}^{(k)}$, and mortality rate coefficient $\bar{r}_{MOR,i}^{(k)}$. It must be realized that this particular formulation does not imply that these three parameters reflect three independent biological phenomena. Since the present model is intended for the simulation of the actual striped bass young-of-the-year populations in the Hudson River and since sufficiently accurate data to specify growth and mortality rates for striped bass are not presently available, the three-parameter formulation was selected to achieve flexibility in simulating the observed temporal distributions.

In general, the growth rate coefficient $\bar{r}_{GRW,i}^{(k)}$, the mortality rate coefficient $\bar{r}_{MOR,i}^{(k)}$, and the apparent survival probability $\bar{R}_{SRV,i}^{(k)}$ are assumed to vary according to the local population density of the life stage and the local temperature and salinity conditions in the estuary. Hence these coefficients can be expressed in terms of their optimum values and correction factors [consistent with postulates (a) through (e) on p. 11] as

$$\bar{r}_{GRW,i}^{(k)} = \bar{r}_{OP,GRW}^{(k)} C_{P,GRW}^{(k)}[\bar{p}_i^{(k)}] C_{T,GRW}^{(k)}(\bar{T}_i) C_{S,GRW}^{(k)}(\bar{S}_i), \quad (3.15)$$

$$\bar{r}_{MOR,i}^{(k)} = \bar{r}_{OP,MOR}^{(k)} C_{P,MOR}^{(k)}[\bar{p}_i^{(k)}] C_{T,MOR}^{(k)}(\bar{T}_i) C_{S,MOR}^{(k)}(\bar{S}_i), \quad (3.16)$$

$$\bar{R}_{SRV,i}^{(k)} = \bar{R}_{OP,SRV}^{(k)} C_{P,SRV}^{(k)}[\bar{p}_i^{(k)}] C_{T,SRV}^{(k)}(\bar{T}_i) C_{S,SRV}^{(k)}(\bar{S}_i), \quad (3.17)$$

where

$$\begin{aligned}\bar{r}_{OP,GRW}^{(k)} &= \text{optimum (maximum) growth rate coefficient for life stage "k"}, \\ C_{P,GRW}^{(k)}[\bar{p}_i^{(k)}] &= \text{correction factor for nonoptimum population density conditions for growth to the next life stage for life stage "k" in discrete element "i"}, \\ C_{T,GRW}^{(k)}(\bar{T}_i) &= \text{correction factor for nonoptimum temperature conditions for growth to the next life stage for life stage "k" in discrete element "i"}, \\ C_{S,GRW}^{(k)}(\bar{S}_i) &= \text{correction factor for nonoptimum salinity conditions for growth to the next life stage for life stage "k" in discrete element "i"}, \\ \bar{r}_{OP,MOR}^{(k)} &= \text{optimum (minimum) mortality rate coefficient for life stage "k"}, \\ C_{P,MOR}^{(k)}[\bar{p}_i^{(k)}] &= \text{correction factor for nonoptimum population density conditions for mortality for life stage "k" in discrete element "i"}, \\ C_{T,MOR}^{(k)}(\bar{T}_i) &= \text{correction factor for nonoptimum temperature conditions for mortality for life stage "k" in discrete element "i"}, \\ C_{S,MOR}^{(k)}(\bar{S}_i) &= \text{correction factor for nonoptimum salinity conditions for mortality for life stage "k" in discrete element "i"}, \\ \bar{R}_{OP,SRV}^{(k)} &= \text{optimum apparent survival probability of life stage "k"}, \\ C_{P,SRV}^{(k)}[\bar{p}_i^{(k)}] &= \text{correction factor for nonoptimum population density conditions for survival for life stage "k" in discrete element "i"},\end{aligned}\quad (3.18)$$

$C_{TSRV,i}^{(k)}(\bar{T}_i)$ = correction factor for nonoptimum temperature conditions for survival for life stage "k" in discrete element "i".

$C_{SSRV,i}^{(k)}(\bar{S}_i)$ = correction factor for nonoptimum salinity conditions for survival for life stage "k" in discrete element "i".

The particular forms of the correction factors for the nonoptimum conditions will be considered in the subsequent discussions of the effects of population density, temperature, and salinity conditions on the biological characteristics (Sects. 3.4, 3.5.1, and 3.5.2 respectively).

According to the general formulation of the growth rates into the next life stage $\dot{p}_{GRW,i}^{(k)}$ and mortality rates $\dot{p}_{MOR,i}^{(k)}$, Eqs. (3.12) and (3.13), it is possible to independently adjust the growth rate coefficient $\bar{r}_{GRW,i}^{(k)}$, mortality rate coefficient $\bar{r}_{MOR,i}^{(k)}$, and the apparent survival probability $\bar{R}_{SRV,i}^{(k)}$ according to the nonoptimum conditions in the system. However, it must be realized that, in reality, in response to temperature, salinity, or population density variations in a nonoptimum range, these three parameters do not reflect three independent biological phenomena; from biological considerations there is an overlap or redundancy among the three parameters. This overlap is advantageous, since it allows flexibility in terms of modeling temperature, salinity, and population density effects. For example, the single phenomenon of an increase in the time rate of mortality of life stage "k" in a discrete element "i", $\dot{p}_{MOR,i}^{(k)}$, Eq. (3.13), could be simulated in the model by either decreasing the apparent survival probability $\{C_{p,SRV,i}^{(k)}[\bar{p}_i^{(k)}]$ less than one, Eq. (3.17)}, increasing the mortality rate coefficient $\{C_{p,MOR,i}^{(k)}[\bar{p}_i^{(k)}]$ greater than one, Eq. (3.16)}, or both.

In simulating the temporal distributions of standing crops, increasing or decreasing the value of the apparent survival probability of a life stage "k", $\bar{R}_{SRV,i}^{(k)}$, primarily increases or decreases, respectively, the maximum values of the standing crops of the next life stage "k + 1" and of the subsequent life stages. Similarly, increasing or decreasing the growth rate coefficient $\bar{r}_{GRW,i}^{(k)}$ and/or mortality rate coefficient $\bar{r}_{MOR,i}^{(k)}$ of a life stage "k" primarily decreases or increases, respectively, the spread as well as the maximum value of the curve representing standing crop vs time of the particular life stage. Hence the three parameters of the model can be effectively employed to obtain both qualitatively and quantitatively accurate simulations of the striped bass young-of-the-year standing crops in the Hudson River.

3.2.3 Formulation of Optimum Growth Rate Coefficient and Optimum Mortality Rate Coefficient

One of the important properties of the populations of the biologically defined life stages is that an individual striped bass cannot exist in a life stage longer than the duration of the life stage [property (d)]. To incorporate this property in the formulation of the population model, the optimum growth rate coefficient $\bar{r}_{OP,GRW}^{(k)}$ and the optimum mortality rate coefficient $\bar{r}_{OP,MOR}^{(k)}$ were defined as the inverse of the optimum duration of the life stage; that is,

$$\bar{r}_{OP,GRW}^{(k)} = \bar{r}_{OP,MOR}^{(k)} = 1 / \Delta t_{OP,DUR}^{(k)} \quad (3.19)$$

where

$$\Delta t_{OP,DUR}^{(k)} = \text{optimum duration of life stage "k", that is, the minimum expected time required for an organism to pass through life stage "k"}. \quad (3.20)$$

This definition for the optimum growth rate coefficient $\bar{r}_{OP,GRW}^{(k)}$ and the optimum mortality rate coefficient $\bar{r}_{OP,MOR}^{(k)}$ is appropriate, provided the age-frequency distribution of fish in the life stage is

approximately uniform so that both growth and mortality transfers may be conceptualized as occurring at the end of the life stage. However, it must be realized that the age-frequency distribution of individuals in a life stage may not be uniform. For example, the population of post-yolk-sac larvae (6.5–15 mm in total length) may consist predominantly of fish less than 11 mm. By increasing the number of life stages, and thereby shortening the duration of each, however, one can compensate for nonuniformity of the age distribution. Hence, by taking finer divisions of life stages, greater uniformity of the temporal distribution of organisms within each life stage and greater accuracy [Eqs. (3.12) and (3.13)] can be obtained.

3.2.4 Empirical Estimation of Effective Apparent Survival Probabilities

The data from the 1973 ichthyoplankton survey in the Hudson River [33] can be reduced [24] to weekly temporal distributions of the standing crops of the striped bass life stages for the period May through November. From these temporal distributions, it is possible to estimate the approximate durations for the life stages. These estimates can be supplemented by estimates of life-stage durations from laboratory and hatchery studies under different conditions of temperature, salinity, and population density. However, due to the overlapping of life stages with appreciably different durations and due to the sampling problems reflected in the data, it is not possible to obtain from the observed temporal distributions an accurate estimate of the true survival probability of a life stage. Although the hatchery studies may provide an upper bound, it can be safely assumed that survival in the natural environment is lower (by as much as an order of magnitude or more) than the optimum survival probabilities obtained with the present striped bass hatchery methods. Thus the natural survival probability of each life stage is very poorly defined. However, an apparent survival probability $R_{s_{k+1}}^{(A)}$ can be empirically estimated for each life stage from the observed temporal distributions of the standing crops for each life stage, as described in the following paragraphs.

In the applications of the present model to the simulations of the 1973 data, the apparent survival probabilities were varied by trial and error until adequate simulations of the observed temporal distributions of the standing crops of all the life stages in the river were obtained, by using the following systematic procedure. The initial estimates for the survival probabilities were determined by considering the temporal distribution of the total striped bass standing crop and of the individual life-stage standing crops [24], as shown for hypothetical distributions in Fig. 3.3. Considering the temporal distributions of the standing crop of each life stage, the final time of existence in the river for each life stage was estimated. The simulations were started with a juvenile population (conditions at time D in Fig. 3.3), and the only unknown parameters, apparent survival probabilities of the three juvenile life stages, were varied until adequate simulations of the observed data for juvenile populations [24] were obtained. After the apparent survival probabilities for the juveniles were established, the simulations were started with post-yolk-sac larva and juvenile populations (conditions at time C in Fig. 3.3), and the only unknown parameter, apparent survival probability of the post-yolk-sac larva life stage, was varied until adequate simulations of the observed data for post-yolk-sac larva and juvenile populations were obtained. After the apparent survival probabilities for the post-yolk-sac larva and juvenile life stages were determined, the same procedure was used to determine the apparent survival probability of the yolk-sac larva life stage (using conditions at time B in Fig. 3.3 as the starting point for the simulations) and then the apparent survival probability of the egg life stage (using conditions at time A in Fig. 3.3 as the starting point for the simulations). This systematic procedure provided for the determination of the apparent survival probability of each life stage separately, while still retaining an adequate simulation of the observed temporal distribution for each life stage at each step. Hence this procedure eliminated the

Fig. 3.3. Hypothetical temporal distributions of striped bass young-of-the-year standing crops in the Hudson River.

necessity of combinatorial iterations of the apparent survival probabilities for all the life stages simultaneously.

Considering the inaccuracies involved in the sampling of the young-of-the-year populations, the temporal distribution of the total standing crop in the estuary (similar to Fig. 3.3) can only be determined approximately [25]. Hence the apparent survival probabilities, estimated by the above procedure, can only be determined approximately. Considering that the survival of organisms will vary in response to biotic and abiotic factors which change over time (e.g., population density, food availability, predation, temperature, and salinity), it is realistic to assume that the apparent survival probabilities of the life stages also will vary. Hence the value for the apparent survival probability of a life stage $\bar{R}_{\text{RV},i}^{(h)}$, determined from the temporal distributions of the standing crops, represents only an effective apparent survival probability [as compared with optimum apparent survival probability; see Eq. (3.18)] for the period of the simulation and for all the discrete elements along the estuary. The distinction between the use of the effective apparent survival probability and the optimum apparent survival probability are discussed in Sect. 3.6.2.

3.2.5 Concept of Residual Life-Stage Population Density and Formulation of Growth and Mortality Rates After Input from Previous Life Stage Ceases

It is important to realize that Eqs. (3.12) and (3.13) are valid for a life stage only when the rate of gain of population from the previous life stage is greater than zero. After the end of the spawning period,

this condition ceases to be satisfied in a sequential order through the life stages. The present forms, Eqs. (3.12) and (3.13), of the growth into the next life stage $\bar{p}_{GRW}^{(k)}$ and the mortality rate $\bar{p}_{MOR}^{(k)}$ tend to simulate exponential behavior of the life-stage populations. That is, the population of a life stage can never become zero by growth to the next life stage and mortality; rather it will always tend to zero in an exponentially decaying manner. Consequently, the present form of the model would simulate conditions corresponding to some individual fish existing in a life stage considerably longer than the duration of the life stage. In reality, after the rate of gain of population from the previous life stage becomes zero, the remaining population in the life stage must necessarily decrease to zero in a time equal to the duration of the life stage, since no individual fish can exist in a life stage longer than the duration of the biologically defined life stage [property (d), p. 17]. This problem, which is inherent to all existing, multi-life-stage dynamic population models (e.g., refs 1-3,) was eliminated in the formulation of the present model by considering the concept of "residual" life-stage population densities $\bar{p}_{RES}^{(k)}$ and by modifying the definitions of the growth and mortality rate terms in Eqs. (3.14) and (3.15) as

$$\bar{p}_{GRW}^{(k)} = \bar{r}_{GRW}^{(k)} \bar{R}_{SRV}^{(k)} \bar{p}_{RES}^{(k)} \quad (3.21)$$

$$\bar{p}_{MOR}^{(k)} = \bar{r}_{MOR}^{(k)} [1 - \bar{R}_{SRV}^{(k)}] \bar{p}_{RES}^{(k)} \quad (3.22)$$

At the start of the computations, the residual life-stage population densities are set equal to zero for all life stages in all discrete elements; that is,

$$\bar{p}_{RES}^{(k)}(t_0) = \bar{p}_0^{(k)}(t_0) = \bar{p}_{00}^{(k)} = 0 \quad (3.23)$$

During the computations, the residual population density for life stage "k", $\bar{p}_{RES}^{(k)}$, is evaluated based on the growth rate of life stage "k-1" into life stage "k". For k = 1 (egg):

$$\text{if } \bar{p}_{GRW}^{(1)} > 0, \quad \text{then } \bar{p}_{RES}^{(1)} = \bar{p}_0^{(1)} \quad (3.24)$$

$$\text{if } \bar{p}_{GRW}^{(1)} \leq 0, \text{ then}$$

$$\begin{cases} \bar{p}_{RES}^{(1)} = \bar{p}_0^{(1)}, & \text{if } \bar{p}_{RES}^{(0)} < \bar{p}_0^{(1)} \\ \bar{p}_{RES}^{(1)} = \bar{p}_{RES}^{(0)}, & \text{if } \bar{p}_{RES}^{(0)} \geq \bar{p}_0^{(1)} \end{cases} \quad (3.25)$$

where $\bar{p}_{RES}^{(0)}$ is the residual egg population density from the previous time step in the computations

For $2 \leq k \leq K$:

$$\text{if } \bar{p}_{GRW}^{(k)} > 0, \quad \text{then } \bar{p}_{RES}^{(k)} = \bar{p}_0^{(k)} \quad (3.26)$$

$$\text{if } \bar{p}_{GRW}^{(k)} \leq 0, \text{ then}$$

$$\begin{cases} \bar{p}_{RES}^{(k)} = \bar{p}_0^{(k)}, & \text{if } \bar{p}_{RES}^{(k-1)} < \bar{p}_0^{(k)} \\ \bar{p}_{RES}^{(k)} = \bar{p}_{RES}^{(k-1)}, & \text{if } \bar{p}_{RES}^{(k-1)} \geq \bar{p}_0^{(k)} \end{cases} \quad (3.27)$$

where p_{ik}^* is the residual population density of life stage "k" from the previous time step in the computations. Equations (3.23) through (3.27) represent a novel feature of the present dynamic population model which warrants further elaboration.

Considering the egg life stage as an example, Eq. (3.24) indicates that during the spawning period, when the rate of egg deposition $p_{i,ea}$ in discrete element "i" is greater than zero, the residual egg population density p_{ik}^* is identically equal to the simulated egg population density $p_{i,ea}$ in the discrete element; hence the growth and mortality rates, $p_{i,ek}$ and $p_{i,ek}^*$, respectively, Eqs (3.21) and (3.22), are evaluated as standard first-order rate forms consistent with the previous unmodified forms, Eqs (3.12) and (3.13). However, when spawning terminates, that is, egg deposition rate $p_{i,ea}$ in discrete element "i" becomes zero, the model considers two alternatives. If the existing residual egg population density in the discrete element, from the previous time step, is less than the new value of the simulated egg population density in the discrete element, then the residual value is set equal to the simulated value of the egg population density. Although this case occurs very seldom, it may occur due to the net transport of eggs into the discrete element from the adjacent discrete elements at such large rates that the net number of eggs transported into discrete element "i" more than balances the number of eggs lost from discrete element "i" due to mortality and growth to the yolk-sac larva life stage.

However, if the existing residual egg population density in the discrete element, from the previous time step, is equal to or higher than the new value of the simulated egg population density in the discrete element, which is the most common condition after the spawning period, the value of the residual egg population density remains equal to its value from the previous time step in the computations. Consequently, the growth and mortality rates $p_{i,ek}$ and $p_{i,ek}^*$, respectively, are evaluated from Eqs (3.21) and (3.22) for fixed values of $p_{i,ea}$ during the computational period. This formulation results in an approximately constant population reduction rate for the egg life stage, and an approximately constant rate of gain for the yolk-sac life stage in the discrete element. Small variations from the constant rates could occur due to the correction factors associated with nonoptimum population density, temperature, and salinity conditions. Hence the model avoids the unrealistic first-order forms for the formulation of growth and mortality rates for the egg population after the end of the spawning period. Furthermore, the present formulation guarantees that after a time period equal to the duration of the egg life stage following the termination of egg deposition, the egg population is zero.

The present formulation also realistically simulates the growth and mortality rates of each later life stage by incorporating the necessary modifications, similar to the ones for the egg life stage, which change the first-order, exponential decay-type forms to the linear forms, Eqs (3.26) and (3.27), after the rate of gain from the previous life stage becomes zero.

Hence a dynamic life-stage model can be realistically formulated in terms of three parameters: apparent survival probability R_{ik}^* , growth rate coefficient $r_{i,ek}^*$, and mortality rate coefficient $r_{i,ek}$. Using these parameters one can define, from Eqs (3.12) and (3.13), the growth rate (per unit volume) into the next life stage $p_{i,ek}^*$ and the mortality rate (per unit volume) $p_{i,ek}$. These in turn enter into the net local time rate of variation of population density of the life stage p'' , Eqs (3.9) and (3.10), and into the governing discrete element equation of the computer simulation model, Eq. (2.9).

3.3 MOBILITY CHARACTERISTICS OF THE LIFE STAGES

The later life stages of the striped bass young-of-the-year (Juvenile I, Juvenile II, and Juvenile III) are highly mobile, a characteristic which has important implications in assessing power plant impacts. For example, migration to shoal areas can significantly influence the longitudinal distributions, and the

ability of juveniles to avoid the intakes reduces their susceptibility to entrainment and impingement at the power plants. The present model considers these important effects based on the biological characteristics of the striped bass in various life stages and according to the physical conditions and the geometry of the river. This approach is taken rather than introducing empirical modifications in the formulations to simulate shoaling and intake avoidance (e.g., refs. 1-3).

Since, contrary to the tidal-average hypothesis of the models, the life-stage populations actually exist under strong, periodic tidal flow conditions in the estuary, the ultimate longitudinal effect of migratory behavior necessarily depends, in part, on the ability to swim against the tidal currents. Similarly, susceptibility to entrainment and impingement also depends, in part, on the ability to swim against the intake flow velocities.

In the general formulation of the present model, the early life stages (egg, yolk-sac larva, and post-yolk-sac larva) are assumed to have no appreciable mobility characteristics which can directly influence their longitudinal motions in the estuary or their ability to avoid the intakes. It should be realized that the possible daily variations in the vertical distributions of these life stages are not included here in the general definitions of the mobility characteristics. Indeed, the vertical motions of the early life stages can indirectly influence their longitudinal motions and avoidance at the intakes.

Approximate biological mobility characteristics are assigned to the later life stages (Juvenile I, Juvenile II, and Juvenile III) based on the definitions of the following variables:

$$\begin{aligned}
 V_{k,m}^{u} &= \text{approximate maximum speed which characterizes the mobility of life stage "k"}, \\
 \Delta t_{k,m}^{u} &= \text{approximate sustained duration at approximate maximum speed of life stage "k"}, \\
 \gamma_{k,i}^{u} &= \text{intake avoidance parameter for life stage "k"}, \\
 \gamma_{k,s}^{u} &= \text{shoaling effect parameter for life stage "k"}, \\
 \gamma_{k,c}^{u} &= \text{crowding effect parameter for life stage "k"}
 \end{aligned}
 \tag{3.28}$$

The available information about the swimming characteristics of the striped bass young-of-the-year is based on limited experimental data [39,40] concerning the maximum swimming speeds and the fatigue times which were determined by observing different sized fish, corresponding to different life stages, under uniform flow conditions generated in a laboratory apparatus. Based on the results of these studies, approximate values were assigned to the mobility characteristics, as listed in Table 3.2. It must be emphasized that the parameters employed in any model to simulate the effects of swimming ability of the striped bass young-of-the-year cannot be considered as completely accurate representations of the actual mobility and behavioral characteristics of these later life stages. However, considering the uncertainties in the river sampling data and other input data to the general model, the assumed values for

Table 3.2. Approximate data employed in the computer simulation model for the mobility characteristics of life-stage populations

Life-stage index (k)	Life stage	Maximum swimming speed $V_{k,m}^{u}$ (fps)	Sustained duration $\Delta t_{k,m}^{u}$ (hr)	Intake avoidance parameter $\gamma_{k,i}^{u}$	Shoaling effect parameter $\gamma_{k,s}^{u}$	Crowding effect parameter $\gamma_{k,c}^{u}$
4	Juvenile I	0.50	2.00	0.00	0.4	0.2
5	Juvenile II	1.00	4.00	0.80	0.4	0.2
6	Juvenile III	1.00	6.00	1.00	0.4	0.2

the mobility characteristics in Table 3.2 are indeed acceptable to achieve sufficiently accurate simulations of the shoaling and intake avoidance conditions for the life-stage populations.

To incorporate the effects of the nonoptimum conditions of life-stage population densities $\bar{p}^k$, temperature $\bar{T}$, and salinity $\bar{S}$ on the mobility characteristics of the life-stage populations, the maximum swimming speeds $\bar{V}_{\text{mob}}^k$ can be modified by appropriate correction factors, depending on the local conditions in the discrete elements, as

$$\bar{V}_{\text{mob},i}^k = \bar{V}_{\text{mob}}^k C_{p,\text{mob}}^k[\bar{p}^k] C_{T,\text{mob}}^k(\bar{T}) C_{S,\text{mob}}^k(\bar{S}), \quad (3.29)$$

where

$$\begin{aligned} \bar{V}_{\text{mob},i}^k &= \text{maximum swimming speed of life stage "k" in discrete element "i"}, \\ C_{p,\text{mob}}^k[\bar{p}^k] &= \text{correction factor for nonoptimum population density conditions in discrete element "i" which affect the mobility of life stage "k"}, \\ C_{T,\text{mob}}^k(\bar{T}) &= \text{correction factor for nonoptimum temperature conditions in discrete element "i" which affect the mobility of life stage "k"}, \\ C_{S,\text{mob}}^k(\bar{S}) &= \text{correction factor for nonoptimum salinity conditions in discrete element "i" which affect the mobility of life stage "k"}, \end{aligned} \quad (3.30)$$

The particular forms of the correction factors for the nonoptimum conditions for the mobility characteristics of the life stages will be considered in the subsequent discussions of the effects of population density, temperature, and salinity conditions on the biological characteristics.

3.4 MODELING OF THE COMPENSATORY MECHANISMS

The proper modeling of the net effect of all compensatory mechanisms involving the striped bass young-of-the-year in the Hudson River would require the consideration of the general ecological system, including multispecies populations, food limitation, predation, and other interaction phenomena among the species. In view of our present understanding of complex ecological systems, it is not possible to develop a predictive simulation model incorporating all these effects.

The available information about the striped bass does not provide direct evidence relating to the existence of or the significance of possible compensatory mechanisms operating on the life stages of the young-of-the-year population. However, assuming the occurrence of compensation sometime in the life cycle of all biological species existing in limited environments, it is likely that compensation is operational (but at unknown levels) during the first year of life of the striped bass [1-3, 26, 41].

The general formulation of the computer simulation model incorporates compensatory mechanisms for each biological characteristic of each life stage. These compensatory mechanisms were introduced in Sects. 3.1, 3.2, and 3.3 as multiplicative correction factors for spawning rates, Eq. (3.7), for apparent survival probabilities, Eq. (3.17), for growth and mortality rate coefficients, Eqs. (3.15) and (3.16), and for maximum swimming speeds, Eq. (3.30), of all life stages. These correction factors are introduced to simulate the effects of nonoptimum population density conditions in the system. The particular forms of correction factors are based on the following assumptions:

- a. The correction factor for nonoptimum population densities associated with a biological characteristic of a life stage in a discrete element depends only on the population density of the particular life stage in the particular discrete element.

This assumption in a sense imposes limitations on the generality of the formulation, since under realistic conditions the overall compensatory mechanisms for a life stage could depend on food limitations, predation, cannibalism, and numerous other factors which depend on the populations of different life stages and possibly on the populations of other biological species in the estuary.

- b. For every biological characteristic of a life stage, there exists an associated critical population density below which the variations in population density do not affect the biological characteristic. Below the critical density, the multiplicative correction factor remains unity, so that the compensatory mechanism does not operate until the critical population density is exceeded in the discrete element.

This assumption seems realistic for most mechanisms, such as food limitation and predation, which may contribute to compensation.

- c. The compensatory mechanism for a biological characteristic of a life stage becomes effective in a discrete element when the population density exceeds the critical level. For population densities higher than the critical level, the multiplicative correction factor decreases (or increases as for the mortality rate coefficient) linearly from the optimum value of unity.

The assumed linear variation for the population density dependence of the biological characteristics represents the first-order approximation of any functional dependence. In the absence of more detailed information to the contrary, it is the most plausible variation from a mathematical point of view. The linear variation is commonly used, for example, in logistic models [13] to represent dependence of population growth rate on the size of the population.

- d. For every biological characteristic of a life stage, there exists a maximum population density above which the biological characteristic remains at a value that is most detrimental to the life stage.

The maximum population density represents the second necessary parameter, in addition to the critical population density, for determining the slope of the compensatory correction factor. In the applications of the simulation model, the population densities in the discrete elements never actually reach the maximum population density. Thus the parameter is used strictly as a convenient means of specifying the slope of the linear variation for the correction factor.

3.4.1 Formulation of the Population Density Correction Factor for Spawning Rate

The correction factor for nonoptimum population density conditions for spawning rate, Eq. (3.7), is formulated according to the four assumptions about compensation; that is,

$$\begin{aligned}
 &\text{for } \bar{p}^{(k)} \leq \bar{p}_{cr,spw}^{(k)} : \\
 &\quad C_{p,spw}^{(k)}[\bar{p}^{(k)}] = 1 ; \\
 &\text{for } \bar{p}_{cr,spw}^{(k)} < \bar{p}^{(k)} < \bar{p}_{mx,spw}^{(k)} : \\
 &\quad C_{p,spw}^{(k)}[\bar{p}^{(k)}] = [\bar{p}^{(k)} - \bar{p}_{mx,spw}^{(k)}] [\bar{p}_{cr,spw}^{(k)} - \bar{p}_{mx,spw}^{(k)}] ; \\
 &\text{for } \bar{p}^{(k)} \geq \bar{p}_{mx,spw}^{(k)} : \\
 &\quad C_{p,spw}^{(k)}[\bar{p}^{(k)}] = 0 ;
 \end{aligned} \tag{3.11}$$

where

- $\bar{p}_{CR,SPW}$ = critical population density above which the spawning rate decreases linearly with increasing population density of life stage "k".
- $\bar{p}_{MX,SPW}$ = maximum population density above which the spawning rate is assumed as zero for life stage "k".

(3.32)

The schematic representation of the correction factor, Eq. (3.31), is shown in Fig. 3.4 as a function of the population density of dummy adult spawners $\bar{p}_i$.

Fig. 3.4. Schematic representation of population density correction factor for spawning rate.

3.4.2 Formulation of the Population Density Correction Factor for Apparent Survival Probability

The correction factor for nonoptimum population density conditions for survival, Eq. (3.17), is formulated similarly:

for $\bar{p}^{(k)} \leq \bar{p}_{CR,SRV}^{(k)}$,

$$C_{P,SRV,i}^{(k)}[\bar{p}^{(k)}] = 1;$$

for $\bar{p}_{CR,SRV}^{(k)} < \bar{p}^{(k)} < \bar{p}_{MX,SRV}^{(k)}$,

$$C_{P,SRV,i}^{(k)}[\bar{p}^{(k)}] = [\bar{p}^{(k)} - \bar{p}_{MX,SRV}^{(k)}] / [\bar{p}_{CR,SRV}^{(k)} - \bar{p}_{MX,SRV}^{(k)}];$$

(3.33)

for $\bar{p}^{(k)} \geq \bar{p}_{MX,SRV}^{(k)}$,

$$C_{P,SRV,i}^{(k)}[\bar{p}^{(k)}] = 0;$$

where

$$\begin{aligned} \bar{p}_{CR,SRV}^{(h)} &= \text{critical population density above which the apparent survival probability} \\ &\quad \text{decreases linearly with increasing population density of life stage "k".} \\ \bar{p}_{MX,SRV}^{(h)} &= \text{maximum population density above which the apparent survival probability is} \\ &\quad \text{assumed to be zero for life stage "k".} \end{aligned} \quad (3.34)$$

The schematic representation of the correction factor, Eq. (3.33), is shown in Fig. 3.5 as a function of the population density $\bar{p}^{(h)}$. The correction factor $\bar{C}_{p,SRV}^{(h)}[\bar{p}^{(h)}]$ represents the changes in the apparent survival probability $\bar{R}_{SRV}^{(h)}$, which can occur without directly affecting the mortality rate coefficient or growth rate coefficient.

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Fig. 3.5. Schematic representation of population density correction factor for apparent survival probability.

3.4.3 Formulation of the Population Density Correction Factor for the Growth Rate Coefficient

The correction factor for nonoptimum population density conditions for growth into the next life stage, Eq. (3.15), is formulated according to the four assumptions about compensation: that is,

$$\begin{aligned} \text{for } \bar{p}^{(h)} &\leq \bar{p}_{CR,GRW}^{(h)} : \\ C_{p,GRW}^{(h)}[\bar{p}^{(h)}] &= 1 ; \\ \text{for } \bar{p}_{CR,GRW}^{(h)} &< \bar{p}^{(h)} < \bar{p}_{MX,GRW}^{(h)} : \\ C_{p,GRW}^{(h)}[\bar{p}^{(h)}] &= [\bar{p}^{(h)} - \bar{p}_{MX,GRW}^{(h)}] [\bar{p}_{CR,GRW}^{(h)} - \bar{p}_{MX,GRW}^{(h)}] ; \\ \text{for } \bar{p}^{(h)} &\geq \bar{p}_{MX,GRW}^{(h)} : \\ C_{p,GRW}^{(h)}[\bar{p}^{(h)}] &= 0 ; \end{aligned} \quad (3.35)$$

where

- $\bar{p}_{CR,GRW}^{(k)}$ = critical population density above which the growth rate coefficient decreases linearly with increasing population density of life stage "k",
 $\bar{p}_{MX,GRW}^{(k)}$ = maximum population density above which the growth rate coefficient is assumed to be zero for life stage "k".

(3.36)

The schematic representation of the correction factor, Eq. (3.35), is shown in Fig. 3.6 as a function of the population density $\bar{p}_i^{(k)}$. The correction factor $\bar{C}_{p,GRW}^{(k)}[\bar{p}_i^{(k)}]$ represents the changes in the apparent growth rate coefficient $\bar{r}_{GRW}^{(k)}$ which can occur without directly affecting the apparent survival probability and mortality rate coefficient.

Fig. 3.6. Schematic representation of population density correction factor for the growth rate coefficient to the next life stage.

3.4.4 Formulation of the Population Density Correction Factor for the Mortality Rate Coefficient

The correction factor for nonoptimum population density conditions for mortality rate, Eq. (3.16), must be of a form which increases with increasing population density above the critical conditions. Such a form for the correction factor is formulated according to the four assumptions about compensation; that is,

for $\bar{p}_i^{(k)} \leq \bar{p}_{CR,MOR}^{(k)}$,

$$C_{p,MOR}^{(k)}[\bar{p}_i^{(k)}] = 1;$$

for $\bar{p}_{CR,MOR}^{(k)} < \bar{p}_i^{(k)} < \bar{p}_{MX,MOR}^{(k)}$,

$$C_{p,MOR}^{(k)}[\bar{p}_i^{(k)}] = 1 + C_{MX,MOR}^{(k)}[\bar{p}_i^{(k)} - \bar{p}_{CR,MOR}^{(k)}] [\bar{p}_{MX,MOR}^{(k)} - \bar{p}_{CR,MOR}^{(k)}];$$

(3.37)

for $\bar{p}_i^{(k)} \geq \bar{p}_{MX,MOR}^{(k)}$,

$$C_{p,MOR}^{(k)}[\bar{p}_i^{(k)}] = [C_{MX,MOR}^{(k)}]^{-1};$$

where

- $\bar{p}_{CR,MOR}^{(h)}$ = critical population density above which the mortality rate coefficient increases linearly with increasing population density of life stage "k".
- $\bar{p}_{MX,MOR}^{(h)}$ = maximum population density above which mortality is assumed to be catastrophic for life stage "k". (3.38)
- $\bar{C}_{MX,MOR}^{(h)}$ = value of the mortality rate coefficient representing the catastrophic mortality rate corresponding to $\bar{p}_{MX,MOR}^{(h)}$ for life stage "k" [i.e., $\bar{C}_{MX,MOR}^{(h)} \gg 1$].

The schematic representation of the correction factor, Eq. (3.37), is shown in Fig. 3.7 as a function of the population density $\bar{p}^{(h)}$. The correction factor $\bar{C}_{p,MOR}^{(h)}[\bar{p}^{(h)}]$ represents the changes in the mortality rate coefficient $\bar{r}_{MOR}^{(h)}$, which can occur without directly affecting the apparent survival probability and growth rate coefficient.

The definition of the population density correction factor for the mortality rate coefficient includes an additional parameter, $\bar{C}_{MX,MOR}^{(h)}$, Eq. (3.37), and a discontinuity in the function to represent catastrophic conditions. The linear variation part of the function, Eq. (3.37), Fig. 3.7, introduces a monotonically increasing correction to the mortality rate coefficient which tends toward a value significantly greater than the mortality rate coefficient under optimum conditions [i.e., $\bar{C}_{MX,MOR}^{(h)} \gg 1$].

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Fig. 3.7. Schematic representation of population density correction factor for the mortality rate coefficient.

The discontinuous jump in the function to the cubic power of $\bar{C}_{M\backslash MOB}^{(k)}$ is primarily for computational convenience to reduce the population of the life stage very rapidly in simulations of catastrophic conditions.

3.4.5 Formulation of the Population Density Correction Factor for Swimming Speed

The correction factor for nonoptimum population density conditions for swimming speed, Eq. (3.29), is formulated according to the four assumptions about compensation: that is,

$$\begin{aligned}
 &\text{for } \bar{p}_i^{(k)} < \bar{p}_{OP, MOB}^{(k)} : \\
 &\quad C_{p, MOB}^{(k)}[\bar{p}_i^{(k)}] = \bar{p}_i^{(k)} / \bar{p}_{OP, MOB}^{(k)} ; \\
 &\text{for } \bar{p}_{OP, MOB}^{(k)} \leq \bar{p}_i^{(k)} \leq \bar{p}_{CR, MOB}^{(k)} : \\
 &\quad C_{p, MOB}^{(k)}[\bar{p}_i^{(k)}] = 1 ; \\
 &\text{for } \bar{p}_{CR, MOB}^{(k)} < \bar{p}_i^{(k)} < \bar{p}_{MX, MOB}^{(k)} : \\
 &\quad C_{p, MOB}^{(k)}[\bar{p}_i^{(k)}] = [\bar{p}_i^{(k)} - \bar{p}_{MX, MOB}^{(k)}] / [\bar{p}_{CR, MOB}^{(k)} - \bar{p}_{MX, MOB}^{(k)}] ; \\
 &\text{for } \bar{p}_i^{(k)} \geq \bar{p}_{MX, MOB}^{(k)} : \\
 &\quad C_{p, MOB}^{(k)}[\bar{p}_i^{(k)}] = 0 ;
 \end{aligned} \tag{3.39}$$

where

$$\begin{aligned}
 \bar{p}_{OP, MOB}^{(k)} &= \text{optimum population density below which the swimming speed decreases linearly with decreasing population density of life stage "k"}, \\
 \bar{p}_{CR, MOB}^{(k)} &= \text{critical population density above which the swimming speed decreases linearly with increasing population density of life stage "k"}, \\
 \bar{p}_{MX, MOB}^{(k)} &= \text{maximum population density above which the swimming speed is assumed as zero for life stage "k"}.
 \end{aligned} \tag{3.40}$$

The schematic representation of the correction factor, Eq. (3.39), is shown in Fig. 3.8 as a function of the population density $\bar{p}_i^{(k)}$.

The correction factor $C_{p, MOB}^{(k)}[\bar{p}_i^{(k)}]$ for the swimming speed, Eq. (3.39), Fig. 3.8, does not represent a compensatory function in the usual sense of increasing population density being detrimental to the biological characteristic. The particular form assumes that for very low levels of population density, the mobility of the life stage increases with increasing population density. This part of the function is intended to represent the strong tendency of the striped bass juveniles to school and to be more mobile collectively than as individuals.

In summary, the present formulation incorporates a population density-dependent function for each of the biological characteristics explicitly considered in the model for each of the life stages. Hence the computer simulation model has the capability to consider various possible compensatory mechanisms which could affect the striped bass young-of-the year populations in the Hudson River.

Fig. 3.8. Schematic representation of population density correction factor for swimming speed.

3.5 MODELING OF THE EFFECTS OF TEMPERATURE AND SALINITY CONDITIONS

The biological characteristics of the striped bass populations depend on the temperature and salinity conditions in the estuary. In the general formulation of the model, the effects of nonoptimum temperature and salinity conditions were introduced as multiplicative correction factors for the biological characteristics of spawning rates, Eq. (3.6), apparent survival probabilities, Eq. (3.17), growth rate coefficients and mortality rate coefficients, Eqs. (3.15) and (3.16), and swimming speeds, Eq. (3.29). These correction factors are defined below as functions of temperature and salinity in the discrete elements.

The particular expressions for the correction factors were formulated according to the following three simplifying but plausible assumptions:

- For any biological characteristic of a life stage, there exist certain ranges of temperature and salinity for which the particular characteristic has an optimum value; that is, the correction factors for nonoptimum conditions attain values of unity.
- For temperature and salinity conditions outside of the ranges of optimum conditions, the biological characteristics of a life stage change according to the multiplicative correction factors which vary linearly with temperature and salinity from their optimum values of unity.

- c. For any biological characteristic of a life stage, there exist minimum temperature and salinity conditions (may not apply for certain characteristics) below which the biological characteristic remains either at its minimum or at a value most detrimental to the life stage. Similarly, there exist maximum temperature and salinity conditions above which the biological characteristic remains either at its minimum or at a value most detrimental to the life stage.

These three assumptions about the general forms of the correction factors correspond to first-order approximations for the actual (although possibly unknown) functional relations which represent the dependencies of the biological characteristics of the life stages on temperature and salinity.

3.5.1 Formulation of the Correction Factor for Nonoptimum Temperature Conditions for Spawning Rate

The observed data for egg distributions and temperature conditions in the Hudson River indicate that the spawning period is generally limited to a fixed temperature range, with the peak spawning rates occurring about the midpoint of the range. Hence the correction factor for nonoptimum temperature conditions for spawning is formulated, according to the three assumptions about the general form, as follows:

$$\begin{aligned}
 &\text{for } \bar{T}_i \leq \bar{T}_{\text{MIN,SPW}}^{(k)} : \\
 &\quad C_{\text{TEMP},i}^{(k)}(\bar{T}_i) = 0 ; \\
 &\text{for } \bar{T}_{\text{MIN,SPW}}^{(k)} < \bar{T}_i < \bar{T}_{\text{OPT,SPW}}^{(k)} : \\
 &\quad C_{\text{TEMP},i}^{(k)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{\text{MIN,SPW}}^{(k)}] [\bar{T}_{\text{OPT,SPW}}^{(k)} - \bar{T}_{\text{MIN,SPW}}^{(k)}] ; \\
 &\text{for } \bar{T}_{\text{OPT,SPW}}^{(k)} \leq \bar{T}_i \leq \bar{T}_{\text{MAX,SPW}}^{(k)} : \\
 &\quad C_{\text{TEMP},i}^{(k)}(\bar{T}_i) = 1 ; \\
 &\text{for } \bar{T}_{\text{MAX,SPW}}^{(k)} < \bar{T}_i < \bar{T}_{\text{MIN,SPW}}^{(k)} : \\
 &\quad C_{\text{TEMP},i}^{(k)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{\text{MAX,SPW}}^{(k)}] [\bar{T}_{\text{OPT,SPW}}^{(k)} - \bar{T}_{\text{MAX,SPW}}^{(k)}] ; \\
 &\text{for } \bar{T}_i \geq \bar{T}_{\text{MIN,SPW}}^{(k)} : \\
 &\quad C_{\text{TEMP},i}^{(k)}(\bar{T}_i) = 0 ;
 \end{aligned} \tag{3.41}$$

where

$$\begin{aligned}
 &\bar{T}_{\text{MIN,SPW}}^{(k)} = \text{minimum temperature below which spawning does not occur, and above which} \\
 &\quad \text{the spawning rate increases with increasing temperature for life stage "k"}, \\
 &\bar{T}_{\text{OPT,SPW}}^{(k)} = \text{lower temperature bound at which the spawning rate attains the optimum value} \\
 &\quad \text{for life stage "k"}, \\
 &\bar{T}_{\text{MAX,SPW}}^{(k)} = \text{higher temperature bound above which the spawning rate decreases, from the} \\
 &\quad \text{optimum value, with increasing temperature for life stage "k"}, \\
 &\bar{T}_{\text{MIN,SPW}}^{(k)} = \text{maximum temperature above which spawning does not occur for life stage "k"}.
 \end{aligned} \tag{3.42}$$

The schematic representation of the assumed mathematical form, Eq. (3.41), of the correction factor for nonoptimum temperature conditions for spawning rate is shown in Fig. 3.9.

Fig. 3.9. Schematic representation of the correction factor for nonoptimum temperature conditions for spawning rate.

The assumed mathematical form, Eq. (3.41), for the temperature dependence of spawning rate indicates that four parameter values for temperature, $\bar{T}_{MN, SPW}^{(h)}$, $\bar{T}_{OL, SPW}^{(h)}$, $\bar{T}_{OH, SPW}^{(h)}$, and $\bar{T}_{MX, SPW}^{(h)}$, are required from observed spawning behavior to define the correction factor for nonoptimum temperature conditions for the spawning rate. Since the information about the effects of temperature on the spawning rate is not directly available, these parameters were estimated by considering the temporal distributions of the egg population and of the temperature in the Hudson River during the spawning period.

3.5.2 Formulation of the Correction Factor for Nonoptimum Temperature Conditions for Apparent Survival Probability

The temperature conditions in the estuary could also influence the apparent survival probabilities of the life stages. Hence the correction factor for nonoptimum temperature conditions for apparent survival probability to the next life stage is formulated according to the three assumptions about the general form as follows:

for $\bar{T}_i \leq \bar{T}_{MN, SRV}^{(h)}$,

$$C_{T, SRV, i}^{(h)}(\bar{T}_i) = 0;$$

for $\bar{T}_{MN, SRV}^{(h)} < \bar{T}_i < \bar{T}_{OH, SRV}^{(h)}$,

$$C_{T, SRV, i}^{(h)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{MN, SRV}^{(h)}] [\bar{T}_{OH, SRV}^{(h)} - \bar{T}_{MN, SRV}^{(h)}];$$

for $\bar{T}_{OH, SRV}^{(h)} \leq \bar{T}_i \leq \bar{T}_{MX, SRV}^{(h)}$,

$$C_{T, SRV, i}^{(h)}(\bar{T}_i) = 1;$$

for $\bar{T}_{OL,SRV}^{(k)} < \bar{T}_i < \bar{T}_{OH,SRV}^{(k)}$,

$$C_{T,SRV}^{(k)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{MN,SRV}^{(k)}] [\bar{T}_{OH,SRV}^{(k)} - \bar{T}_{MN,SRV}^{(k)}];$$

for $\bar{T}_i \geq \bar{T}_{MN,SRV}^{(k)}$,

$$C_{T,SRV}^{(k)}(\bar{T}_i) = 0;$$

where

$\bar{T}_{MN,SRV}^{(k)}$ = minimum temperature below which survival to the next life stage is not possible, and above which the apparent survival probability increases with increasing temperature for life stage "k".

$\bar{T}_{OL,SRV}^{(k)}$ = lower temperature bound at which the apparent survival probability attains the optimum value for life stage "k".

$\bar{T}_{OH,SRV}^{(k)}$ = higher temperature bound above which the apparent survival probability decreases, from the optimum value, with increasing temperature for life stage "k". (3.44)

$\bar{T}_{MX,SRV}^{(k)}$ = maximum temperature above which survival to the next life stage is not possible for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.43), of the correction factor for nonoptimum temperature conditions for apparent survival probability is shown in Fig. 3.10.

The assumed mathematical form, Eq. (3.43), for the temperature dependence of the apparent survival probability indicates that four parameter values for temperature, $\bar{T}_{MN,SRV}^{(k)}$, $\bar{T}_{OL,SRV}^{(k)}$, $\bar{T}_{OH,SRV}^{(k)}$, and

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Fig. 3.10. Schematic representation of the correction factor for nonoptimum temperature conditions for apparent survival probability.

$\bar{T}_{\text{MS,GRW}}^{\text{hi}}$ are required to specify the correction factor for nonoptimum temperature conditions for the apparent survival probability to the next life stage. In the applications of the simulation model, these parameters were specified in such a manner that the temperature dependence of the apparent survival probability was not utilized.

3.5.3 Formulation of the Correction Factor for Nonoptimum Temperature Conditions for the Growth Rate Coefficient

The durations of the life stages depend, in part, on the temperature conditions [42-44]. The rate of growth to the next life stage is slower early in the summer when the temperatures in the river are usually below the optimum conditions. Hence the correction factor for nonoptimum temperature conditions for the growth rate coefficient is formulated according to the three assumptions about the general form: that is,

$$\begin{aligned}
 \text{for } \bar{T}_i &\leq \bar{T}_{\text{MS,GRW}}^{\text{hi}} : \\
 C_{\text{GRW},i}^{\text{hi}}(\bar{T}_i) &= 0 ; \\
 \text{for } \bar{T}_{\text{MS,GRW}}^{\text{hi}} < \bar{T}_i < \bar{T}_{\text{OH,GRW}}^{\text{hi}} : \\
 C_{\text{GRW},i}^{\text{hi}}(\bar{T}_i) &= [\bar{T}_i - \bar{T}_{\text{MS,GRW}}^{\text{hi}}] [\bar{T}_{\text{OH,GRW}}^{\text{hi}} - \bar{T}_{\text{MS,GRW}}^{\text{hi}}] ; \\
 \text{for } \bar{T}_{\text{OH,GRW}}^{\text{hi}} \leq \bar{T}_i \leq \bar{T}_{\text{OH,GRW}}^{\text{hi}} : \\
 C_{\text{GRW},i}^{\text{hi}}(\bar{T}_i) &= 1 ; \\
 \text{for } \bar{T}_{\text{OH,GRW}}^{\text{hi}} < \bar{T}_i < \bar{T}_{\text{MS,GRW}}^{\text{hi}} : \\
 C_{\text{GRW},i}^{\text{hi}}(\bar{T}_i) &= [\bar{T}_i - \bar{T}_{\text{MS,GRW}}^{\text{hi}}] [\bar{T}_{\text{OH,GRW}}^{\text{hi}} - \bar{T}_{\text{MS,GRW}}^{\text{hi}}] ; \\
 \text{for } \bar{T}_i &\geq \bar{T}_{\text{MS,GRW}}^{\text{hi}} : \\
 C_{\text{GRW},i}^{\text{hi}}(\bar{T}_i) &= 0 ;
 \end{aligned} \tag{3.45}$$

where

$$\begin{aligned}
 \bar{T}_{\text{MS,GRW}}^{\text{hi}} &= \text{minimum temperature below which growth to the next life stage cannot occur} \\
 &\quad \text{and above which the growth rate coefficient increases with increasing} \\
 &\quad \text{temperature for life stage "k"}, \\
 \bar{T}_{\text{OH,GRW}}^{\text{hi}} &= \text{lower temperature bound at which the growth rate coefficient attains the} \\
 &\quad \text{optimum value for life stage "k"}, \\
 \bar{T}_{\text{OH,GRW}}^{\text{hi}} &= \text{higher temperature bound above which the growth rate coefficient decreases} \\
 &\quad \text{from the optimum value, with increasing temperature for life stage "k"}, \\
 \bar{T}_{\text{MS,GRW}}^{\text{hi}} &= \text{maximum temperature above which growth to the next life stage cannot occur} \\
 &\quad \text{for life stage "k"}.
 \end{aligned} \tag{3.46}$$

The schematic representation of the assumed mathematical form, Eq. (3.45), of the correction factor for nonoptimum temperature conditions for the growth rate coefficient is shown in Fig. 3.11.

The assumed mathematical form, Eq. (3.45), for the temperature dependence of the growth rate coefficient indicates again that four parameter values for temperature, $\bar{T}_{\text{MS,GRW}}^{\text{hi}}$, $\bar{T}_{\text{OH,GRW}}^{\text{hi}}$, $\bar{T}_{\text{OH,GRW}}^{\text{hi}}$, and $\bar{T}_{\text{MS,GRW}}^{\text{hi}}$, are required for a life stage to define the correction factor for nonoptimum temperature

Fig. 3.11. Schematic representation of the correction factor for nonoptimum temperature conditions for the growth rate coefficient to the next life stage.

conditions for the growth rate coefficient. In the applications of the simulation model, values of the four parameters were specified as input to the model based on available laboratory data [42-44] about the durations of the life stages.

3.5.4 Formulation of the Correction Factor for Nonoptimum Temperature Conditions for the Mortality Rate Coefficient

The temperature conditions in the estuary could also influence the mortality rates of the life stages. Hence the correction factor for nonoptimum temperature conditions for the mortality rate coefficient is formulated according to the three assumptions about the general form; that is,

$$\text{for } \bar{T}_i \leq \bar{T}_{MX,WR}^{(n)} :$$

$$C_{T,WR}^{(n)}(\bar{T}_i) = [C_{MX,WR}^{(n)}]^1 ;$$

$$\text{for } \bar{T}_{MX,WR}^{(n)} < \bar{T}_i < \bar{T}_{OH,WR}^{(n)} :$$

$$C_{T,WR}^{(n)}(\bar{T}_i) = 1 + C_{MX,WR}^{(n)}[\bar{T}_i - \bar{T}_{OH,WR}^{(n)}][\bar{T}_{MX,WR}^{(n)} - \bar{T}_{OH,WR}^{(n)}] ;$$

$$\text{for } \bar{T}_{OH,WR}^{(n)} \leq \bar{T}_i \leq \bar{T}_{OL,WR}^{(n)} :$$

$$C_{T,WR}^{(n)}(\bar{T}_i) = 1 ;$$

$$\text{for } \bar{T}_{OL,WR}^{(n)} < \bar{T}_i < \bar{T}_{MIN,WR}^{(n)} :$$

$$C_{T,WR}^{(n)}(\bar{T}_i) = 1 + C_{OL,WR}^{(n)}[\bar{T}_i - \bar{T}_{MIN,WR}^{(n)}][\bar{T}_{OL,WR}^{(n)} - \bar{T}_{MIN,WR}^{(n)}] ;$$

$$\text{for } \bar{T}_i \geq \bar{T}_{MIN,WR}^{(n)} :$$

$$C_{T,WR}^{(n)}(\bar{T}_i) = [C_{MIN,WR}^{(n)}]^1 ;$$

(3.47)

where

$\bar{T}_{MIN, MOR}^{(h)}$ = minimum temperature below which the mortality is assumed to be catastrophic and above which the mortality rate coefficient decreases with increasing temperature for life stage "k".

$\bar{T}_{OL, MOR}^{(h)}$ = lower temperature bound at which the mortality rate coefficient attains its minimum value for life stage "k".

$\bar{T}_{OH, MOR}^{(h)}$ = higher temperature bound above which the mortality rate coefficient increases from the minimum value, with increasing temperature for life stage "k". (3.48)

$\bar{T}_{MX, MOR}^{(h)}$ = maximum temperature above which the mortality is assumed to be catastrophic for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.47), of the correction factor for nonoptimum temperature conditions for the mortality rate coefficient is shown in Fig. 3.12.

The assumed mathematical form, Eq. (3.47), for the temperature dependence of the mortality rate coefficient indicates that four parameter values for temperature, $\bar{T}_{MIN, MOR}^{(h)}$, $\bar{T}_{OL, MOR}^{(h)}$, $\bar{T}_{OH, MOR}^{(h)}$, and $\bar{T}_{MX, MOR}^{(h)}$, and one parameter for the additional severe mortality rate $C_{MX, MOR}^{(h)}$ need to be specified for determining the correction factor for nonoptimum temperature conditions for the mortality rate coefficient. The cubic power of $C_{MX, MOR}^{(h)}$ ($>> 1$), employed in the definition of the correction factor for

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Fig. 3.12. Schematic representation of the correction factor for nonoptimum temperature conditions for the mortality rate coefficient.

representing catastrophic temperature conditions, is assumed for computational convenience in order to cause almost instantaneous reduction in the population of a life stage within the minimum time step of the simulations. Hence it must be considered as a parameter of the model without any quantitative significance in representing the biological characteristics of the life stages.

3.5.5 Formulation of the Correction Factor for Nonoptimum Temperature Conditions for Swimming Speed

The temperature conditions in the estuary also affect swimming ability. Hence the correction factor for nonoptimum temperature conditions for swimming speed of the juvenile life stages is formulated according to the three assumptions about the general form; that is,

$$\begin{aligned}
 &\text{for } \bar{T}_i \leq \bar{T}_{\text{min}, \text{swim}}^{(k)} : \\
 &\quad C_{T, \text{swim}}^{(k)}(\bar{T}_i) = 0 ; \\
 &\text{for } \bar{T}_{\text{min}, \text{swim}}^{(k)} < \bar{T}_i < \bar{T}_{\text{opt}, \text{swim}}^{(k)} : \\
 &\quad C_{T, \text{swim}}^{(k)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{\text{min}, \text{swim}}^{(k)}] [\bar{T}_{\text{opt}, \text{swim}}^{(k)} - \bar{T}_{\text{min}, \text{swim}}^{(k)}] ; \\
 &\text{for } \bar{T}_{\text{opt}, \text{swim}}^{(k)} \leq \bar{T}_i \leq \bar{T}_{\text{max}, \text{swim}}^{(k)} : \\
 &\quad C_{T, \text{swim}}^{(k)}(\bar{T}_i) = 1 ; \\
 &\text{for } \bar{T}_{\text{opt}, \text{swim}}^{(k)} < \bar{T}_i < \bar{T}_{\text{max}, \text{swim}}^{(k)} : \\
 &\quad C_{T, \text{swim}}^{(k)}(\bar{T}_i) = [\bar{T}_i - \bar{T}_{\text{min}, \text{swim}}^{(k)}] [\bar{T}_{\text{opt}, \text{swim}}^{(k)} - \bar{T}_{\text{min}, \text{swim}}^{(k)}] ; \\
 &\text{for } \bar{T}_i \geq \bar{T}_{\text{max}, \text{swim}}^{(k)} : \\
 &\quad C_{T, \text{swim}}^{(k)}(\bar{T}_i) = 0 ;
 \end{aligned} \tag{3.49}$$

where

$\bar{T}_{\text{min}, \text{swim}}^{(k)}$ = minimum temperature below which the fish has no swimming ability and above which the swimming speed increases with increasing temperature for life stage "k".

$\bar{T}_{\text{opt}, \text{swim}}^{(k)}$ = lower temperature bound at which the fish can swim at maximum speed for life stage "k".

$\bar{T}_{\text{max}, \text{swim}}^{(k)}$ = higher temperature bound above which the swimming speed decreases, from the maximum speed, with increasing temperature for life stage "k". (3.50)

$\bar{T}_{\text{min}, \text{swim}}^{(k)}$ = maximum temperature above which the fish has no swimming ability for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.49), of the correction factor for nonoptimum temperature conditions for swimming speed is shown in Fig. 3.13.

The assumed mathematical form, Eq. (3.49), for the temperature dependence of the swimming speed indicates that four parameter values for temperature, $\bar{T}_{\text{min}, \text{swim}}^{(k)}$, $\bar{T}_{\text{opt}, \text{swim}}^{(k)}$, $\bar{T}_{\text{max}, \text{swim}}^{(k)}$, and $\bar{T}_{\text{min}, \text{swim}}^{(k)}$, are required to completely determine the correction factor for nonoptimum temperature conditions for swimming speed.

Fig. 3.13. Schematic representation of the correction factor for nonoptimum temperature conditions for swimming speed.

3.5.6 Formulation of the Correction Factor for Nonoptimum Salinity Conditions for Spawning Rate

The striped bass are known to spawn primarily in fresh water. Hence, it is evident that the longitudinal distribution and rate of egg deposition in the Hudson River depend in part on salinity, and in particular, on the location of the salt front along the estuary during the spawning period. Hence the correction factor for nonoptimum salinity conditions for spawning rate is formulated according to the three assumptions about the general form; that is,

for $\bar{S}_i \leq \bar{S}_{\min, \text{spw}}$,

$$C_{\text{spw}, i}^{(h)}(\bar{S}_i) = 0;$$

for $\bar{S}_{\min, \text{spw}} < \bar{S}_i < \bar{S}_{\max, \text{spw}}$,

$$C_{\text{spw}, i}^{(h)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{\min, \text{spw}}] [\bar{S}_{\max, \text{spw}} - \bar{S}_{\min, \text{spw}}];$$

for $\bar{S}_{\max, \text{spw}} \leq \bar{S}_i \leq \bar{S}_{\text{opt}, \text{spw}}$,

$$C_{\text{spw}, i}^{(h)}(\bar{S}_i) = 1;$$

for $\bar{S}_{\text{opt}, \text{spw}} < \bar{S}_i < \bar{S}_{\max, \text{spw}}$,

$$C_{\text{spw}, i}^{(h)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{\max, \text{spw}}] [\bar{S}_{\text{opt}, \text{spw}} - \bar{S}_{\max, \text{spw}}];$$

for $\bar{S}_i \geq \bar{S}_{\max, \text{spw}}$,

$$C_{\text{spw}, i}^{(h)}(\bar{S}_i) = 0;$$

(3.51)

where

- $\bar{S}_{\min,spw}^{(h)}$ = minimum salinity below which spawning does not occur and above which the spawning rate increases with increasing salinity for life stage "k".
- $\bar{S}_{\min,spw}^{(h)}$ = lower salinity bound at which the spawning rate attains the optimum value for life stage "k".
- $\bar{S}_{\max,spw}^{(h)}$ = higher salinity bound above which the spawning rate decreases, from the optimum value, with increasing salinity for life stage "k".
- $\bar{S}_{\max,spw}^{(h)}$ = maximum salinity above which spawning does not occur for life stage "k".

(3.52)

The schematic representation of the assumed mathematical form, Eq. (3.51), of the correction factor for nonoptimum salinity conditions for spawning rate is shown in Fig. 3.14.

The assumed mathematical form, Eq. (3.51), for the salinity dependence of the spawning rate indicates that four parameter values for salinity, $\bar{S}_{\min,spw}^{(h)}$, $\bar{S}_{\min,spw}^{(h)}$, $\bar{S}_{\max,spw}^{(h)}$, and $\bar{S}_{\max,spw}^{(h)}$, are required to specify the correction factor for nonoptimum salinity conditions for the spawning rate. The form of salinity dependence of spawning conditions included in the present model can be employed to simulate both the rate and longitudinal distribution of spawning in the estuary based on the salinity intrusion in the Hudson River.

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Fig. 3.14. Schematic representation of the correction factor for nonoptimum salinity conditions for spawning rate.

3.5.7 Formulation of the Correction Factor for Nonoptimum Salinity Conditions for Apparent Survival Probability

The salinity conditions in the estuary could also affect the apparent survival probabilities of the life stages. Hence the correction factor for nonoptimum salinity conditions for apparent survival probability is formulated according to the three assumptions about the general form; that is,

for $\bar{S}_i \leq \bar{S}_{min}^{(k)}$,

$$C_{k, surv}^{(k)}(\bar{S}_i) = 0;$$

for $\bar{S}_{min}^{(k)} < \bar{S}_i < \bar{S}_{opt}^{(k)}$,

$$C_{k, surv}^{(k)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{min}^{(k)}] [\bar{S}_{opt}^{(k)} - \bar{S}_{min}^{(k)}];$$

for $\bar{S}_{opt}^{(k)} \leq \bar{S}_i \leq \bar{S}_{max}^{(k)}$,

$$C_{k, surv}^{(k)}(\bar{S}_i) = 1;$$

(3.53)

for $\bar{S}_{min}^{(k)} < \bar{S}_i < \bar{S}_{max}^{(k)}$,

$$C_{k, surv}^{(k)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{min}^{(k)}] [\bar{S}_{max}^{(k)} - \bar{S}_{min}^{(k)}];$$

for $\bar{S}_i \geq \bar{S}_{max}^{(k)}$,

$$C_{k, surv}^{(k)}(\bar{S}_i) = 0;$$

where

$\bar{S}_{min}^{(k)}$ = minimum salinity below which survival to the next life stage is not possible and above which the apparent survival probability increases with increasing salinity for life stage "k".

$\bar{S}_{opt}^{(k)}$ = lower salinity bound at which the apparent survival probability attains the optimum value for life stage "k". (3.54)

$\bar{S}_{max}^{(k)}$ = higher salinity bound above which the apparent survival probability decreases from the optimum value, with increasing salinity for life stage "k".

$\bar{S}_{max}^{(k)}$ = maximum salinity above which survival to the next life stage is not possible for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.53), of the correction factor for nonoptimum salinity conditions for apparent survival probability is shown in Fig. 3.15.

The assumed mathematical form, Eq. (3.53), for the salinity dependence of the apparent survival probability indicates that four parameter values for salinity, $\bar{S}_{min}^{(k)}$, $\bar{S}_{opt}^{(k)}$, $\bar{S}_{max}^{(k)}$, and $\bar{S}_{max}^{(k)}$, are required to specify the correction factor for nonoptimum salinity conditions for the apparent survival probability.

Fig. 3.15. Schematic representation of the correction factor for nonoptimum salinity conditions for apparent survival probability.

3.5.8 Formulation of the Correction Factor for Nonoptimum Salinity Conditions for Growth Rate Coefficient

The actual duration of the life stages may also depend on the salinity conditions in the estuary. For example, the salinity distribution, particularly the location of the salt front, could influence the available food, and it can indirectly affect the growth rate to the next life stage, due to food limitation. Hence the correction factor for nonoptimum salinity conditions for the growth rate coefficient is formulated according to the three assumptions about the general form; that is,

for $\bar{S}_i \leq \bar{S}_{MN,GRW}^{(h)}$,

$$C_{S,GRW,i}^{(h)}(\bar{S}_i) = 0;$$

for $\bar{S}_{MN,GRW}^{(h)} < \bar{S}_i < \bar{S}_{MH,GRW}^{(h)}$,

$$C_{S,GRW,i}^{(h)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{MN,GRW}^{(h)}] [\bar{S}_{MH,GRW}^{(h)} - \bar{S}_{MN,GRW}^{(h)}];$$

for $\bar{S}_{MH,GRW}^{(h)} \leq \bar{S}_i \leq \bar{S}_{MX,GRW}^{(h)}$,

$$C_{S,GRW,i}^{(h)}(\bar{S}_i) = 1;$$

for $\bar{S}_{MX,GRW}^{(h)} < \bar{S}_i < \bar{S}_{MY,GRW}^{(h)}$,

$$C_{S,GRW,i}^{(h)}(\bar{S}_i) = [\bar{S}_i - \bar{S}_{MX,GRW}^{(h)}] [\bar{S}_{MY,GRW}^{(h)} - \bar{S}_{MX,GRW}^{(h)}];$$

for $\bar{S}_i \geq \bar{S}_{MY,GRW}^{(h)}$,

$$C_{S,GRW,i}^{(h)}(\bar{S}_i) = 0;$$

(3.55)

where

$\bar{S}_{min,grw}^{(k)}$ = minimum salinity below which growth to the next life stage cannot occur and above which the growth rate coefficient increases with increasing salinity for life stage "k".

$\bar{S}_{opt,grw}^{(k)}$ = lower salinity bound at which the growth rate coefficient attains the optimum value for life stage "k". (3.56)

$\bar{S}_{opt,grw}^{(k)}$ = higher salinity bound above which the growth rate coefficient decreases, from the optimum value, with increasing salinity for life stage "k".

$\bar{S}_{max,grw}^{(k)}$ = maximum salinity above which growth to the next life stage cannot occur for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.55), of the correction factor for nonoptimum salinity conditions for the growth rate coefficient is shown in Fig. 3.16.

The assumed mathematical form, Eq. (3.55), for the salinity dependence of the growth rate coefficient indicates that four parameter values for salinity, $\bar{S}_{min,grw}^{(k)}$, $\bar{S}_{opt,grw}^{(k)}$, $\bar{S}_{opt,grw}^{(k)}$, and $\bar{S}_{max,grw}^{(k)}$, are required to specify the correction factor for nonoptimum salinity conditions for the growth rate coefficient.

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Fig. 3.16. Schematic representation of the correction factor for nonoptimum salinity conditions for the growth rate coefficient to the next life stage.

3.5.9 Formulation of the Correction Factor for Nonoptimum Salinity Conditions for the Mortality Rate Coefficient

The salinity conditions in the estuary could also affect the mortality rates of the life stages. Hence the correction factor for nonoptimum salinity conditions for the mortality rate coefficient is formulated according to the three assumptions about the general form; that is,

for $S_i \leq S_{MX,MOR}^{(k)}$.

$$C_{S,MOR}^{(k)}(S_i) = [C_{MX,MOR}^{(k)}]^{-1} ;$$

for $S_{MX,MOR}^{(k)} < S_i < S_{OH,MOR}^{(k)}$.

$$C_{S,MOR}^{(k)}(S_i) = 1 + C_{MX,MOR}^{(k)}[S_i - S_{OH,MOR}^{(k)}] [S_{MX,MOR}^{(k)} - S_{OH,MOR}^{(k)}] ;$$

for $S_{OH,MOR}^{(k)} \leq S_i \leq S_{MX,MOR}^{(k)}$.

$$C_{S,MOR}^{(k)}(S_i) = 1 ;$$

for $S_{OH,MOR}^{(k)} < S_i < S_{MX,MOR}^{(k)}$.

$$C_{S,MOR}^{(k)}(S_i) = 1 + C_{MX,MOR}^{(k)}[S_i - S_{OH,MOR}^{(k)}] [S_{MX,MOR}^{(k)} - S_{OH,MOR}^{(k)}] ;$$

for $S_i \geq S_{MX,MOR}^{(k)}$.

$$C_{S,MOR}^{(k)}(S_i) = [C_{MX,MOR}^{(k)}]^{-1} ;$$

(3.57)

where

$\bar{S}_{MX,MOR}^{(k)}$ = minimum salinity below which the mortality is assumed to be catastrophic and above which the mortality rate coefficient decreases with increasing salinity for life stage "k".

$\bar{S}_{OH,MOR}^{(k)}$ = lower salinity bound at which the mortality rate coefficient attains its minimum value for life stage "k". (3.58)

$\bar{S}_{OH,MOR}^{(k)}$ = higher salinity bound above which the mortality rate coefficient increases, from the minimum value, with increasing salinity for life stage "k".

$\bar{S}_{MX,MOR}^{(k)}$ = maximum salinity above which the mortality is assumed to be catastrophic for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.57), of the correction factor for nonoptimum salinity conditions for the mortality rate coefficient is shown in Fig. 3.17.

The assumed mathematical form, Eq. (3.57), for the salinity dependence of the mortality rate coefficient indicates that four parameter values for salinity, $\bar{S}_{MX,MOR}^{(k)}$, $\bar{S}_{OH,MOR}^{(k)}$, $\bar{S}_{OH,MOR}^{(k)}$, and $\bar{S}_{MX,MOR}^{(k)}$, and one parameter value for the additional severe mortality rate $C_{MX,MOR}^{(k)}$ need to be specified for determining the correction factor for nonoptimum salinity conditions for the mortality rate coefficient. The cubic power of $C_{MX,MOR}^{(k)}$ ($\gg 1$), employed in the definition of the correction factor for representing catastrophic salinity conditions, is assumed for computational convenience in order to cause almost instantaneous reduction in the population of a life stage within the minimum time step of the simulations. Hence it must be considered as a parameter of the model without any quantitative significance in representing the biological characteristics of the life stages.

Fig. 3.17. Schematic representation of the correction factor for nonoptimum salinity conditions for the mortality rate coefficient.

3.5.10 Formulation of the Correction Factor for Nonoptimum Salinity Conditions for Swimming Speed

The analysis of the impingement data from Indian Point [45] indicates that impingement of striped bass young-of-the-year may depend on the salinity conditions, particularly on the location of the salt front. Hence the correction factor for nonoptimum salinity conditions for maximum swimming speed is formulated, according to the three assumptions about the general form, as follows:

for $\bar{S}_i \leq \bar{S}_{TH,MOR}^{(h)}$,

$$C_{S,MOR,i}^{(h)}(\bar{S}_i) = 1;$$

for $\bar{S}_{TH,MOR}^{(h)} < \bar{S}_i < \bar{S}_{MH,MOR}^{(h)}$,

$$C_{S,MOR,i}^{(h)}(\bar{S}_i) = 1 - 0.5[\bar{S}_i - \bar{S}_{TH,MOR}^{(h)}] / [\bar{S}_{MH,MOR}^{(h)} - \bar{S}_{OL,MOR}^{(h)}];$$

for $\bar{S}_{MH,MOR}^{(h)} \leq \bar{S}_i \leq \bar{S}_{OH,MOR}^{(h)}$,

$$C_{S,MOR,i}^{(h)}(\bar{S}_i) = 0.5;$$

for $\bar{S}_{OH,MOR}^{(h)} < \bar{S}_i < \bar{S}_{MX,MOR}^{(h)}$,

$$C_{S,MOR,i}^{(h)}(\bar{S}_i) = 1 - 0.5[\bar{S}_i - \bar{S}_{OH,MOR}^{(h)}] / [\bar{S}_{MH,MOR}^{(h)} - \bar{S}_{OH,MOR}^{(h)}];$$

for $\bar{S}_i \geq \bar{S}_{MX,MOR}^{(h)}$,

$$C_{S,MOR,i}^{(h)}(\bar{S}_i) = 1;$$

(3.59)

where

- $\bar{S}_{OL,MOB}^{(k)}$ = minimum salinity below which the fish has maximum swimming speed and above which the swimming speed decreases with increasing salinity for life stage "k".
- $\bar{S}_{ML,MOB}^{(k)}$ = lower salinity bound at which the swimming speed of the fish is reduced to its minimum value for life stage "k". (3.60)
- $\bar{S}_{MH,MOB}^{(k)}$ = higher salinity bound above which the swimming speed of the fish increases from the minimum value, with increasing salinity for life stage "k".
- $\bar{S}_{OH,MOB}^{(k)}$ = maximum salinity above which the fish has maximum swimming speed for life stage "k".

The schematic representation of the assumed mathematical form, Eq. (3.59), of the correction factor for nonoptimum salinity conditions for swimming speed is shown in Fig. 3.18.

The assumed mathematical form, Eq. (3.59), for the salinity dependence of the swimming speed indicates that four parameter values for salinity, $\bar{S}_{OL,MOB}^{(k)}$, $\bar{S}_{ML,MOB}^{(k)}$, $\bar{S}_{MH,MOB}^{(k)}$, and $\bar{S}_{OH,MOB}^{(k)}$, are required to specify the correction factor for nonoptimum salinity conditions for swimming speed. It is important to note that the correction factor is defined to represent reduced mobility condition, arbitrarily assumed as half of the maximum swimming speed, in a finite salinity range between $\bar{S}_{ML,MOB}^{(k)}$ and $\bar{S}_{MH,MOB}^{(k)}$. The salinity conditions outside of the somewhat broader range of $\bar{S}_{OL,MOB}^{(k)}$ to $\bar{S}_{OH,MOB}^{(k)}$ are assumed to have no effect on the optimum mobility conditions. The salinity dependence of the swimming speed for juveniles may be due both to physiological effects (e.g., osmotic and ionic regulation) and to more general ecological phenomena (e.g., concentration of juveniles at the salt front, where food tends to be abundant).

Fig. 3.18. Schematic representation of the correction factor for nonoptimum salinity conditions for swimming speed.

3.6 PARAMETER DATA FOR THE MODELING OF THE BIOLOGICAL CHARACTERISTICS

The assumed forms of the correction factors for nonoptimum conditions, Eqs. (3.31) through (3.60), can approximately incorporate the effects of population density, temperature, and salinity on the biological characteristics of the striped bass young-of-the-year. The quantitative determination of the parameters in these correction factors requires extensive and reasonably reliable data either from field studies or from laboratory experiments which approximately simulate the conditions in the estuary. However, presently available biological data about the striped bass young-of-the-year are not sufficient to specify all the parameters for the correction factors employed in the general formulation. Consequently, although the simulation model is capable of incorporating various biologically significant phenomena in the analysis, certain correction factors for nonoptimum conditions associated with the representation of those phenomena have not been utilized in the application of the model.

In the general formulation of the simulation model and its computer code (Appendix), all previously described correction factors for nonoptimum conditions were retained, regardless of the availability or unavailability of the necessary biological data. Since all correction factors have optimum values of unity corresponding to their associated optimum conditions, the correction factors for which data are not available can be readily set equal to unity in the applications of the model. This procedure eliminates the effect of the particular condition on the biological characteristics of the striped bass. Considering the general forms of the correction factors, Figs. (3.4) through (3.18), it is evident that the ranges over which the values are equal to unity are defined by sets of double parameters corresponding to "lower optimum" and "higher optimum" values of the associated conditions. Hence by specifying unrealistic dummy values for the "lower optimum" and "higher optimum" bounds which can never be exceeded during a simulation, all the correction factors for which sufficient data are not available can be identically set equal to unity while still directly utilizing the computational forms in the model without any modifications in the general formulation of the model or its computer code.

3.6.1 Parameter Data for Spawning Conditions

The parameter data employed in the simulation model for optimum spawning rate $\bar{r}_{sp}^{(0)}$ and for the correction factors, $C_{p,sp}^{(1)}[\bar{p}^{(0)}]$, $C_{T,sp}^{(1)}(\bar{T})$, and $C_{S,sp}^{(1)}(\bar{S})$, associated with population density $\bar{p}^{(0)}$, temperature $\bar{T}$, and salinity $\bar{S}$, respectively, are presented in Table 3.3 for the dummy spawning adult age-group.

The population density correction factor for spawning rate, Eq. (3.31), is not utilized in the model, since there is no evidence that the average spawning rate of adult striped bass depends on the population density of the spawners. The critical population density for spawning $\bar{p}_{cr,sp}^{(0)}$ is specified as 10' per 1000 ft', which is much higher than the actual densities for the spawning population in the river. Consequently, the linear variation part of the population density dependence, Eq. (3.31), Fig. 3.4, is unreachable in the model, and the value of the population density correction factor for spawning rate, $C_{p,sp}^{(1)}[\bar{p}^{(0)}]$, is always unity for all simulations.

The correction factor for nonoptimum temperature conditions for spawning rate $C_{T,sp}^{(1)}(\bar{T})$, Eq. (3.41), is fully utilized in the model. The effects of temperature on spawning were estimated by considering the 1973 temporal distributions of eggs [24] and temperature [46] in the estuary.

Due to the lack of adequate quantitative data, the option to model the dependence of spawning on salinity is not utilized. Since the salinity $\bar{S}$ in the estuary is limited to a range of 0.0 to 1.0 parts of salt per part of water by definition (i.e., 0 to 1000 ppt), the lower optimum $\bar{S}_{ln,sp}^{(0)}$ and higher optimum

Table 3.3. Parameter data employed in the simulation model for spawning conditions

Correction factor parameters for nonoptimum conditions												
(k)	Life stage	Optimum spawning rate (No. egg/hr/fish), $\bar{r}_{OP.SPW}^{(k)}$	Population density (No./1000 ft ³), $C_{s.SPW}^{(k)} [P^{(k)}]$		Temperature (°F), $C_{T.SPW}^{(k)} (T)$				Salinity, ^a $C_{s.SPW}^{(k)} (S)$			
			Critical, $\bar{P}_{CR.SPW}^{(k)}$	Maximum, $\bar{P}_{MX.SPW}^{(k)}$	Minimum, $\bar{T}_{MN.SPW}^{(k)}$	Lower optimum, $\bar{T}_{OL.SPW}^{(k)}$	Higher optimum, $\bar{T}_{OH.SPW}^{(k)}$	Maximum, $\bar{T}_{MX.SPW}^{(k)}$	Minimum, $\bar{S}_{MN.SPW}^{(k)}$	Lower optimum, $\bar{S}_{OL.SPW}^{(k)}$	Higher optimum, $\bar{S}_{OH.SPW}^{(k)}$	Maximum, $\bar{S}_{MX.SPW}^{(k)}$
7	Dummy spawning adult	24.0	(10 ³) ^b	(10 ³) ^b	54.0	58.0	62.0	66.0	-2.0 ^b	-1.0 ^b	1.0 ^b	2.0 ^b

^aSalinity as parts of salt per part of seawater; multiplication by 1000 gives parts per thousand (ppt).

^bParameter value chosen such that the correction factor is 1.0 at all times for all simulations.

$S_{lim,SPB}$ parameter values of -1.0 and 1.0, respectively, guarantee that the correction factor for non-optimum salinity conditions for spawning rate $C_{SSPB}^{(1)}(\bar{S})$, Eq. (3.51), remains as unity for all simulations.

3.6.2 Parameter Data for Survival Conditions to the Next Life Stage

The parameter data employed in the simulation model for optimum apparent survival probabilities $\bar{R}_{OP,SRV}^{(k)}$ and for the correction factors $C_{PSRV}^{(k)}[\bar{p}^{(k)}]$, $C_{TSRV}^{(k)}(\bar{T})$, and $C_{SSRV}^{(k)}(\bar{S})$ associated with the effects of population density $\bar{p}^{(k)}$, temperature $\bar{T}$, and salinity $\bar{S}$, respectively, are presented in Table 3.4.

The effective values $\bar{R}_{EF,SRV}^{(k)}$ for the apparent survival probabilities of the life stages were determined by applying the model, without utilizing the population density correction factors, according to the schematic procedure outlined in Sect. 3.2.1 (see Fig. 3.3), based on the 1973 temporal distributions of the life-stage standing crops in the estuary [24].

The necessary parameters for the generalized form of the population density correction factors $C_{PSRV}^{(k)}[\bar{p}^{(k)}]$, Eq. (3.33), were determined as follows. As a reference point for estimating the maximum population densities that could occur in the river for different life stages, the hypothetical clean river conditions (i.e., without any plants on the river in operation) were simulated. In this simulation the constant effective values for the apparent survival probabilities as determined from 1973 temporal distributions of the life-stage standing crops were used. The flow conditions in the river and the distributions of temperature and salinity were assumed to be the same as for 1973. Furthermore, the spawning rate and spawning distribution along the river were also assumed to be the same as in 1973. The results of this simulation were used to estimate the maximum weekly averaged population density $\bar{p}_{MX,CLR}^{(k)}$ for each life stage which might have occurred under clean river conditions in 1973. These maximum population density values were used as a reference point in estimating the necessary parameters of the population density correction factors for the apparent survival probabilities of the life stages.

Considering the short duration (generally less than two days) of the egg life stage, it is assumed that the effect of compensation can be neglected. Hence the optimum survival probability $\bar{R}_{OP,SRV}^{(1)}$ is assumed to be equal to the effective apparent survival probability $\bar{R}_{EF,SRV}^{(1)}$, and the parameter value for the critical population density is assigned as 10^3 per 1000 ft³, which is much higher than the egg population densities occurring in the Hudson River. Consequently, the linear variation part of the population density correction factor, Eq. (3.33), Fig. 3.5, is unreachable in the model for the egg life stage, and hence the value of the population density correction factor for apparent survival probability $C_{PSRV}^{(1)}[\bar{p}^{(1)}]$ is always unity.

For later life stages (yolk-sac larva, post-yolk-sac larva, Juvenile I, Juvenile II, and Juvenile III), the population density correction factors for apparent survival probabilities $C_{PSRV}^{(k)}[\bar{p}^{(k)}]$, $k \geq 2$, Eq. (3.33), Fig. 3.5, are utilized based on the maximum weekly averaged population densities for the clean river case according to the following methodology. The parameter value for the critical population density $\bar{p}_{CR,SRV}^{(k)}$, Eq. (3.33), is assumed to be 10% of the maximum weekly averaged population density $\bar{p}_{MX,CLR}^{(k)}$ for the clean river case for each life stage (see Table 3.4); that is,

$$\bar{p}_{CR,SRV}^{(k)} = 0.1 \bar{p}_{MX,CLR}^{(k)} \quad k \geq 2. \quad (3.61)$$

Furthermore, the parameter value for the maximum population density $\bar{p}_{MX,SRV}^{(k)}$, Eq. (3.33), is assumed as twice the maximum weekly averaged population density $\bar{p}_{MX,CLR}^{(k)}$ for the clean river case (see Table 3.4); that is,

$$\bar{p}_{MX,SRV}^{(k)} = 2 \bar{p}_{MX,CLR}^{(k)} \quad k \geq 2. \quad (3.62)$$

Table 3.4. Parameter data employed in the simulation model for mortality conditions

Correction factor parameters for nonoptimum conditions																
(h)	Life stage	Effective apparent survival probability, $R_{eff,av}$	Optimum apparent survival probability, $R_{opt,av}$	Population density (No./1000 ft ³), $C_{pop,av}$ [ft ³]			Temperature (°F), $C_{T,av}$ (°F)			Salinity, $C_{S,av}$ (‰)						
				Critical, $C_{crit,av}$	Maximum, $C_{max,av}$	Minimum, $C_{min,av}$	Lower optimum, $C_{low,av}$	Higher optimum, $C_{high,av}$	Maximum, $T_{max,av}$	Minimum, $T_{min,av}$	Lower optimum, $S_{low,av}$	Higher optimum, $S_{high,av}$	Maximum, $S_{max,av}$			
1	Egg	0.36	0.36	(10) ³	(10) ³	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			
2	Yolk-sac larva	0.40	0.56	0.354	7.000	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			
3	Post-yolk-sac larva	0.64	0.75	0.278	5.540	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			
4	Juvenile I	0.90	0.93	0.092	1.940	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			
5	Juvenile II	0.90	0.93	0.057	1.140	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			
6	Juvenile III	0.95	0.97	0.022	0.440	10.0	20.0 ^a	900 ^b	999	-2.0	-1.0 ^c	1.0 ^c	2.0			

^aSalinity as parts of salt per part of seawater; multiplication by 1000 gives parts per thousand (ppt).

^bParameter value chosen such that the correction factor is 1.0 at all times for all simulations.

The parameter value for the optimum survival probabilities $\bar{R}_{OP,SRV}^{(h)}$, Eq. (3.17), is assumed to be higher than the effective apparent survival probability $\bar{R}_{EF,SRV}^{(h)}$ by 30% of the difference between the maximum possible survival probability of unity and the effective apparent survival probability $\bar{R}_{EF,SRV}^{(h)}$ (see Table 3.4); that is,

$$\bar{R}_{OP,SRV}^{(h)} = \bar{R}_{EF,SRV}^{(h)} + 0.3[1 - \bar{R}_{EF,SRV}^{(h)}], \quad k \geq 2. \quad (3.63)$$

The 30% value was selected in order to have the total number of juveniles (Juvenile I, II, and III life stages) at the end of the simulations, using the 1973 power plant conditions, be approximately the same with or without compensation. The simulation of the 1973 data [24] for the striped bass young-of-the-year populations was repeated with the values (Table 3.4) of the optimum survival probability $\bar{R}_{OP,SRV}^{(h)}$, Eq. (3.17), and the values (Table 3.4) for critical population density $\bar{p}_{CR,SRV}^{(h)}$ and maximum population density $\bar{p}_{MX,SRV}^{(h)}$ for the population density correction factor $C_{p,SRV}^{(h)}[\bar{p}^{(h)}]$, Eq. (3.33) in order to check the effect of the assumed population density dependences of the apparent survival probabilities $\bar{R}_{SRV}^{(h)}$ on the temporal distributions of the life-stage standing crops in the estuary. The computer results agreed reasonably well with the 1973 data [24], indicating that the assumed parameter values (Table 3.4) were acceptable for further simulations with the model.

The option to include the temperature dependency of the apparent survival probabilities is not employed in the applications of the model. Since the actual water conditions in the estuary do not drop below the lower optimum temperature $\bar{T}_{OL,SRV}^{(h)}$ of 20° F and do not exceed the higher optimum temperature $\bar{T}_{OH,SRV}^{(h)}$ of 90° F, the linear variation parts of the temperature dependence form, Eq. (3.43), Fig. 3.10, are not attainable in the model. Hence the values of the correction factors for nonoptimum temperature conditions $C_{T,SRV}^{(h)}(T)$ always remain as unity in the computations.

The option to include the salinity dependence of the apparent survival probabilities is not employed in the applications of the model. Again the assumed parameter values for the lower optimum salinity $\bar{S}_{OL,SRV}^{(h)}$ and higher optimum salinity $\bar{S}_{OH,SRV}^{(h)}$ of -1.0 and 1.0, respectively, guarantee that the correction factors for nonoptimum salinity conditions $C_{S,SRV}^{(h)}(\bar{S})$ remain as unity for all simulations.

3.6.3 Parameter Data for Growth Conditions to the Next Life Stage

The parameter data employed in the simulation model for the optimum growth rate coefficients $\bar{r}_{OP,GRW}^{(h)}$ and for the correction factors $C_{p,GRW}^{(h)}[\bar{p}^{(h)}]$, $C_{T,GRW}^{(h)}(\bar{T})$, and $C_{S,GRW}^{(h)}(\bar{S})$ associated with the effects of population density $\bar{p}^{(h)}$, temperature $\bar{T}$, and salinity $\bar{S}$, respectively, are presented in Table 3.5 for all life stages.

The values for the optimum growth rate coefficient $\bar{r}_{OP,GRW}^{(h)}$ in Table 3.5 were determined as the inverses of the optimum durations of the life stages (see Table 3.1).

The compensatory part of the population density correction factor $C_{p,GRW}^{(h)}[\bar{p}^{(h)}]$, Eq. (3.35), Fig. 3.6, for the growth rate coefficient is not utilized in the applications of the model. The parameter value for critical population density $\bar{p}_{CR,GRW}^{(h)}$, Eq. (3.35), is specified as 10^5 per 1000 ft³, which is much higher than the population densities occurring in the Hudson River. Consequently, the linear variation part of the population density dependence, Eq. (3.35), Fig. 3.6, is unreachable in the model, and the value of the population density correction factor for the growth rate coefficient $C_{p,GRW}^{(h)}[\bar{p}^{(h)}]$ is always unity for all simulations.

The parameter values for the temperature dependence of the growth rate coefficient of the egg life stage were determined based on the available data [44] about the hatching time of striped bass eggs. Hence the correction factor for nonoptimum temperature conditions for the growth rate coefficient

Table 3.3. Parameter data employed in the simulation model for growth conditions to the next life stage

Correction factor parameters for nonoptimum conditions												
(k)	Life stage	Optimum growth rate coefficient (1/hr), $r_{OP,GRW}^{(k)}$	Population density (No./1000 ft. ³), $C_{P,GRW}^{(k)}$		Temperature (°F), $C_{T,GRW}^{(k)}$			Salinity, ‰, $C_{S,GRW}^{(k)}$				
			Critical, $P_{CR,GRW}^{(k)}$	Maximum, $P_{MX,GRW}^{(k)}$	Minimum, $T_{MN,GRW}^{(k)}$	Lower optimum, $T_{OL,GRW}^{(k)}$	Higher optimum, $T_{OH,GRW}^{(k)}$	Maximum, $T_{MX,GRW}^{(k)}$	Minimum, $S_{MN,GRW}^{(k)}$	Lower optimum, $S_{OL,GRW}^{(k)}$	Higher optimum, $S_{OH,GRW}^{(k)}$	Maximum, $S_{MX,GRW}^{(k)}$
1	Egg	0.35×10^{-1}	(10) ^b	(10) ^b	50	75	85	95	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b
2	Yolk-sac larva	0.60×10^{-1}	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b
3	Post-yolk-sac larva	0.19×10^{-1}	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b
4	Juvenile I	0.10×10^{-1}	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b
5	Juvenile II	0.34×10^{-1}	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b
6	Juvenile III	0.24×10^{-1}	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0 ^b

^aSalinity as parts of salt per part of seawater; multiplication by 1000 gives parts per thousand (ppt).

^bParameter values chosen such that the correction factor is 1.0 at all times for all simulations.

$C_{T,GR}^{(h)}(\bar{T})$, Eq. (3.45), Fig. 3.11, for the egg life stage is fully utilized in the computer simulation model. However, since data for the later life stages (i.e., yolk-sac larva, post-yolk-sac larva, Juvenile I, Juvenile II, and Juvenile III) are not as extensive as for the life stage, the option to include the temperature dependence of the growth rate coefficient for these later life stages is not employed in the model. Since the actual water conditions in the estuary do not drop below the lower optimum temperature $\bar{T}_{O,GR}^{(h)}$ of 20° F and do not exceed the higher optimum temperature $\bar{T}_{H,GR}^{(h)}$ of 90° F, the linear variation parts of the temperature dependence form, Eq. (3.45), Fig. 3.11, are not attainable for the later life stages, $k \geq 2$, in the model. Hence the values of the correction factors for nonoptimum temperature conditions $C_{T,GR}^{(h)}(\bar{T})$ always remain as unity in the computations.

Although the growth of certain life stages may depend on salinity and particularly on the location of the salt front in the estuary, the option to implement the dependence of growth to the next life stage on salinity is not utilized in the applications of the model, due to the lack of adequate quantitative data. The assumed parameter values for the lower optimum salinity $\bar{S}_{O,GR}^{(h)}$ and higher optimum salinity $\bar{S}_{H,GR}^{(h)}$ of -1.0 and 1.0, respectively, guarantee that the correction factors for nonoptimum salinity conditions for the growth rate coefficients $C_{S,GR}^{(h)}(\bar{S})$, Eq. (3.55), Fig. 3.16, remain as unity for all simulations.

3.6.4 Parameter Data for Mortality Conditions

The parameter data employed in the simulation model for optimum mortality rate coefficients $r_{OP,MOR}^{(h)}$ and for the correction factors $C_{P,MOR}^{(h)}[p^{(h)}]$, $C_{T,MOR}^{(h)}(\bar{T})$, and $C_{S,MOR}^{(h)}(\bar{S})$ associated with the effects of population densities $p^{(h)}$, temperature T , and salinity S , respectively, are presented in Table 3.6.

Consistent with the method of estimating the optimum growth rate coefficients, the optimum mortality rate coefficients $r_{OP,MOR}^{(h)}$ in Table 3.6 were estimated as the inverse of the optimum durations of the life stages (see Table 3.1).

The compensatory part of the population density correction factor $C_{P,MOR}^{(h)}[p^{(h)}]$, Eq. (3.37), Fig. 3.7, for the mortality rate coefficient is not utilized in the applications of the model. The parameter value for critical population density $\bar{p}_{CR,MOR}^{(h)}$, Eq. (3.37), is specified as 10³ per 1000 ft³, which is much higher than the population densities occurring in the Hudson River. Consequently, the linear variation part of the population density dependence, Eq. (3.37), Fig. 3.7, is unreachable in the model, and the value of the population density correction factor for the mortality rate coefficient $C_{P,MOR}^{(h)}[p^{(h)}]$ is always unity for all simulations.

Although mortality undoubtedly depends in part on water temperature, the option to implement the temperature dependence of the mortality rate coefficients is not employed in the applications of the model. Since the actual water conditions in the estuary do not drop below the lower optimum temperature $\bar{T}_{O,MOR}^{(h)}$ of 20° F and do not exceed the higher optimum temperature $\bar{T}_{H,MOR}^{(h)}$ of 90° F, the linear variation parts of the temperature dependence form, Eq. (3.47), Fig. 3.12, are not attainable in the model. Hence the values of the correction factors for nonoptimum temperature conditions $C_{T,MOR}^{(h)}(\bar{T})$ always remain as unity in the computations.

The mortality of certain life stages may depend on salinity and particularly on the location of the salt front in the estuary. However, the option to implement the salinity dependence of the mortality rate coefficient is not employed in the applications of the model, due to the lack of adequate quantitative data. The assumed parameter values for lower optimum salinity $\bar{S}_{O,MOR}^{(h)}$ and higher optimum salinity $\bar{S}_{H,MOR}^{(h)}$ of -1.0 and 1.0, respectively, guarantee that the correction factors for nonoptimum salinity conditions for the mortality rate coefficient $C_{S,MOR}^{(h)}(\bar{S})$, Eq. (3.57), Fig. 3.17, remain as unity for all simulations.

Table 3.6. Parameter data employed in the simulation model for mortality conditions

(k)	Life stage	Optimum mortality rate coefficient (1/hr), $C_{OP,MOR}^{(k)}$	Maximum mortality rate factor $C_{MX,MOR}^{(k)}$	Correction factor parameters for nonoptimum conditions									
				Population density (No./1000 ft ³), $C_{P,MOR}^{(k)} (P^{(k)})$			Temperature (°F), $C_{T,MOR}^{(k)} (T)$			Salinity, ^a $C_{S,MOR}^{(k)} (S)$			
				Critical, $P_{CR,MOR}^{(k)}$	Maximum, $P_{MX,MOR}^{(k)}$	Minimum, $P_{MN,MOR}^{(k)}$	Lower optimum, $T_{OL,MOR}^{(k)}$	Higher optimum, $T_{OH,MOR}^{(k)}$	Maximum, $T_{MX,MOR}^{(k)}$	Minimum, $S_{MN,MOR}^{(k)}$	Lower optimum, $S_{OL,MOR}^{(k)}$	Higher optimum, $S_{OH,MOR}^{(k)}$	Maximum, $S_{MX,MOR}^{(k)}$
1	Egg	0.35×10^{-1}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0
2	Yolk-sac larva	0.69×10^{-2}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0
3	Post-yolk-sac larva	0.19×10^{-2}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0
4	Juvenile I	0.10×10^{-2}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0
5	Juvenile II	0.34×10^{-3}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0
6	Juvenile III	0.24×10^{-3}	10.0	(10) ^b	(10) ^b	10	20 ^b	900 ^b	999	-2.0	-1.0 ^b	1.0 ^b	2.0

^aSalinity as parts of salt per part of seawater; multiplication by 1000 gives parts per thousand (ppt).

^bParameter values chosen such that the correction factor is 1.0 at all times for all simulations.

3.6.5 Parameter Data for Mobility Conditions

The parameter data employed in the simulation model for maximum swimming speed V_{max}^{ij} , swimming duration $\Delta t_{\text{max}}^{ij}$, and the correction factors for nonoptimum conditions, $C_{p_{\text{max}}}^{ij}(p^{ij})$, $C_{T_{\text{max}}}^{ij}(T)$, and $C_{S_{\text{max}}}^{ij}(S)$, associated with the life-stage population density p^{ij} , temperature T , and salinity S , respectively, are presented in Table 3.7 for the Juvenile I, Juvenile II, and Juvenile III life stages, which have capabilities to migrate longitudinally in the estuary.

As discussed in Sect. 3.3, the values for maximum swimming speed V_{max}^{ij} and the duration $\Delta t_{\text{max}}^{ij}$ at maximum speed were approximated based on the experimental results of laboratory studies [39, 40].

The option to implement the dependence of the maximum swimming speed V_{max}^{ij} on population density is not utilized in the applications of the model. The parameter value for critical population density p_{crit}^{ij} , Eq. (3.39), is specified as 10' per 1000 ft³, which is much higher than the population densities occurring in the Hudson River. Consequently, the linear variation part of the population density dependence, Eq. (3.39), Fig. 3.8, is unreachable in the model, and the value of the population density correction factor for swimming speed $C_{p_{\text{max}}}^{ij}(p^{ij})$ is always unity for all simulations.

The correction factors for nonoptimum temperature conditions for swimming speed $C_{T_{\text{max}}}^{ij}(T)$, Eq. (3.49), Fig. 3.13, were fully utilized in the applications of the simulation model. The parameter values for the effects of temperature in Table 3.7 were estimated based on the results of laboratory studies [40].

The parameter values for the salinity dependence of the swimming speed V_{max}^{ij} were based on the Indian Point impingement studies [45]. The data indicate that impingement at Indian Point is higher when the salinity is in the range of 1.0 to 3.0 ppt. This result most likely is not due to the direct effect of the salinity on swimming speed but rather to an indirect effect of a combination of physiological factors (e.g., osmotic and ionic stress) and ecological factors (e.g., food for the juvenile striped bass tends to be concentrated at the salt front). Hence the assumed form of the correction factor for swimming speed $C_{S_{\text{max}}}^{ij}(S)$, Eq. (3.59), Fig. 3.18, is utilized, with the parameter values in Table 3.7, in the applications of the simulation model.

In summary, the general formulation of the model can approximately incorporate the available data about the biological characteristics of the striped bass life stages according to the assumed forms of the correction factors for nonoptimum conditions in the estuary. When sufficient data are not available, dummy parameters are selected which make the correction factors unity.

Table 3.7. Parameter data employed in the simulation model for mobility conditions

Correction factor parameters for nonoptimum conditions														
(k)	Life stage	Maximum swimming speed (fps), $V_{\max}^{(k)}$	Duration (hr), $\Delta t^{(k)}$	Population density (No./1000 ft ³), $C_P^{(k)}$ (ppt)				Temperature (°F), $C_T^{(k)}$ (°F)			Salinity,* $C_S^{(k)}$ (‰)			
				Optimum, $P_{OP}^{(k)}$	Critical, $P_{CR}^{(k)}$	Maximum, $P_{MX}^{(k)}$	Minimum, $P_{MN}^{(k)}$	Lower optimum, $T_{OL}^{(k)}$	Higher optimum, $T_{OH}^{(k)}$	Maximum, $T_{MX}^{(k)}$	Lower optimum, $S_{OL}^{(k)}$	Lower minimum, $S_{ML}^{(k)}$	Higher minimum, $S_{MH}^{(k)}$	Higher optimum, $S_{OH}^{(k)}$
4	Juvenile I	0.5	2.0	0.0	(10 ³) ^b	(10 ³) ^b	30	75	85	95	0.1 × 10 ⁻¹	0.2 × 10 ⁻¹	0.4 × 10 ⁻¹	0.1 × 10 ⁻¹
5	Juvenile II	1.0	4.0	0.0	(10 ³) ^b	(10 ³) ^b	30	75	85	95	0.1 × 10 ⁻¹	0.2 × 10 ⁻¹	0.4 × 10 ⁻¹	0.1 × 10 ⁻¹
6	Juvenile III	1.0	6.0	0.0	(10 ³) ^b	(10 ³) ^b	30	75	85	95	0.1 × 10 ⁻¹	0.2 × 10 ⁻¹	0.4 × 10 ⁻¹	0.1 × 10 ⁻¹

*Salinity as parts of salt per part of seawater; multiplication by 1000 gives parts per thousand (ppt)

^bParameter values chosen such that the correction factor is 1.0 at all times for all simulations.

4. MODELING OF THE LONGITUDINAL MIXING TRANSPORT FOR STRIPED BASS LIFE-STAGE POPULATIONS

The actual hydrodynamic conditions in the Hudson River are dominated by the semidiurnal tidal flow, even during periods of high net freshwater flow. The actual motions of the striped bass young-of-the-year populations, particularly those of the early life stages, are controlled by the tidal flow conditions in the estuary. However, since the present model considers only tidal-averaged and daily averaged one-dimensional conditions, the formulation of the longitudinal convection is necessarily based on the net freshwater flow in the estuary. For each discrete element of the model, the convective transport rates for life-stage populations into and out of the element, Eq. (2.9), are formulated according to the freshwater flow rates $\bar{G}_{i+1/2}$ across the upstream and downstream enclosure surfaces of the discrete element. According to the fundamental hypothesis of the tidal-averaged and daily averaged one-dimensional models, excluding the freshwater convective transport, the totality of the remaining effects that could result in the displacement of the life-stage populations in the estuary must be incorporated into the general formulation of an overall longitudinal mixing transport phenomenon. The tidal-averaged and cross-section-averaged longitudinal velocity $\bar{V}(t,x)$ and the life-stage population densities $\bar{p}^k(t,x)$, which are the principal unknown variables of the model, are indeed different from the actual short-time dependent and three-dimensional properties of the longitudinal velocity component $u(t,x,y,z)$ and the life-stage population densities $p^k(t,x,y,z)$ (see Fig. 4.1).

Furthermore, the actual motions of the fish in the later life stages do not necessarily correspond to the flow conditions, since the juveniles can migrate longitudinally (as well as laterally and vertically) by swimming relative to the water flow in the estuary. The actual longitudinal velocity and the population density of the life stages on the enclosure surfaces $\bar{A}_{i+1/2}$ of the discrete elements (see Fig. 4.1) can be represented as follows:

$$u_{i+1/2}^{(k)}(t,x,y,z) = \bar{V}_{i+1/2}(t,x) + \bar{u}_{i+1/2}^{(k)}(t,x,y,z) + \bar{V}_{i+1/2}^{(k)}(t,x,y,z), \quad (4.1)$$

$$p_{i+1/2}^{(k)}(t,x,y,z) = \bar{p}_{i+1/2}^{(k)}(t,x) + \bar{p}_{i+1/2}^{(k)}(t,x,y,z), \quad (4.2)$$

where

$u_{i+1/2}^{(k)}(t,x,y,z)$ = actual, short-time-dependent, cross-section-variable, longitudinal velocity component of life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of discrete element "i".

$\bar{V}_{i+1/2}(t,x) = \bar{G}_{i+1/2} / \bar{A}_{i+1/2}$ = tidal-averaged and cross-section-averaged net freshwater flow velocity on the enclosure surface $\bar{A}_{i+1/2}$ of discrete element "i".

$\bar{u}_{i+1/2}^{(k)}(t,x,y,z)$ = the difference (velocity "defect") between the actual short-time-dependent, cross-section-variable, longitudinal velocity component and the tidal-averaged and cross-section-averaged net freshwater flow velocity on the enclosure surface $\bar{A}_{i+1/2}$ of discrete element "i". (4.3)

$\bar{V}_{i+1/2}^{(k)}(t,x,y,z)$ = actual short-time-dependent, cross-section-variable, longitudinal migration velocity of life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of discrete element "i".

$p_{i+1/2}^{(k)}(t,x,y,z)$ = actual short-time-dependent, cross-section-variable population density of life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of discrete element "i".

$\bar{p}^{(k)}_{ij}(t,x)$ = tidal-averaged and cross-section-averaged population density of life stage "k" on the enclosure surface $\bar{A}_{ij}$ of discrete element "i".

$\bar{p}^{* (k)}_{ij}(t,x,y,z)$ = the difference between the actual short-time-dependent, cross-section-variable population density and the tidal-averaged and cross-section-averaged population density of life stage "k" on the enclosure surface $\bar{A}_{ij}$ of discrete element "i".

It is important to note that all the terms in Eqs. (4.1) and (4.2), which represent the short-time-dependent and cross-section-variable conditions, include both the variations within the tidal cycle and the random turbulent fluctuations of the longitudinal velocity component and the population densities of the life stages. Although the two different time-scale phenomena can be separated in the formulation to treat the tidal variations and the turbulent fluctuations separately, the particular definitions, Eqs. (4.1) and (4.2), are sufficient for the formulation of the transport fluxes in the model.

According to the fundamental assumptions of the tidal-averaged and cross-section-averaged one-dimensional models, the terms representing the short-time-dependent, cross-section-variable differences for the longitudinal velocity component u^{*}_{ij} and for the life-stage population densities $\bar{p}^{* (k)}_{ij}$, together with the migration velocity $V^{(k)}_{ij}$, result in the general integral expressions for the population transport fluxes $\bar{g}^{(k)}_{ij}$ on the enclosure surfaces $\bar{A}_{ij}$ of the discrete elements as

$$\begin{aligned} \bar{g}^{(k)}_{ij} = & (1/T) \int_0^T \int_{\bar{A}_{ij}} \bar{p}^{(k)}_{ij} u^{*}_{ij} dA dt \\ & + (1/T) \int_0^T \int_{\bar{A}_{ij}} \bar{p}^{* (k)}_{ij} V^{(k)}_{ij} dA dt. \end{aligned} \quad (4.4)$$

From theoretical considerations, the two integrals in Eq. (4.4) can be integrated for the evaluation of the life-stage population transport flux $\bar{g}^{(k)}_{ij}$, provided appropriate data for the velocity conditions and the life-stage population densities are available to represent the approximate variations within the tidal cycle and over the cross sections. However, the quantity and quality of the available data [33-36] for the tidal and cross-sectional variations of the life-stage population densities do not justify the determination of the transport fluxes $\bar{g}^{(k)}_{ij}$ from the integrals, Eq. (4.4), since the inherent sampling errors in the available data could produce errors in $\bar{g}^{(k)}_{ij}$ beyond the limit of accuracy of the one-dimensional formulation. Hence, in the development of the simulation model, the analytical approach for the determination of the integrals was discarded, and a pragmatic approach was adopted to formulate the different phenomena which contribute to the longitudinal life-stage population transport in the estuary as

$$\bar{g}^{(k)}_{ij} = [\bar{g}^{(k)}_{ij}]_{tid} + [\bar{g}^{(k)}_{ij}]_{def} + [\bar{g}^{(k)}_{ij}]_{mig}, \quad (4.5)$$

where

$[\bar{g}^{(k)}_{ij}]_{tid}$ = tidal dispersion transport flux due to periodic tidal flow conditions,

$[\bar{g}^{(k)}_{ij}]_{def}$ = convective defect transport flux due to the cross-sectional variation of the net freshwater flow velocity and cross-sectional variations of tidal-averaged population density, (4.6)

$[\bar{g}^{(k)}_{ij}]_{mig}$ = migratory transport flux due to the mobility of the populations for life stage "k" on the enclosure surface $\bar{A}_{ij}$ of discrete element "i".

In the general formulation of the present model these three fundamental contributions to the longitudinal population transport flux for life stage "k" are considered separately based on (a) tidal flow conditions, (b) vertical and lateral variations in the density distributions, and (c) the migratory behavior of the older life-stage populations in the estuary.

4.1 FORMULATION OF THE TIDAL DISPERSION TRANSPORT FLUX

The time averaging of the actual three-dimensional, semidiurnal tidal conditions in an estuary over the tidal cycle results in a longitudinal mixing transport for passive organisms in the water. This well-established phenomenon [47] occurs due to the shear profiles of the axial velocity and the vertical turbulent eddy diffusion which exist in the estuary throughout the tidal period. For the early life stages (egg, yolk-sac larva, and post-yolk-sac larva), the tidal dispersion effect contributes considerably to the overall longitudinal transport, since these life-stage populations predominantly behave as passive organisms in the flow regimes of the estuary. Hence, based on the results of the previous studies [47], the tidal dispersion transport flux can be approximately formulated as

$$[\bar{g}_{1D}^k]_{i+1/2} = -(\bar{E}_{1D})_{i+1/2} \left[\frac{\partial \bar{p}^k}{\partial x} \right]_{i+1/2} \quad (4.7)$$

where

$$(\bar{E}_{1D})_{i+1/2} = \text{tidal dispersion coefficient at the location of the enclosure surface } A_{i+1/2} \text{ of the discrete element "i".} \quad (4.8)$$

The formulation of tidal dispersion transport employed in a previous model [2] is based on a longitudinally varying dispersion coefficient that was previously determined for the modeling of the salinity intrusion phenomenon in the Hudson River [6]. It should be recognized that this particular salinity intrusion dispersion coefficient is strictly limited to salinity intrusion in the Hudson River, because it includes in its definition the totality of stratification effects, two-layer conditions, and the timewise, discontinuous, semidiurnal ocean salinity conditions in an embedded form.

It is clear that the striped bass life-stage populations in the estuary do not behave like salt. In particular, the three dominant phenomena which are essential for the justification of high salinity dispersion coefficient values (stratification, two-layer conditions, and discontinuous ocean salinity variations) do not all have counterparts in the striped bass young-of-the-year populations. However, there is not sufficient information to independently estimate the appropriate dispersion coefficients for the transport of the striped bass life-stage populations. Hence, it is reasonable to use the classical form of the dispersion coefficient for completely passive contaminants in estuaries [47]; that is,

$$(\bar{E}_{1D})_{i+1/2} \cong 6(\lambda_{BO})^{1/2} \bar{V}_{i+1/2} \bar{D}_{i+1/2} \quad (4.9)$$

where

$$\begin{aligned} \lambda_{BO} &\cong 0.002 = \text{bottom friction coefficient for turbulent flow in estuaries [47]}, \\ \bar{D}_{i+1/2} &= \text{mean water depth at the "i+1/2" enclosure surface of the discrete element "i".} \end{aligned} \quad (4.10)$$

Substituting Eq. (4.9) in Eq. (4.7) and expressing the spatial derivative term in finite difference form consistent with the discrete-element formulation of the present model, the tidal dispersion transport flux for the life-stage populations becomes

$$[\bar{g}_{1D}^k]_{i+1/2} = +12(\lambda_{BO})^{1/2} \bar{V}_{i+1/2} \bar{D}_{i+1/2} [\bar{p}_{i+1/2}^k - \bar{p}_i^k] (\Delta x_{i+1/2} + \Delta x_i) \quad (4.11)$$

Hence the tidal dispersion part $[g_{\text{tid}}^{(h)}]_{i,j}$ of the general life-stage population transport flux $g_{i,j}^{(h)}$ can be expressed in terms of the physical conditions in the river, that is, bottom friction coefficient $\lambda_{b(i,j)}$, Eq. (4.10), mean water level depth $D_{i,j}$, Eq. (2.1), the maximum tidal speed $\bar{V}_{i,j}$, Eq. (2.2), assumed lengths of the discrete elements $\Delta x_{i,j}$ and $\Delta x_{j,i}$ and the life-stage population densities $\bar{p}_{i,j}^{(h)}$ and $\bar{p}_{j,i}^{(h)}$ in the adjacent discrete elements which have the common enclosure surfaces $A_{i,j}$.

4.2 FORMULATION OF THE CONVECTIVE DEFECT TRANSPORT FLUX

According to the general formulation of the model, the longitudinal convection terms, Eq. (2.9), are based on the net freshwater rates $\bar{G}_{i,j}$ and on the tidal-averaged and cross-section-averaged mean values of the life-stage population densities $\bar{p}_{i,j}^{(h)}$. The actual existence of periodic temporal and spatial variations of the turbulent velocity profiles $u(t,x,y,z)$ and the life-stage population densities $p^{(h)}(t,x,y,z)$ were considered in the formulation of the tidal dispersion transport fluxes $[g_{\text{tid}}^{(h)}]_{i,j}$, Eq. (4.11). In addition to the dispersion transport, the tidal-averaged spatial variations of the net turbulent flow profiles and the life-stage population densities over the cross-sectional areas result in an additional longitudinal transport effect due to the defect in the formulation of the convective transport fluxes on a tidal-averaged one-dimensional model.

Considering the general expression for the population transport fluxes, Eq. (4.4), it is evident that the evaluation of the integral will depend on the particular spatial distributions of the velocity defect $u_{\text{def}}^{(h)}(t,x,y,z)$ and the life-stage population density differences $p_{\text{def}}^{(h)}(t,x,y,z)$ during the tidal cycle. Hence, noting that the tidal flow can be represented by the characteristic parameter maximum tidal speed $\bar{V}_{i,j}$ and assuming that local similarity-type cross-sectional distributions exist for velocity and population densities, the integral expression, Eq. (4.4), can always be integrated into a form such as

$$[g_{\text{def}}^{(h)}]_{i,j} = -C_{\text{def},i,j}(\bar{V}_{i,j})(\lambda_{b(i,j)})^{-1} \bar{\Delta p}_{i,j}^{(h)} [\bar{G}_{i,j} \bar{A}_{i,j}] p_{i,j}^{(h)}, \quad (4.12)$$

where

$C_{\text{def},i,j}(\bar{V}_{i,j})$ = convective defect coefficient which depends on the maximum tidal speed and which results from the integration of the product of the assumed local similarity-type spatial distribution functions for velocity and life-stage population densities,

$\bar{\Delta p}_{i,j}^{(h)}$ = density defect coefficients which represent the overall parametric relations between the actual temporal and spatial distributions of the life-stage population densities over the cross-sectional areas relative to their tidal-averaged and cross-section-averaged values $\bar{p}_{i,j}^{(h)}$. (4.13)

Theoretically, both coefficients can be determined provided that reliable data for the cross-sectional distributions of velocity and life-stage population densities are available. The local similarity-type functions can be constructed from the data to evaluate the integral, Eq. (4.4), in order to obtain the coefficients in the integrated form of the convective defect transport flux $[g_{\text{def}}^{(h)}]_{i,j}$, Eq. (4.12). However, since the available data [31-33] for the cross-sectional variations of the life-stage population densities can only indicate that the densities are higher at the bottom of the river, it is evident that the coefficients, Eq. (4.13), cannot be determined by the evaluation of the integrals, Eq. (4.4).

An alternate approach to determine the coefficients in the convective defect transport flux expression, Eq. (4.12), is to utilize the longitudinal distribution data for the life-stage population and to

simulate the distributions by the model in a systematic manner by considering different values for the coefficients until the best fit between the computer results and the data is achieved. In this indirect, parametric-study-type approach, it is sufficient to have only one unspecified parameter in Eq. (4.12) to be determined according to the simulations. Hence the values for the bottom friction coefficient $\lambda_{b0,1}$ and convective defect coefficient $C_{DEF,1,2}(V_{1,2})$ were arbitrarily specified as

$$\lambda_{b0,1} = 0.002 \text{ (ref. 41)} \quad C_{DEF,1,2}(\bar{V}_{1,2}) = 10. \quad (4.14)$$

The computer simulation model was applied with the 1973 physical data and plant operational conditions (to be discussed later) to determine the particular values for the defect coefficients $\bar{\Delta p}_{CR,1,2}^{(h)}$, Eq. (4.13), which produced the best simulations of the 1973 longitudinal distributions of the life-stage populations [24]. To simplify the iterations for best-fit values, it was assumed that the density defect coefficient $\bar{\Delta p}_{CR,1,2}^{(h)}$ for a life stage was approximately the same over all discrete-element enclosure surfaces along the estuary. For eggs, yolk-sac larvae, and post-yolk-sac larvae, the following values for the density defect coefficient were considered:

$$\text{for } k = 1, 2, 3, \quad \bar{\Delta p}_{CR,1,2}^{(h)} = \bar{\Delta p}_{CR}^{(h)} = 0, 0.9, 1.8, 2.0. \quad (4.15)$$

Since juveniles have well-developed swimming capabilities, a value of zero was assigned to the density defect coefficient for each of the three juvenile life stages; that is,

$$\text{for } k = 4, 5, 6, \quad \bar{\Delta p}_{CR,1,2}^{(h)} = \bar{\Delta p}_{CR}^{(h)} = 0. \quad (4.16)$$

The computer simulations indicated that the coefficient values of 0 (no convective defect transport) and 0.9 (moderate convective defect transport) caused rapid flushing of the young-of-the-year populations out of the river with poor simulations of the 1973 distributions. The results with 1.8 and 2.0 values for the coefficient both produced acceptable simulations of the longitudinal distributions of the life-stage populations within the accuracy bounds of the observed data. The final choice of 1.8 for the value of this parameter for all three life stages (egg, yolk-sac larva, and post-yolk-sac larva) was made because it produced a slightly better simulation of the weekly averaged values for both the longitudinal distributions and the standing crops for all life-stage populations in the river during May 1 to October 15, 1973. Hence the integrated expression, Eq. (4.12), for the convective defect transport flux $[\bar{g}_{DEF}^{(h)}]_{1,2}$, Eq. (4.5), was approximated in terms of the known physical conditions in the river and the life-stage population densities $\bar{p}_{1,2}^{(h)}$.

4.3 FORMULATION OF THE MIGRATORY TRANSPORT FLUX

In addition to the movement with the longitudinal convective motion due to the net freshwater flow and longitudinal dispersion due to the diurnal tidal flow, it is known that striped bass larvae and juveniles also exhibit various kinds of migratory behavior. Since a tidal-averaged, one-dimensional model cannot incorporate three-dimensional motions directly and in detail, only their ultimate longitudinal effects must be considered in the general formulation of the migratory transport flux $[\bar{g}_{MIG}^{(h)}]_{1,2}$, Eq. (4.5).

4.3.1 Migratory Transport Fluxes for Early Life Stages

Diurnal variations in the population densities of yolk-sac larvae and particularly post-yolk-sac larvae have been observed in the ichthyoplankton samples taken at different depths [31, 32]. The

population densities are generally higher near the surface during the night than during the day, and they are generally highest near the bottom at all times [31, 32]. These indications of diurnal vertical migratory motions can be attributed to various physical, behavioral, and ecological factors, such as responses to light, flow conditions, and avoidance of predators, as well as to sampling-gear avoidance, which can result in low catches in upper strata during daylight hours. Since the vertical migratory motions appear to be diurnal, the distributional effects are approximately evenly divided between the ebb and flood stages of the 12.4-hr semidiurnal tidal flow in the estuary. Hence a significant convective, defect-type longitudinal transport, resulting only from the changes in vertical distributions and the turbulent velocity profiles of the tidal flow conditions, cannot be expected. Furthermore, because considerably higher population densities are apparent near the bottom at most times and because the vertical migratory motions only partially alter these predominant distributions, the net convective defect transport, resulting from daily and tidal-averaged distributional conditions, would be greater than the longitudinal transport due to the vertical motions. Hence it is realistic to neglect the effects of vertical migrations in the modeling of the longitudinal motions of the early life stages.

Since the early life stages do not exhibit any other pronounced behavioral motions in the estuary, the migratory transport fluxes for eggs, yolk-sac larvae, and post-yolk-sac larvae are assumed as identically zero; that is,

$$[g_{\text{vii}}^{\text{vii}}]_{i=1} = 0, \quad \text{for } k = 1, 2, 3, \quad i = 1, 2, \dots, N, \quad (4.17)$$

on all discrete-element enclosure surfaces in the general formulation of the model.

4.3.2 Migratory Transport Fluxes for Later Life Stages

The later life stages (Juvenile I, Juvenile II, and Juvenile III) of the striped bass young-of-the-year tend to migrate to and remain in shoal areas in the river [33,48]. Hence, after July, juvenile populations start concentrating in the Newburgh-Beacon and, particularly, in the Tappan Zee-Haverstraw Bay regions where ample shoal areas exist along the riverbank. The available data [33,48] indicate that, regardless of the freshwater flow convection and tidal dispersion transport, juvenile populations tend to stay in these areas and therefore must resist the hydrodynamic conditions in the river. Consequently, their ability to swim and their behavioral preference for shoal areas become dominant in controlling the longitudinal distribution of the life-stage populations.

In the present computer simulation model, the longitudinal migration of the juvenile life-stage populations is formulated according to the phenomenological concept of the "potential law of migration," which was introduced in a mathematical field theory for complex ecological systems [19] and in a discretized model for human population dynamics in multiple community urban systems [20].

It is realized that, regardless of the continuous, downstream net freshwater flow convection hypothesis of the tidal-averaged models, the life-stage populations in reality can move considerable distances up and down the estuary, due to the tidal excursion. Hence, in a sense, they have the ability to survey the availability of shoaling areas and the abundance of food at different locations along the estuary without expending significant effort. Consequently, if a juvenile life-stage population has the physiological ability to resist the tidal flow currents, they can then select an "optimum" shoal area within the tidal excursion range in which to stay until the conditions reach a level such that the available food in the area becomes low enough to stimulate the juveniles to seek another area with better conditions along the estuary. In the present model, two dimensionless potentials are formulated to describe the longitudinal migrations of the juvenile life-stage populations from one element to an adjacent element along the estuary.

4.3.2.1. Positive potential of shoal preference. Consider a location $x_{i+1/2}$ along the estuary between two discrete elements at x_i and x_{i+1} . Assume that the particular location is in a region with a shoal area represented by the value of a shoal parameter $R_{SM,i+1/2}$. During the tidal cycle, if the fish behave as passive organisms without trying to swim against the tidal flow in the estuary, they will be exposed to the variations of the shoal parameter R_{SM} upstream and downstream of their initial location $x_{i+1/2}$ up to a distance of half the tidal excursion $L_{TD,i+1/2}$. Hence the two limiting values of the shoal parameter R_{SM} that the fish experience during the tidal cycle can be expressed in Taylor's series form based on the value of the shoal parameter $R_{SM,i+1/2}$ at the initial location $x_{i+1/2}$ as

$$R_{SM}(x_{i+1/2} - \frac{1}{2}L_{TD,i+1/2}) = R_{SM,i+1/2} - \left(\frac{\partial R_{SM}}{\partial x} \right)_{i+1/2} \left(\frac{1}{2}L_{TD,i+1/2} \right) + \dots, \quad (4.18)$$

$$R_{SM}(x_{i+1/2} + \frac{1}{2}L_{TD,i+1/2}) = R_{SM,i+1/2} + \left(\frac{\partial R_{SM}}{\partial x} \right)_{i+1/2} \left(\frac{1}{2}L_{TD,i+1/2} \right) + \dots,$$

where the higher-order terms in the series are neglected.

The available data [33,48] indicate that juveniles prefer to exist in shoal areas as opposed to nonshoal areas, presumably due to the greater availability of food and the tendency of the juveniles to school in these shallow regions. The life-stage population $p_{i+1/2}^{(j)}$, initially at location $x_{i+1/2}$ with a shoal parameter value of $R_{SM,i+1/2}$, will be exposed to a "potential" which will influence its migratory behavior as a comparison ratio of the difference in the shoal area parameter R_{SM} experienced during the tidal cycle to the shoal area parameter $R_{SM,i+1/2}$ which existed at the beginning of the tidal cycle; that is,

$$(\nabla R_{SM})_{i+1/2} = \frac{1}{(R_{SM})_{i+1/2}} [R_{SM}(x_{i+1/2} + \frac{1}{2}L_{TD,i+1/2}) - R_{SM}(x_{i+1/2} - \frac{1}{2}L_{TD,i+1/2})]. \quad (4.19)$$

Hence, substituting Eq.(4.18) in Eq. (4.19), the positive potential of shoal preference becomes

$$(\nabla R_{SM})_{i+1/2} = \left[\frac{1}{2}L_{TD,i+1/2} \right] \left(\frac{\partial R_{SM}}{\partial x} \right)_{i+1/2}. \quad (4.20)$$

It is important to note that the potential of shoal preference is in the form of the gradient of the shoal parameter; it is strictly dimensionless, regardless of the definition of the geometric parameter R_{SM} representing the abundance of shoal area along the estuary.

4.3.2.2. Negative potential of crowding. In the formulation of migratory behavior models it is not realistic to consider only preference-type, positive potentials. Positive potentials will tend to create high local densities of juveniles, which in turn could result in local food limitations. Hence, if the simple but plausible assumption is made that the local availability of food for juveniles is negatively correlated with the local population density of juveniles, then it can be argued that their migratory behavior is influenced by a negative potential of crowding which causes the juveniles to migrate away from the regions of high population density. During a tidal cycle the life-stage population $p_{i+1/2}^{(j)}$ also experiences variations of the life-stage population density $p^{(j)}$, as well as of the shoal parameter R_{SM} , upstream and downstream of its initial location $x_{i+1/2}$ up to a distance of half the tidal excursion $L_{TD,i+1/2}$. Hence the two limiting values of the life-stage population density experienced during the tidal cycle can also be expressed in Taylor's series form based on the life-stage population density $p_{i+1/2}^{(j)}$ at the initial location $x_{i+1/2}$ as

$$\bar{p}^{(k)}(x_{i-1,2} - \frac{1}{2}L_{tid,i-1,2}) = \bar{p}^{(k)}_{i-1,2} - \left[\frac{\partial \bar{p}^{(k)}}{\partial x} \right]_{i-1,2} [\frac{1}{2}L_{tid,i-1,2}] + \dots \quad (4.21)$$

$$\bar{p}^{(k)}(x_{i+1,2} + \frac{1}{2}L_{tid,i+1,2}) = \bar{p}^{(k)}_{i+1,2} + \left[\frac{\partial \bar{p}^{(k)}}{\partial x} \right]_{i+1,2} [\frac{1}{2}L_{tid,i+1,2}] + \dots$$

where the higher-order terms in the series are neglected. Considering the undesirable effect of crowding, the fish in the life-stage populations $p^{(k)}_{i,2}$ initially at $x_{i,2}$ exhibit a "negative potential" to migrate toward the less-crowded locations. This negative potential is approximated by the ratio of the difference in the life-stage population density $\bar{p}^{(k)}$ experienced during the tidal cycle to the life-stage population density $\bar{p}^{(k)}_{i,2}$ which existed at the beginning of the tidal cycle; that is,

$$\nabla p^{(k)}_{i,2} = \frac{-1}{\bar{p}^{(k)}_{i,2}} [\bar{p}^{(k)}(x_{i+1,2} + \frac{1}{2}L_{tid,i+1,2}) - \bar{p}^{(k)}(x_{i-1,2} - \frac{1}{2}L_{tid,i-1,2})] \quad (4.22)$$

Hence, substituting Eq. (4.21) in Eq. (4.22), the negative potential of crowding becomes

$$\nabla p^{(k)}_{i,2} = -[L_{tid,i-1,2} \bar{p}^{(k)}_{i-1,2}] \left[\frac{\partial \bar{p}^{(k)}}{\partial x} \right]_{i-1,2} \quad (4.23)$$

It is again important to note that the negative potential of crowding is in the form of the gradient of the life-stage population density; it is strictly dimensionless.

4.3.2.3 Net potential of migration. The positive potential of shoal preference $(\nabla R_{shc})_{i,2}$ and the negative potential of crowding $\nabla p^{(k)}_{i,2}$ work as opposing effects in controlling the migratory behavior of the life-stage population $p^{(k)}_{i,2}$, depending on the relative importance of the two potentials. Hence, the net potential of migration can be expressed as a weighted linear combination of the two potentials; that is,

$$\nabla M^{(k)}_{i,2} = \gamma^{(k)}_{shc} (\nabla R_{shc})_{i,2} + \gamma^{(k)}_{crw} \nabla p^{(k)}_{i,2} \quad (4.24)$$

where

$$\begin{aligned} \gamma^{(k)}_{shc} &= \text{shoaling effect parameter for life stage "k"}, \\ \gamma^{(k)}_{crw} &= \text{crowding effect parameter for life stage "k"}. \end{aligned} \quad (4.25)$$

It is important to note that dimensionless weighting parameters for shoaling preference and undesirable crowding conditions, $\gamma^{(k)}_{shc}$ and $\gamma^{(k)}_{crw}$, respectively, are not necessarily constants. In the general ecological sense the parameters are functions of the physical conditions in the estuary, population densities of the life stages, and other biotic factors such as food limitation and predation.

4.3.2.4 Migration velocity based on ability to resist flow. The net migration rate of a life-stage population depends on the mobility characteristics of the life stage. Since the general model is tidal-averaged and one-dimensional, longitudinal migration is only meaningful if a life-stage population changes its position relative to the flow conditions for times longer than the period of the tidal cycle. Hence, although the juvenile populations can move effortlessly with the tidal velocity, for the net migration to occur they must be able to resist reversals in tidal flow conditions in the estuary. The net migration velocity at a location $x_{i,2}$ depends partly on the swimming speed of the fish in a life stage and

the duration it can swim against the tide. A detailed analysis of the mobility characteristics of fish in flowing streams is extremely complicated and definitely beyond the scope of this study. However, within the limits of accuracy of the present simulation model, an approximation can be assumed in the form of ratios based on the distance a fish can travel during a tidal cycle according to its maximum swimming speed and duration:

$$[V_{\text{mig}}^{(k)}]_{i+1/2} = \frac{1}{2} V_{\text{swim},i+1/2} \left[\frac{\bar{\Delta t}_{\text{swim}}^{(k)}}{\bar{\Delta t}_{\text{swim}}^{(k)} + (V_{i+1/2} T_{\text{tid}})} \right], \quad (4.26)$$

or

$$[V_{\text{mig}}^{(k)}]_{i+1/2} = \frac{1}{2} V_{\text{swim},i+1/2} \left[\frac{\bar{\Delta t}_{\text{swim}}^{(k)}}{\bar{\Delta t}_{\text{swim}}^{(k)} + T_{\text{tid}}} \right], \quad (4.27)$$

where

$[V_{\text{mig}}^{(k)}]_{i+1/2}$ = tidal-averaged longitudinal migration velocity for life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of the discrete element "i",

$V_{\text{swim},i+1/2}$ = maximum swimming speed of life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of the discrete element "i", (4.28)

T_{tid} = semidiurnal tidal period $\cong 12.4$ hr.

The factor $1/2$ is introduced for mathematical convenience. Since the weighting coefficients $\gamma_{\text{sh}}^{(k)}$ and $\gamma_{\text{psh}}^{(k)}$, Eq. (4.25), are not yet defined, accurate specification of this factor in the definition of the migration velocity $[V_{\text{mig}}^{(k)}]_{i+1/2}$ is not essential to the formulation of the migratory transport model.

Based on the above discussions, the migratory transport flux $[g_{\text{mig}}^{(k)}]_{i+1/2}$, Eq. (4.6), for the life stage "k" on the enclosure surface $\bar{A}_{i+1/2}$ of the discrete element "i" can be formed, according to the general potential law of migration, as

$$[g_{\text{mig}}^{(k)}]_{i+1/2} = [V_{\text{mig}}^{(k)}]_{i+1/2} \bar{M}_{i+1/2}^{(k)} p_{i+1/2}^{(k)}. \quad (4.29)$$

Substituting Eqs. (4.20) and (4.23) in Eq. (4.24) and then substituting Eq. (4.24) in Eq. (4.29) and rearranging,

$$[g_{\text{mig}}^{(k)}]_{i+1/2} = \frac{1}{2} V_{\text{swim},i+1/2} \left[\frac{\bar{\Delta t}_{\text{swim}}^{(k)}}{T_{\text{tid}}} \right] L_{\text{tid},i+1/2} \cdot \left\{ \gamma_{\text{sh}} \left[\frac{p_{i+1/2}^{(k)}}{(R_{\text{shc}})_{i+1/2}} \right] \left(\frac{\partial R_{\text{shc}}}{\partial x} \right)_{i+1/2} - \gamma_{\text{psh}} \left[\frac{\partial p^{(k)}}{\partial x} \right]_{i+1/2} \right\}. \quad (4.30)$$

The derivatives of the shoal parameter R_{shc} and the life-stage population density $p^{(k)}$, representing the one-dimensional forms of the gradients, can be expressed in finite-difference form consistent with the discrete-element formulation of the model on the general enclosure surface $\bar{A}_{i+1/2}$ as

$$\begin{aligned} \left(\frac{\partial R_{\text{shc}}}{\partial x} \right)_{i+1/2} &= \mp 2 \left[\frac{(R_{\text{shc}})_{i+1} - (R_{\text{shc}})_i}{\Delta x_{i+1} + \Delta x_i} \right], \\ \left(\frac{\partial p^{(k)}}{\partial x} \right)_{i+1/2} &= \mp 2 \left[\frac{p_{i+1}^{(k)} - p_i^{(k)}}{\Delta x_{i+1} + \Delta x_i} \right]. \end{aligned} \quad (4.31)$$

Hence, generalizing the expression for the migratory transport flux $[g_{\text{mig}}^{(n)}]_{i-1,2}$ on the enclosure surface $\bar{A}_{i-1,2}$ by substituting Eq. (4.31) in Eq. (4.30) and rearranging, the final form becomes

$$[g_{\text{mig}}^{(n)}]_{i-1,2} = V_{\text{shoal},i-1,2} \left[\frac{\Delta x_{\text{shoal}}^{(n)}}{L_{\text{tid}}} \right] \left(\frac{L_{\text{tid},i-1,2}}{\Delta x_{i-1,2} + \Delta x} \right) \cdot \left\{ \pm \gamma_{\text{sh}}^{(n)} \left[\frac{p_{i-1,2}^{(n)}}{(R_{\text{sh}})_{i-1,2}} \right] [(R_{\text{sh}})_{i-1} - (R_{\text{sh}})_i] \pm \gamma_{\text{crw}}^{(n)} [\bar{p}_{i-1}^{(n)} - \bar{p}_i^{(n)}] \right\} \quad (4.32)$$

The assumed values for the shoaling effect parameter $\gamma_{\text{sh}}^{(n)}$ and the crowding effect $\gamma_{\text{crw}}^{(n)}$ were already presented in Table 3.2.

This migratory behavior model for the juvenile populations, although novel from biological modeling considerations, is conceptually similar to well-established phenomenological transport models developed in the physical sciences. However, it is also realized that one of the criteria in evaluating a mathematical model is the pragmatic test of its ability to simulate the actual observed conditions in the estuary. In the applications of the model to the simulation of the 1973 data, the computer results for the juvenile populations were shown to agree very well with the observed occurrence of high population densities in the expected shoal areas.

In summary, based on plausible assumptions and without requiring modifications in the general formulation of the model, the unknown longitudinal transport fluxes $g_{i-1,2}^{(n)}$ of the fundamental discrete-element equation (2.9) can be expressed in terms of the known physical conditions in the estuary and the principal unknowns, that is, life-stage population densities $p_i^{(n)}$ by considering individual formulations for the tidal dispersion fluxes $[g_{\text{tid}}^{(n)}]_{i-1,2}$, Eq. (4.11), convective defect transport fluxes $[g_{\text{def}}^{(n)}]_{i-1,2}$, Eq. (4.12), and migratory transport fluxes $[g_{\text{mig}}^{(n)}]_{i-1,2}$, Eq. (4.32).

5. MODELING OF THE ENTRAINMENT AND IMPINGEMENT AT THE POWER PLANTS

The model has the capability for simulating the removal and replenishment of life-stage populations by the power plants at different locations along the river, depending on the locations of the intake and the discharge structures. The present computer simulation model formulates the net reduction rates of the life-stage populations by the power plants in three parts: (a) The removal rates of the populations from the river segments that contain the intakes are determined by the population densities of the life stages at the intakes and the specified plant flow rates. (b) The intake population densities are reduced to obtain the population densities at the discharges, based on the survival probabilities of the life stages upon passage through the plant cooling system. (c) The replenishment rates of the populations are determined according to the discharge population densities and plant flow rates in the river segments containing the discharges.

The physical operational conditions of the power plants are employed as inputs to the model, based on specifications for the existing units. The susceptibilities to entrainment and impingement and the survival probabilities of the life-stage populations upon passage through the plant cooling systems are determined according to the operational conditions of the power plants and the biological characteristics of the life stages.

5.1 FORMULATION OF THE LIFE-STAGE POPULATION DENSITIES AT THE INTAKES

Since the general formulation of the model is longitudinally one-dimensional, it cannot predict the vertical and lateral variations in the distributions of striped bass life-stage populations in the estuary. Considering that the intake structures are located at the shores of the river, it is quite conceivable that the population densities in the water entering the intakes are different than the tidal-averaged mean life-stage population densities in the elements containing the intakes. To incorporate the possible difference between the intake population density and the mean population density in the discrete element, the present model employs a general expression in terms of various factors which are representative of the effects of the physical conditions and of the biological characteristics of the striped bass life stages. Hence the intake life-stage population density $p_{i,m}^{(k)}$ is formulated as

$$p_{i,m}^{(k)} = f_{i,i}^{(k)} (C_{g+o})_{i,m} [1 - f_{avd,i,m}^{(k)}] p_{i,m}^{(k)} \quad (5.1)$$

where

$f_{i,i}^{(k)}$ = intake population density distribution factor (i.e., ratio of the population density in the immediate vicinity of an intake to the mean population density in the discrete element of the intake) for life stage "k".

$(C_{g+o})_{i,m}$ = intake geometry factor (i.e., ratio of the population density of a life stage in the water entering the intake to the population density of the life stage in the immediate vicinity of the intake) for power plant "m". (5.2)

$f_{avd,i,m}^{(k)}$ = intake avoidance factor for life stage "k" which depends on the mobility characteristics of life stage "k" in discrete element "i" and the flow conditions at the intake of power plant "m".

$p_{i,m}^{(k)}$ = population density of life stage "k" in discrete element "i" which contains the intake of power plant "m".

The intake factors, Eq. (5.2), employed in the definition of the intake life-stage population density $p_{iN}^{(k)}$, require specific information about the life-stage populations in the estuary and plant operational conditions which warrant special consideration.

5.1.1 Determination of Intake Population Density Distribution Factor

The values for the intake population density distribution factor $f_{iN}^{(k)}$, Eqs. (5.1) and (5.2), can only be determined by additional information about the vertical and lateral distributions of the life-stage population densities in the particular discrete elements containing each power plant intake. It should be emphasized that, if information about the vertical and lateral distributions is not available, considerations of consistency in modeling dictate that the intake density ratio must be assumed as unity, because this value represents the correct theoretical value corresponding to the least-prejudiced estimate in any one-dimensional formulation.

The available data about the vertical and lateral variations of various life-stage populations in the estuary [49] do not directly justify the selection of extremely low values (e.g., 0.1 and 0.2 [18, 49, 50]) for the intake population density distribution factors $f_{iN}^{(k)}$ for the life stages. However, the data, disregarding the potential biases due to the sampling design and differences in sampling techniques, do justify overall intake density factor values between 0.5 and 1.0 for the entrainable life stages. It must be realized that the data reflect both vertical and lateral differences in distribution, which the intake population density factor $f_{iN}^{(k)}$, Eq. (5.2), is intended to incorporate, as well as intake geometry and avoidance effects, which the intake geometry factor $(C_{i,10})_{iN}^{(k)}$ and the intake avoidance factor $f_{iN}^{(k)}$, Eq. (5.2), are intended to include in the present model.

In addition, there exists strong indirect evidence that the intake population density distribution factors $f_{iN}^{(k)}$ may indeed be less than unity; this evidence is based on the data for the longitudinal distributions of the life-stage populations and the results from a parametric study using the present model to simulate the 1973 conditions in the estuary. To achieve reasonable simulations with the 1973 data, it was necessary to use relatively high values for the density defect coefficient $\Delta p_{iN}^{(k)}$, Eq. (4.13), for the early life stages (egg, yolk-sac larva, and post-yolk-sac larva). This result suggests that significant vertical and/or lateral variations in the distribution of the life-stage populations do indeed exist in the estuary, with high concentrations occurring near the bottom or near the shores. This distribution of the populations results in the retardation of the convective downstream motion of the populations by the net freshwater flow. Although the apparent existence of significant convective defect-type transport indicates that considerable vertical and lateral variations in the distributions of the life-stage populations must exist, this does not automatically imply that a comparable large reduction from unity must exist for the values of the intake density distribution factor $f_{iN}^{(k)}$. Considering the locations of the intakes at the shores, substantive reduction in the values of the factor could exist if the variations in the life-stage population densities are predominantly in the vertical direction. Conversely, if the variations are predominantly in the lateral direction, then, in view of the shore locations of the intakes, the values could be greater than unity. Considering the 1973 data [31, 32, 49, 50], it is evident that the vertical variations of the early life stages are indeed more pronounced than are the lateral variations, although the sampling in the shoal areas for these early life stages was very limited prior to August 1973. Nonetheless, it is realistic to assume that the intake population density factors for the existing power plants may be less than 1.0 for eggs, yolk-sac larvae, and early post-yolk-sac larvae. Juveniles (and perhaps late-post-yolk-sac larvae), however, are found predominantly in shallow water, and thus the intake population density factors for these life stages, not considering intake geometry effects and avoidance, may be greater than unity.

In the estimation of a realistic value for the intake population density factor $f_{NI}^{(k)}$, it is not sufficient to consider only the natural variations of the life-stage population distribution in the river in the absence of flow through the plant at the time intake and river transect samples are being taken. From hydrodynamic considerations, the induced flow conditions in the river due to the intake and discharge flows can alter the observed natural distributions in the river. Furthermore, again from hydrodynamic considerations, the influence of the intake flow is not necessarily restricted to a region near the surface and in the immediate vicinity of the intake; indeed, the intake water to a power plant can be drawn from considerable distances from the intake and from various depths, depending on the geometry of the riverbed and the tidal flow conditions in the vicinity of the power plant.

In summary, the 1973 data for the pre-juvenile life stages, in combination with the apparent existence of significant convective defect transport, indicate that in tidal-averaged and cross-section-averaged one-dimensional models, values of less than unity should be used for the intake population density factor $f_{NI}^{(k)}$, Eq. (5.2). However, in view of the lateral distributional effects, the hydrodynamic conditions that may be induced by the intake and discharge flows, and the sampling problems associated with the available data [25], extremely low values should not be assumed for the intake density distribution factors $f_{NI}^{(k)}$ for the life stages in estimating the intake population densities $p_{NI,m}^{(k)}$, Eq. (5.1), for the existing power plants in the Hudson River.

5.1.2 Determination of Intake Geometry Factor

The intake geometry factor $(C_{GIO})_{NI,m}$ is defined to incorporate the effects of the intake geometry and location in the estuary at a particular power plant "m". Intake structures, canals, and pools which are employed in the design of power plants could contain different life-stage population densities from the ones in the immediate vicinity of the power plant intake in the discrete element. Hence, in addition to the intake population density factor $f_{NI}^{(k)}$, Eq. (5.2), which represents the effects of the vertical and lateral distributions, it is necessary to include the intake geometry factor $(C_{GIO})_{NI,m}$, Eq. (5.2), for each power plant to determine the intake life-stage population density $p_{NI,m}^{(k)}$.

It must be realized that estimation of values for the intake geometry factor $(C_{GIO})_{NI,m}$, Eq. (5.2), different from the least prejudiced value of unity requires the consideration of the hydrodynamic conditions in the vicinity of the intake which include the effects generated by the intake flow while the power plant is operating.

5.1.3 Formulation of Intake Avoidance Factor

The computer simulation model considers the intake avoidance capabilities of the life-stage populations based on their mobility characteristics. For the juvenile life stages, approximate intake avoidance factors are formulated to simulate the avoidance effects based on the ratios of the swimming speeds of the life stages to the speeds of flow at the intakes as

$$f_{AVD,i,m}^{(k)} = \gamma_{AVD}^{(k)} V_{MOB,i,m} / V_{INT,m} \quad (5.3)$$

where

$\gamma_{AVD}^{(k)}$ = intake avoidance factor for life stage "k",

$V_{MOB,i,m}^{(k)}$ = swimming speed of life stage "k" in the discrete element "i" which contains the intake of the power plant "m",

$V_{INT,m}$ = maximum speed of the intake flow of power plant "m".

Since the swimming speed of the age group $V_{swim,k}^{(h)}$ depends on the temperature T , and salinity S , in the discrete element containing the intake, the model is capable of simulating the observed increase in impingement at the intakes during cold winter periods and under certain salinity conditions.

It is important to note that according to its definition, Eq. (5.1), the intake avoidance factor $f_{AVD,m}^{(h)}$ cannot be greater than unity, since the value of unity implies that the fish in the life stage can completely avoid impingement and entrainment at the intake, due to their swimming abilities. Hence the appropriate check condition is included in the model to guarantee that the intake avoidance factor $f_{AVD,m}^{(h)}$ does not exceed unity. At a value of unity, the intake life-stage population density $p_{INT,m}^{(h)}$, Eq. (5.1), becomes zero, which implies that the operation of the plant does not result in the reduction of the life-stage population in that discrete element.

The values for the intake avoidance coefficient $\gamma_{AVD}^{(h)}$ used in the applications of the simulation model are presented in Table 3.2 for the juvenile life stages.

5.2 FORMULATION OF THE LIFE-STAGE POPULATION DENSITIES AT THE DISCHARGES

The discharge life-stage population density $p_{DIS,m}^{(h)}$ is determined based on the intake life-stage population density $p_{INT,m}^{(h)}$ and the overall reduction in density upon passage through the power plant cooling system as

$$\bar{p}_{DIS,m}^{(h)} = \bar{R}_{OP,PI}^{(h)} \bar{C}_{T,PI}^{(h)} (C_{GEO})_{DIS,m} \bar{p}_{INT,m}^{(h)} \quad (5.5)$$

where

$\bar{R}_{OP,PI}^{(h)}$ = optimum plant survival probability for life stage "k" upon passage through a power plant cooling system.

$\bar{C}_{T,PI}^{(h)}$ = temperature correction factor to reflect a reduced survival probability for life stage "k" at high condenser water temperatures. (5.6)

$(C_{GEO})_{DIS,m}$ = discharge geometry factor for power plant "m".

In the general formulation of the present model it is necessary to determine the discharge life-stage population density $p_{DIS,m}^{(h)}$ rather than the overall plant reduction as in the previous models [1-3, 7], since the present model is capable of considering intake and discharge locations in different discrete elements.

5.2.1 Determination of Optimum Probability of Survival upon Passage Through a Power Plant

Mortality upon passage through any of the existing power plants on the Hudson River appears to be less than 100% for all entrainable life stages if the exposure temperature is not excessive (e.g., the maximum mean temperature of the water in the cooling system <85°F) and if there is no chlorination (which is true most of the time). Thus the values of optimum plant survival probability $\bar{R}_{OP,PI}^{(h)}$, Eq. (5.6), for egg, yolk-sac larva, post-yolk-sac larva, and Juvenile I life stages are assigned to be greater than zero in the applications of the model.

The particular values of optimum plant survival probability $\bar{R}_{OP,PI}^{(h)}$ for the entrainable life stages were estimated based on studies at Indian Point [32]. These values are assumed to be representative for all the power plants. However, it must be realized that the entrainable life stages could be exposed to significantly different mechanical stresses at different power plants. If this were the case, the necessary modifications could readily be achieved in the model by assigning different values to the intake geometry

factors $(C_{GEO})_{INT,m}$, Eq. (5.2), and to the discharge factors $(C_{GEO})_{DIS,m}$, Eq. (5.6), at the different power plants. The only restriction in the model is that it is presently assumed that the overall effect of the differences in mechanical stresses at different power plants is the same for all entrainable life stages.

The optimum plant survival probabilities $R_{OP,PI}^{(k)}$ for the impingeable life stages (i.e., Juvenile II and Juvenile III) are always specified as zero, since it is assumed that all fish impinged on the intake screens will die. However, if evidence becomes available that this assumption is not valid, then the observed survival of Juvenile II and Juvenile III life stages after impingement at different power plants can be readily incorporated in the model by assigning appropriate values to the intake geometry factors $(C_{GEO})_{INT,m}$, Eq. (5.2). Furthermore, differences in the values of the impingement survival probabilities for different life stages can be readily accounted for by adjusting the values of intake population density factor $f_{INT}^{(k)}$ and intake avoidance factor $f_{AVD,m}^{(k)}$ for the impingeable life stages [see Eq. (5.2)].

5.2.2 Formulation of Temperature Correction Factor for Plant Survival Probability

The results of various temperature tolerance experiments [31, 32] indicate that survival of all life stages of striped bass young-of-the-year decreases rapidly as exposure temperatures increase above a critical temperature of approximately 85°F. Hence, in the present model a multiplicative temperature factor $C_{T,PI}^{(k)}$ is included as a linearly varying function of the maximum discharge temperature $\bar{T}_{DIS,PI}$ in the plant cooling system, where $\bar{T}_{DIS,PI}$ is the sum of the intake temperature and the maximum temperature rise for the given power plant; that is,

for $\bar{T}_{DIS,PI} \leq T_{CR,PI}^{(k)}$,

$$C_{T,PI}^{(k)} = 1;$$

for $T_{CR,PI}^{(k)} < \bar{T}_{DIS,PI} < T_{MX,PI}^{(k)}$,

$$C_{T,PI}^{(k)} = [\bar{T}_{DIS,PI} - T_{MX,PI}^{(k)}] / [T_{CR,PI}^{(k)} - T_{MX,PI}^{(k)}]; \quad (5.7)$$

for $\bar{T}_{DIS,PI} \geq T_{MX,PI}^{(k)}$,

$$C_{T,PI}^{(k)} = 0;$$

where

$\bar{T}_{DIS,PI}$ = maximum discharge temperature in the plant cooling system as the sum of the intake temperature and the maximum temperature rise,

$T_{CR,PI}^{(k)}$ = critical temperature above which the plant survival probability decreases (5.8) linearly, from its optimum value, with increasing temperature for life stage "k",

$T_{MX,PI}^{(k)}$ = maximum temperature above which the plant survival probability is assumed to be zero for life stage "k".

The schematic representation of the temperature correction factor $C_{T,PI}^{(k)}$ is shown in Fig. 5.1.

Since the temperature correction factor $C_{T,PI}^{(k)}$, Eq. (5.7), is defined to reflect the reduction in survival probability for a life stage upon passage through a power plant under high exposure temperature conditions, two points must be considered in the estimation of the maximum discharge temperature $\bar{T}_{DIS,PI}$. First, the intake temperature must be determined based on the ambient temperature in the river and the temperature rise in the vicinity of the intake due to the recirculation from the discharge. Hence

Fig. 5.1. Schematic representation of the temperature correction factor to reflect a reduced survival probability for life stage "k" upon passage through a power plant at high cooling water temperatures.

an approximate longitudinal temperature distribution with operational plants is required. Second, the maximum temperature rise must be determined based on the temperature rise in the condenser cooling system and additional temperature rises which may occur due to the operation of auxiliary systems in the power plant.

5.2.3 Determination of Discharge Geometry Factor

The discharge geometry factor (C_{GEO}^k)_{DIS, m} is included in the formulation for computational convenience as a means of easily taking into account the stresses caused by the cooling system which would have a uniform effect on the plant survival probabilities of all entrainable life stages. It can also be used in simulating certain special applications. For example, for a unit with closed-cycle cooling, the discharge geometry factor (C_{GEO}^k)_{DIS, m}, Eq. (5.2), would be assigned a value of zero to represent 100% mortality of all entrainable life stages.

5.3 PARAMETER DATA FOR ENTRAINMENT AND IMPINGEMENT CONDITIONS AT THE POWER PLANTS

The parameter data employed in the simulation model for intake population density factor f_{INT}^k , intake avoidance parameter γ_{AVD}^k , optimum plant survival probability $R_{OPT, PLT}^k$, critical temperature for plant survival $T_{CR, PLT}^k$, and maximum temperature for plant survival $T_{MAX, PLT}^k$ are presented in Table 5.1 for all life stages.

The values for the intake population density factor f_{INT}^k for the entrainable life stages (i.e., egg, yolk-sac larva, post-yolk-sac larva, and Juvenile I) were determined according to the discussion in Sect. 5.1.1 and consideration of the 1973 data [27, 49]. The value of unity was assigned to the impingeable life stages (i.e., Juvenile II and Juvenile III) as the least prejudiced value, since there are no available data for the vertical and lateral distributions of these life stages in the estuary.

Table 5.1. Parameter data employed in the simulation model for plant survival conditions of the life stages

(k)	Life stage	Intake population density factor, $I_{IN}^{(k)}$	Intake avoidance parameter, $\gamma_{AV}^{(k)}$	Optimum plant survival probability, $R_{OPT}^{(k)}$	Critical temperature for plant survival, $T_{CR PT}^{(k)}$ (°F)	Maximum temperature for plant survival, $T_{MAX PT}^{(k)}$ (°F)
1	Egg	0.5	0.0	0.20	85	95
2	Yolk-sac larva	0.5	0.0	0.39	85	95
3	Post-yolk-sac larva	0.5	0.0	0.39	85	95
4	Juvenile I	0.5	0.0	0.28	85	95
5	Juvenile II	1.0	0.8	0.00	85	95
6	Juvenile III	1.0	1.0	0.00	85	95

The value of zero was assigned for the intake avoidance parameter $\gamma_{AV}^{(k)}$ for each entrainable life stage (i.e., egg, yolk-sac larva, post-yolk-sac larva, and Juvenile I), implying that these life stages cannot avoid entrainment at the intakes. In fact, the Juvenile I life stage undoubtedly does have some ability to avoid entrainment at the intakes, although to what extent is unknown. The net effect of this avoidance capability is empirically taken into consideration in using the 1973 data to estimate the intake population density factor $I_{IN}^{(k)}$ for the Juvenile I life stage. The impingeable life stages (i.e., Juvenile II and Juvenile III) were assigned values for the intake avoidance parameter $\gamma_{AV}^{(k)}$ representative of their abilities to swim away from the intakes.

The values for optimum plant survival probability $R_{OPT}^{(k)}$ for the entrainable life stages (i.e., egg, yolk-sac larva, post-yolk-sac larva, and Juvenile I) were determined based on studies at Indian Point [28, 31, 32]. The same values were used for all other power plants based on the assumption that the mechanical stresses associated with passage through the condenser cooling systems do not differ appreciably from those at Indian Point. The assigned values are intended to reflect the long-term probability of survival following passage through a power plant and were calculated by decreasing by 10% the short-term (i.e., 24-hr) probability of plant survival calculated from the Indian Point data. The optimum plant survival probabilities for the impingeable life stages (i.e., Juvenile II and Juvenile III) were taken as zero, according to the discussion in Sect. 5.2.1.

The values for critical temperature $T_{CR PT}^{(k)}$ and maximum temperature $T_{MAX PT}^{(k)}$ for plant survival were determined according to the results of various temperature tolerance experiments [28, 31, 32]. The same temperature values were used for all life stages, since the results of these studies indicated that the survival of all life stages of striped bass young-of-the-year decreases rapidly as exposure temperatures increase above 85°F.

In the application of the present model to the simulation of the 1973 data, the reduction in the striped bass young-of-the-year population, due to entrainment and impingement at the intakes, was determined by considering all the power plants which were operational during the period of sampling in the Hudson River. The operational conditions and the assumed values for the intake geometry factor $(C_{(G,T)})_{INT,m}$ and the discharge geometry factor $(C_{(G,T)})_{DIS,m}$ for these power plants are presented in Table 5.2.

The general formulation of the model considers the plant operational conditions as time-dependent input data based on the periods of operation of the power plant units; that is,

$$G_{INT,m} = G_{INT,m}(t) \text{ (specified),}$$

$$\Delta T_{PT,m} = \Delta T_{PT,m}(t) \text{ (specified),} \quad (5.9)$$

$$V_{INT,m} = V_{INT,m}(t) \text{ (specified).}$$

Table 5.2. Data employed in the simulation model for Hudson River plant operations and intake and discharge geometry factors for 1973

(a)	Power plant	Unit No.	Discrete element "q"	Location, mile point above Battery	In-service date	Capacity (MW)	Plant flow rate, (cfs)	Plant temperature rise, ΔT (°F)	Plant thermal discharge (billion Btu/hr)	Intake velocity, V_{int} (fps)	Plant intake geometry factor, (C _{int})	Plant discharge geometry factor, (C _{dis})
1	Albany	1	7	140		400	784.0	11.0	1,917	1.00	1.0	1.0
2	Danahammer	1	44	66	1951	64	89.0	14.5	2,250	2.90	1.0	1.0
		2			1954	64	89.0					
		3			1959	127	231.0					
		4			1967	253	277.0					
3	Lovett	1	55	42	1949	19	58.0	18.0	3,184	1.52	1.0	1.0
		2			1951	20	58.0	20.0		1.52		
		3			1955	68	96.0	22.0		1.83		
		4			1966	195	237.0	20.0		1.64		
		5			1969	202	272.0	22.0		2.00		
4	Bowline	1	58	37.5	1972	600	855.5	15.0	2,500	0.77	1.0	1.0
5	59th Street		74	5		221	174.0	6.0	0,500	1.00	1.0	1.0

Hence the plant operational data in Table 5.2 were assumed as the representative average operational conditions of the power plants for the simulation of the 1973 data.

The values for intake and discharge geometry factors $(C_{geo})_{intake}$ and $(C_{geo})_{discharge}$, respectively, for all power plants were assumed as unity. Hence, in the application of the model to 1973 data, the entrainment and impingement conditions for all life stages were assumed to be the same for all power plants, except for maximum exposure temperatures which depend on the maximum discharge temperatures T_{DMP} . Since the values for plant temperature rise ΔT_{PTE} were different for different plants (Table 5.2), the values for maximum discharge temperature T_{DMP} , which is the sum of the intake temperature and the plant temperature rise, were also different. Hence the temperature correction factors C_{TPT} , Eq. (5.8), for the life stages were slightly different, and consequently the plant survival probabilities for the life stages were slightly different at the different plants.

In summary, the entrainment and impingement losses can be realistically represented in the present simulation model by considering the approximate effects of the distributions of the life-stage populations in the estuary, the physical operational conditions of the power plants, and the plant survival probabilities of the life stages upon passage through the cooling systems of the power plants.

6. TRIBUTARY FLOWS, RAINFALL, AND RIVERBED TRANSPORT

The general formulation of the simulation model also contains certain features which can be employed to represent the effects of major tributary flows, rainfall, and riverbed drainage on the life-stage population distributions in the estuary.

6.1 FORMULATION OF TRIBUTARY FLOW CONDITIONS

The flows from major tributaries in a river could influence the life-stage population densities in the vicinities of the tributary discharges. Flow from a tributary that is not a spawning or nursery area for the striped bass young-of-the-year could result in the dilution of the life-stage populations in the river downstream of its discharge location. Conversely, flow from a tributary which is a spawning or nursery area for the striped bass young-of-the-year could result in an increase in the densities of the life-stage populations in the river downstream of its discharge location.

Since a large tributary could flow into more than one discrete element, the tributary flow rates G_i are specified as input data to the model according to the elements which contain their discharge areas; that is,

$$G_i = G_i(t) \text{ (specified in time).} \quad (6.1)$$

based on daily observed flow rates in the tributaries.

The life-stage population densities in the tributaries are also assumed as known inputs to the model if they are distinctly different from the river life-stage population densities in the vicinity of the tributaries; that is,

$$p'' = p''(t) \text{ (specified in time).} \quad (6.2)$$

It is important to note that according to the governing discrete-element equation of the model, Eq. (2.9), a tributary discharge with a value of life-stage population density equal to the value in the discrete element cannot affect the life-stage population densities in the river, regardless of the flow rate of the tributary.

In the applications of the model to the 1973 conditions in the Hudson River, the freshwater flow at the Troy Locks was considered as the only tributary in the estuary. The daily freshwater flow at the Troy Locks was employed as input data for the tributary flow rate in the first discrete element $G_{1,1}$ in the model.

The tidal flows between the main river and a tributary could also result in tidal dispersion-type transport. However, considering the limits of accuracy of the general formulation, this effect was not included in the simulation model.

6.2 FORMULATION OF RAINFALL CONDITIONS

Substantial rainfall in the region could conceivably result in local dilutions of the life-stage population densities as well as increasing the net freshwater flow rates in the river. Hence the general formulation incorporates a term for surface flow rate per unit area, representing rainfall, as time-dependent input data to the model; that is,

$$g_{s,i} = g_{s,i}(t) \text{ (specified in time).} \quad (6.3)$$

The surface-flow life-stage population density $\bar{p}_{s,i}^{(h)}$ is a dummy zero parameter for striped bass populations, since the rainfall obviously does not contain any striped bass; that is,

$$\bar{p}_{s,i}^{(h)} \equiv 0, \text{ for all } i, \text{ for all time.} \quad (6.4)$$

In the applications of the model, the effects of rainfall were neglected; hence the surface flow rate term of the model was not utilized in the simulations of the 1973 data.

6.3 FLOW AND ARTIFICIAL TRANSPORT AT THE RIVERBED

The net freshwater flow in the Hudson River increases along the estuary, from its minimum value at the upstream end at the Troy Locks to the maximum flow conditions at the downstream end at the Battery. To approximate the continuous drainage into the river from runoff, minor tributaries, and seepage through the riverbed, a term representing the flow rate per unit area at the riverbed was incorporated in the general formulation as

$$\bar{g}_{r,i} = \bar{g}_{r,i}(t) \text{ (specified in time),} \quad (6.5)$$

as time-dependent input data to the simulation model.

For substantial riverbed flow rates $\bar{g}_{r,i}$, the inclusion of this term becomes important, since the drainage results in the dilution of the life-stage population densities in the river. Furthermore, this term can also be employed as an artifice to represent contributions from small tributaries which may be nursery areas for the striped bass. Thus, the riverbed flow life-stage population densities $\bar{p}_{r,i}^{(h)}$ can be specified, together with the flow rate $\bar{g}_{r,i}$; that is,

$$\bar{p}_{r,i}^{(h)} = \bar{p}_{r,i}^{(h)}(t) \text{ (specified in time).} \quad (6.6)$$

to incorporate the life-stage population transport effects from drainage areas which are not considered in the general flow region of the estuary.

The riverbed transport flux term $\bar{g}_{r,i}^{(h)}$ is strictly intended as an artifice to model certain conditions which cannot be included in the general formulation of the longitudinal transport. Early life stages of striped bass (i.e., eggs and yolk-sac larvae) may accumulate in local deep depressions in the river, almost completely removed from the convective influence of freshwater flow and tidal dispersion. Furthermore, these life-stage populations may be out of reach by the sampling gear, and hence they may not be included in the data obtained by the sampling program. At a later time, these individuals could swim out of the depressions as post-yolk-sac larvae and juveniles, after the end of the spawning period, resulting in an apparent sudden increase of life-stage population densities. The riverbed transport flux term $\bar{g}_{r,i}^{(h)}$ can be formulated as a time-dependent function in terms of local life-stage populations $\bar{p}_{r,i}^{(h)}$; that is,

$$\bar{g}_{r,i}^{(h)} = \bar{g}_{r,i}^{(h)}(t, \bar{p}_{r,i}^{(h)}), \quad (6.7)$$

to approximately represent this phenomenon.

Since the 1973 data do not conclusively indicate the occurrence of this phenomenon, this particular option of the model was not utilized in the simulations of the life-stage population distributions along the estuary.

In summary, the present computer simulation model has the capabilities to approximately incorporate the effects of major tributary flows, rainfall, drainage, and possible "storage" of the early life-stage populations. These effects are probably of secondary importance in comparison to the principal controlling phenomena of growth and transport of striped bass young-of-the-year populations in the Hudson River.

7. INITIAL AND BOUNDARY CONDITIONS FOR THE MODEL

Since the general mathematical system of discrete-element equations, Eq. (2.9), represents a system of coupled, ordinary, first-order differential equations in time, the initial conditions are straightforward as specified values at any arbitrarily assigned time t for the life-stage population densities $p_i^{(k)}$ in all discrete elements; that is,

$$\bar{p}_i^{(k)}(t_0) = \bar{p}_{i,0}^{(k)} \quad (7.1)$$

which are the necessary and sufficient initial conditions for the solution of the system.

According to the formulation of the discrete-element equations of the simulation model, Eq. (2.9), there are no boundary spatial conditions, in the sense of boundary value problems for partial differential equations, since the mathematical system is based on the concept of population balance for the discrete elements. Hence the effects of the spatial boundaries are imposed on the half-point enclosure surfaces of the discrete elements located on the physical or hypothetical boundaries of the flow region of the estuary along the longitudinal x direction.

The boundary half-point conditions for the discrete-element methods are most conveniently formulated by considering imaginary external elements [19, 21] as shown in Fig. 7.1.

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Fig. 7.1. Schematic representation of the upstream and downstream boundary half-point conditions.

Since the formulation of the transport flux terms on the enclosure surfaces of the discrete elements requires the values of the life-stage population densities in the adjacent elements, the specification of the life-stage population densities in the imaginary external elements becomes necessary for the consistency of the general formulation for both internal and boundary elements.

7.1 UPSTREAM BOUNDARY HALF-POINT AND EXTERNAL ELEMENT CONDITIONS

The upstream end of the estuary at the Troy Locks has a well-defined physical half-point boundary condition in the form of a controlled dam. In the formulation of the freshwater flow conditions as input to the model, it is assumed that there is no flow through the dam. Instead, the controlled and measured flow rate at Green Island is assumed as a tributary flow rate in the first discrete element at the upstream end of the estuary.

It is realistic to assume that the life-stage population densities $p_i^{(n)}$ do not vary significantly (a) between the center of the first discrete element and the enclosure surface at the dam, and (b) between the center of the first discrete element and the center of the imaginary external element (Fig. 7.1); that is,

$$\bar{p}_i^{(n)} = \bar{p}_1^{(n)}, \quad \text{for all time.} \quad (7.2)$$

$$\bar{p}_i^{(n)} = \bar{p}_1^{(n)}, \quad \text{for all time.} \quad (7.3)$$

These two conditions are the sufficient upstream boundary half-point conditions for the mathematical system. It is interesting to note that the conditions, Eqs. (7.2) and (7.3), are equivalent to the finite difference form of the boundary condition for impermeable, insulated surfaces encountered in the solution of physical problems.

7.2 DOWNSTREAM BOUNDARY HALF-POINT CONDITIONS AT THE BATTERY

The assumed downstream end of the estuary at the Battery is open to the ocean. It does not represent a physical boundary either for physical flow conditions in the estuary or for the striped bass young-of-the-year populations in the Hudson River. Hence a simple direct boundary half-point condition cannot be assigned to the downstream end at the Battery, similar to the physical dam conditions at the Troy Locks.

It is important to note that since the net freshwater flow is always out of the estuary toward the ocean, the general formulation of the half-point values according to the "second upwind differencing" or "donor cell" method, Eq. (2.11), automatically specifies the value at the boundary half-point as the value in the internal element (see Fig. 7.1) in the formulation of the convection terms in Eq. (2.9). Hence the values for the life-stage population densities are required at the boundary half-point on the hypothetical ocean boundary and in the imaginary ocean external element strictly for the formulation of the derivative expressions, Eqs. (4.7) and (4.32), for the transport flux terms.

The most realistic condition to assume at the hypothetical, open ocean boundary is that the rate of change of life-stage population densities between the last two discrete elements is also equal to the rate of change of life-stage population densities between the downstream boundary element and the imaginary external element. This assumption leads to the mathematical boundary half-point condition as

$$p_{N+1}^{(n)} = p_N^{(n)} + \left(\frac{2\Delta x_N}{\Delta x_N + \Delta x_{N+1}} \right) [p_N^{(n)} - p_{N-1}^{(n)}]. \quad (7.4)$$

The assumed ocean end condition, Eq. (7.4), in a sense implies that the changes that occur in the estuary in the vicinity of the boundary also occur at the same rate on the ocean side vicinity of the boundary. The special realistic properties of this condition with respect to the modeling of thermal conditions in estuaries and coastal regions are discussed in refs. 19, 21, and 22, both from physical and mathematical considerations.

Although the boundary half-point condition, Eq. (7.4), is sufficient from mathematical considerations for the solution of the discrete-element system, Eq. (2.9), an additional ocean end condition is required from the biological point of view. In the formulation of the migration transport model, gradients for the life-stage population density $p^{(k)}$ and the shoal parameter R_{shk} , Eqs. (4.20) and (4.23), were employed according to the potential forms for shoal preference and crowding effects. These particular expressions could result in negative migratory transport fluxes into the estuary from the ocean at the ocean end boundary, depending on the crowding conditions. Although this phenomenon could occur, there is no conclusive evidence to substantiate it, and thus in the formulation of the model a nonlinear discontinuous boundary half-point condition was imposed on the migratory flux:

$$\text{for } [g^{(k)}]_{N+1} < 0, \quad [g^{(k)}]_{N+1} = 0, \quad (7.5)$$

to avoid the in-migration into the estuary.

The formulation of the initial conditions, Eq. (7.1), the boundary half-point and imaginary external-element conditions, Eqs. (7.2) - (7.4), and the constraint condition, Eq. (7.5), on migration flux at the ocean boundary, complete the elimination of the auxiliary unknowns in the governing discrete-element system, Eq. (2.9), for the solution of the principal unknowns, $p^{(k)}$.

8. MATHEMATICAL PROPERTIES AND NUMERICAL SOLUTION OF THE SYSTEM OF DISCRETE-ELEMENT EQUATIONS

The general discrete-element formulation, Eq. (2.9), of the simulation model represents an initial-value problem associated with a nonautonomous system of simultaneous, coupled, ordinary differential equations; that is,

$$\frac{\partial p_i^{(k)}}{\partial t}(t) = \bar{F}_i^{(k)}[t, \bar{p}_{k+1}^{(k)}, \bar{p}^{(k)}, \bar{p}^{(k-1)}] + \bar{G}_i^{(k)}(t) \quad (8.1)$$

$$\bar{p}_i^{(k)}(t_0) = \bar{p}_{i0}^{(k)}, \text{ for all } k \text{ and } i. \quad (8.2)$$

The nonautonomous function $\bar{G}_i^{(k)}(t)$ consists of the temperature-dependent time rate of deposition of egg population density in the discrete element $p_{EG,i}$, Eq. (3.6), by the dummy adult spawning population $p_i^{(k)}$ and the contributions by the tributary flows into the river (see Chap. 6).

According to the formulations of (a) the discrete-element equations, Eq. (2.9), (b) the internal discrete-element half-point values, Eq. (2.11), (c) net local time rate of variation of population density $p_i^{(k)}$, Eqs. (3.9) and (3.10), (d) the transport flux terms $g_i^{(k)}$, Eq. (4.5), (e) the plant intake and discharge conditions, Eqs. (5.1) and (5.5), (f) the tributary flow conditions, Eqs. (6.1) and (6.2), (g) the surface and riverbed conditions, Eqs. (6.5), (6.6), and (6.7), (h) the boundary half-point conditions, Eqs. (7.2), (7.3), (7.4), and (7.5), and (i) the physical conditions in the river being finite for all time, the right-hand-side functions $\bar{F}_i^{(k)}$ and $\bar{G}_i^{(k)}$ of the initial value problem, Eq. (8.1), satisfy the Dirichlet conditions; that is, they are sectionally continuous with a finite number of finite discontinuities in a finite time range. Hence a unique set of continuous solutions $p_i^{(k)}$, as extensions of the initial conditions $p_{i0}^{(k)}$, exists for the initial-value problem, Eqs. (8.1) and (8.2), for $t > t_0$.

A necessary stability criterion for the numerical integration of the system, Eqs. (8.1) and (8.2), by explicit methods is given in refs. 20-23. This criterion, based on discrete perturbation analysis for temperature solutions of a similar system, can be simplified for the present model as

$$\Delta t < \frac{1}{4} \left[\frac{(\Delta x)_{\min}}{(\bar{G}_{i+1/2} - \bar{A}_{i+1/2})_{\max}} \right] \left[\frac{1}{(\bar{A}_i - \bar{A}_{i+1/2})_{\max}} \right] \quad (8.3)$$

This requirement is based on a stability analysis which considers one-step, two-time-level integration by approximating the time derivative directly in its difference form. Hence the stability criterion, Eq. (8.3), is used in the integration of the discrete-element equation, Eq. (2.9), by the simple Euler-Cauchy method. This procedure is equivalent to the solution of the system by an explicit, forward-time-step finite-difference method. For the numerical integration of the discrete-element equation, Eq. (2.9), by more accurate methods (eg., fourth-order Runge-Kutta-Gill), the criterion for the time-step size Δt , Eq. (8.3), can be considered as on the conservative side.

In the applications of the model to the simulations of the 1973 data, the time-step size was specified as

$$\Delta t = 4.0 \text{ hr}, \quad (8.4)$$

which definitely satisfied the stability criterion, Eq. (8.3), for the numerical integration of the governing discrete-element equations by a fourth-order Runge-Kutta-Gill method under the existing flow condition in the river.

9. INPUT DATA FOR PHYSICAL CONDITIONS IN THE HUDSON RIVER

The general formulation of the simulation model requires extensive data about the physical conditions in the estuary which influence the biological characteristics of the striped bass young-of-the-year in the Hudson River.

9.1 GEOMETRIC PROPERTIES OF THE ESTUARY

The cross-sectional profiles of the river were determined from the navigation maps for the Hudson River [51] by considering transects at the upstream and downstream ends of the specified discrete elements which span the 152-mile length of the estuary between the Troy Locks and the Battery. The pertinent, average geometric properties of the 76 discrete elements of 2-mile length which are employed in the model (area, volume, depth, surface width, etc.; Table 9.1) were calculated from the cross-sectional profiles of the specified transects at the upstream and downstream ends of each discrete element.

According to the formulation of the migratory transport flux $[g_{MIG}]_{i-1,2}$, Eq. (4.32), which employs the potential of shoal parameter for the juvenile life stages, it is necessary to define a shoal parameter $(R_{SH})_i$ which represents the actual shoal areas in the estuary. Based on trials with different combinations of the geometric properties in Table 9.1, a quantitative dimensionless shoal parameter R_{SH} for representing the extent of shoaling areas along the estuary was defined as the ratio of the surface width B_i to the depth D_i of the discrete element as

$$(\bar{R}_{SH})_i = \bar{B}_i / \bar{D}_i \quad (9.1)$$

The longitudinal variation of the assumed shoaling parameter $(R_{SH})_i$ along the estuary is shown in Fig. 9.1. The values of the shoaling parameter $(R_{SH})_i$ (Table 9.1 and Fig. 9.1) suggest that the parameter is an

Fig. 9.1. Longitudinal distribution of the shoal parameter for the discrete elements along the Hudson River.

Table 9.1. Average geometric properties of the discrete elements employed in the model

Element i	Location x (ft)	Element length Δx (ft)	Depth $\bar{D}$ (ft)	Area $\bar{A}$ (ft ²)	Volume $\Delta x \bar{A}$ (ft ³)	Surface width $\bar{B}_s$ (ft)	Shoal parameters ($\bar{R}_{sh}$) (dimensionless)
1	0.52000E 04	0.105600E 05	0.162000E 02	0.722249E 04	0.762693E 08	0.525000E 03	0.374074E 02
2	0.150400E 05	0.105600E 05	0.163875E 02	0.996374E 04	0.105217E 09	0.750000E 03	0.457666E 02
3	0.264000E 05	0.105600E 05	0.165375E 02	0.120930E 05	0.127710E 09	0.937500E 03	0.566894E 02
4	0.369600E 05	0.105600E 05	0.255500E 02	0.147863E 05	0.156143E 09	0.975000E 03	0.381605E 02
5	0.475200E 05	0.105600E 05	0.344600E 02	0.160189E 05	0.169160E 09	0.922500E 03	0.267702E 02
6	0.580800E 05	0.105600E 05	0.343850E 02	0.139049E 05	0.146836E 09	0.716250E 03	0.208903E 02
7	0.686400E 05	0.105600E 05	0.343000E 02	0.151453E 05	0.159935E 09	0.843750E 03	0.245991E 02
8	0.792000E 05	0.105600E 05	0.342250E 02	0.197924E 05	0.209008E 09	0.101400E 04	0.296279E 02
9	0.897600E 05	0.105600E 05	0.342500E 02	0.250030E 05	0.264040E 09	0.114150E 04	0.333285E 02
10	0.100320E 06	0.105600E 05	0.343400E 02	0.223418E 05	0.235929E 09	0.114000E 04	0.331974E 02
11	0.110880E 06	0.105600E 05	0.343900E 02	0.191573E 05	0.202301E 09	0.900000E 03	0.261704E 02
12	0.121440E 06	0.105600E 05	0.343500E 02	0.232200E 05	0.245203E 09	0.150000E 04	0.436681E 02
13	0.132000E 06	0.105600E 05	0.342500E 02	0.300675E 05	0.317513E 09	0.187500E 04	0.547445E 02
14	0.142560E 06	0.105600E 05	0.341500E 02	0.291248E 05	0.307557E 09	0.174750E 04	0.511713E 02
15	0.153120E 06	0.105600E 05	0.340250E 02	0.276548E 05	0.292034E 09	0.227250E 04	0.667891E 02
16	0.163680E 06	0.105600E 05	0.340150E 02	0.362744E 05	0.383058E 09	0.375000E 04	0.110246E 03
17	0.174240E 06	0.105600E 05	0.339900E 02	0.335444E 05	0.354229E 09	0.382500E 04	0.112533E 03
18	0.184800E 06	0.105600E 05	0.338600E 02	0.335430E 05	0.354214E 09	0.307500E 04	0.908152E 02
19	0.195360E 06	0.105600E 05	0.337850E 02	0.400980E 05	0.423435E 09	0.262500E 04	0.776972E 02
20	0.205920E 06	0.105600E 05	0.337250E 02	0.337875E 05	0.356796E 09	0.187500E 04	0.555967E 02
21	0.216480E 06	0.105600E 05	0.337000E 02	0.369900E 05	0.390614E 09	0.270000E 04	0.801187E 02
22	0.227040E 06	0.105600E 05	0.337000E 02	0.424956E 05	0.459953E 09	0.510000E 04	0.151339E 03
23	0.237600E 06	0.105600E 05	0.447000E 02	0.707212E 05	0.746815E 09	0.555000E 04	0.124161E 03
24	0.248160E 06	0.105600E 05	0.472000E 02	0.689080E 05	0.727668E 09	0.412500E 04	0.873941E 02
25	0.258720E 06	0.105600E 05	0.471700E 02	0.758155E 05	0.800612E 09	0.427500E 04	0.102518E 03
26	0.269280E 06	0.105600E 05	0.462000E 02	0.787893E 05	0.832014E 09	0.487500E 04	0.105519E 03
27	0.279840E 06	0.105600E 05	0.412000E 02	0.710849E 05	0.750657E 09	0.502500E 04	0.121966E 03
28	0.290400E 06	0.105600E 05	0.462000E 02	0.751462E 05	0.793544E 09	0.427500E 04	0.925325E 02
29	0.300960E 06	0.105600E 05	0.502000E 02	0.976009E 05	0.103067E 10	0.382500E 04	0.761952E 02
30	0.311520E 06	0.105600E 05	0.382000E 02	0.124522E 06	0.131495E 10	0.577500E 04	0.191178E 03
31	0.322080E 06	0.105600E 05	0.437000E 02	0.132664E 06	0.140093E 10	0.582500E 04	0.128719E 03
32	0.332640E 06	0.105600E 05	0.539500E 02	0.115547E 06	0.122018E 10	0.465000E 04	0.861909E 02
33	0.343200E 06	0.105600E 05	0.684375E 02	0.999619E 05	0.105568E 10	0.405000E 04	0.591781E 02
34	0.353760E 06	0.105600E 05	0.721675E 02	0.971676E 05	0.103146E 10	0.345000E 04	0.478055E 02
35	0.364320E 06	0.105600E 05	0.576550E 02	0.105333E 06	0.111231E 10	0.375000E 04	0.650421E 02
36	0.374880E 06	0.105600E 05	0.776400E 02	0.104644E 06	0.110504E 10	0.258750E 04	0.399269E 02

adequate representation of the existence of shoaling areas in the discrete elements. For example, the values of (R_{sh}) , are highest for the Newburgh-Beacon and the Tappan Zee-Haverstraw regions, where the actual shoal areas are extensive and where the juvenile striped bass populations are known to concentrate. It is not expected that this simple index of shoal area would be appropriate for rivers and estuaries in general, but it is judged to be adequate for the Hudson River, which has a single main channel and no major tributaries entering below the Troy Dam.

9.2 FLOW CONDITIONS IN THE ESTUARY

According to the tidal- and daily-averaged, one-dimensional formulation of the model, the net freshwater flow in the river constitutes the convective phenomenon which gradually moves the striped bass young-of-the-year populations from their upstream spawning locations downstream toward the Battery, and the diurnal tidal flow generates the fundamental longitudinal mixing phenomenon (tidal dispersion) along the estuary. Hence the net freshwater flow and the tidal conditions are required as input data to the model.

9.2.1 Formulation of the Net Daily Freshwater Flow Rate Along the Estuary

The net freshwater flow rates at the Troy Locks were obtained from the 1973 daily recorded flow rates at Green Island [52]. The actual data indicated appreciable daily variations (e.g., increase on a certain day followed by a decrease on the next day) in the recorded flow rates, which in a sense represented high-frequency noise in the available data. To eliminate the high-frequency daily variations and to emphasize the more important, gradual seasonal change in the freshwater flow rate, the recorded raw data were averaged over five days. Then, the reduced data for the average daily freshwater flow rate at Green Island were obtained by interpolation from the five-day-averaged flow data as shown in Fig. 9.2.

In the applications of the model to the 1973 data, the daily freshwater flow rate at Green Island (five-day-averaged form, Fig. 9.2) was used as the input data for the tributary flow G_1 in the upstream discrete element ($i = 1$) at the Troy Locks.

To simulate the additions to the freshwater flow rate along the estuary due to the tributaries and drainage, the net freshwater flow rate at Green Island was multiplied by a linearly varying function to determine the local net flow rates in the discrete elements along the estuary as

$$\bar{G}_{i+1} = \bar{G}_1(1 + 0.25x_{i+1}/L_{ES}), \quad (9.2)$$

where

G_1 = five-day-averaged freshwater flow at Green Island (Fig. 9.2).

L_{ES} = total length of the estuary from the Troy Locks to the Battery (i.e., 152 miles).

The factor 1.25 at the Battery corresponds to the approximate, yearly averaged ratio of the lower Hudson net freshwater flow rate to the flow rate at Green Island.

Fig. 9.2. Five-day-averaged daily freshwater flow rate at Green Island for 1973. Source: Data supplied by U.S. Department of the Interior, Geological Survey, Albany, N.Y., July 1974.

9.2.2 Maximum Cross-Section-Averaged Tidal Velocity

The diurnal tidal flow results in different velocity conditions at different locations along the estuary, depending on the cross-sectional areas and the net freshwater flow in the river.

The tidal dispersion coefficient $(\bar{E}_{TD})_{i,j}$ employed in the model, Eq. (4.9), is based on the amplitude of the tidal velocity $V_{i,j}$ at the cross section; hence the input data for tidal conditions can be determined either from the available tidal flow rates or from hydrodynamic computer simulation models [23, 53]. Considering that for the Hudson River the variations in net freshwater flow do not appreciably affect the tidal conditions, the maximum velocities $\bar{V}_{i,j}$ in the discrete elements were determined from a computer simulation model [23] as shown in Fig. 9.3 with a net freshwater flow rate of 6000 cfs at the Troy Locks. These maximum velocities $\bar{V}_{i,j}$ were assumed to remain approximately the same during the period of the 1973 simulations.

Fig. 9.3. Variation of the maximum tidal velocity along the Hudson River.

9.3 TEMPERATURE CONDITIONS IN THE ESTUARY

The model requires realistic input data for the temperature distribution in the river, since according to the general formulation, temperature can affect all the biological characteristics of the striped bass young-of-the-year populations. It is very difficult to obtain reliable data for daily averaged longitudinal temperature which can be directly incorporated as input in the model. Hence, three different sources were used to obtain approximate daily temperature distributions in the river.

9.3.1 Daily Mean Water Temperature in the Estuary

A representative value for the longitudinally averaged water temperature in the river from Troy to the Battery from April 1973 through March 1974 was approximated based on the five-day-averaged data recorded at Verplanck [54] over this same period of time. The daily variation of this longitudinally averaged water temperature T_{5d} is shown in Fig. 9.4.

Since the temperature data at Verplanck [54] cannot be assumed to remain uniform along the entire length of the estuary, the daily mean water temperature in the estuary T_{5d} was modified by considering the actual observed distributions in the river.

Fig. 9.4. Seasonal variations in averaged daily mean water temperature at Verplanck and in salinity at the Battery. Source: Data supplied by New York State Department of Environmental Conservation, Albany, N.Y., August 1974.

9.3.2 Longitudinal Variation of Water Temperature in the Estuary

The available data [46] indicate that longitudinal variations of temperature exist throughout the year with a consistent pattern of decreasing temperature with distance upstream from the Battery, as shown in Fig. 9.5.

Although it is possible to include daily temperature conditions in every discrete element as detailed data, considering the limits of accuracy of the model and the reliability of the limited available data, a simpler, approximate form for the daily, longitudinal distributions was assumed to generate the temperature conditions in the discrete elements. For 1973 simulations, linear variations with a 4°F difference between the Battery and the Troy Locks were employed to approximate the longitudinal variations as

$$T_{SAL} = T_{EST} - 2(1 - 2X/L_{EST}), \text{ in } ^\circ\text{F}. \quad (9.3)$$

based on the daily mean water temperature T_{EST} data at Verplanck (Fig. 9.4) assumed to approximately correspond to the temperature at the half-length of the river.

It must be emphasized that Eq. (9.3) is strictly an empirical formula which is based on very limited data (Fig. 9.5). It is intended only for use in incorporating the effects of temperature on the biological

Fig. 9.5. Longitudinal variations of cross-section-averaged temperature in the Hudson River for different months in 1973.
Source: Data supplied by New York State Department of Environmental Conservation, Albany, N.Y., August 1974

characteristics of the striped bass life stages. Hence, it should not be construed as representing the detailed daily variations of the actual temperature distributions along the Hudson River.

9.3.3 Temperature Rise in the Vicinity of Plant Discharges

Thermal discharges also increase the temperature in the river, depending on the operational conditions of the power plants and the flow and surface cooling conditions in the river. Accurate assessment of the thermal impact requires careful considerations, since it constitutes an important part of the overall environmental impact of a power plant.

In the formulation of the computer simulation model for the striped bass young-of-the-year populations, the longitudinal temperature distributions are required as input data which can include the results of a detailed thermal analysis. However, since the assessment of the thermal impact is not the concern of the present study, the incremental temperature effects of thermal discharges are approximated based on a simple modified solution of the tidal-averaged energy equation with freshwater and longitudinal transport due to tidal dispersion. Hence the temperature change in the river due to the discharge of a power plant with $\Delta T_{PI,m}$ condenser temperature rise, located at $x_{DTS,m}$ along the river, is approximated in the discrete elements as follows:

for $x_i < x_{DTS,m}$,

$$\Delta T_{i,m} = \Delta T_{PI,m} R_{DTS,m} [(G_{DTS})_m - G_i] \cdot \exp \left\{ \left[\sqrt{1 + (4h_{t,i}^* E_{TD,i} A_i^*) (\rho C_p D_i G_i^*)} + 1 \right] (x_i - x_{DTS,m}) \right\} ; \quad (9.4)$$

for $x_i > x_{DTS,m}$,

$$\Delta T_{i,m} = \Delta T_{PI,m} R_{DTS,m} [(G_{DTS})_m - G_i] \cdot \exp \left\{ - \left[\sqrt{1 + (4h_{t,i}^* E_{TD,i} A_i^*) (\rho C_p D_i G_i^*)} - 1 \right] (x_i - x_{DTS,m}) \right\} ; \quad (9.5)$$

where

$R_{DTS,m}$ = a factor for the near-field dilution effects (assumed as 0.5 for the simulations) for power plant "m".

$h_{t,i}^*$ = surface heat transfer coefficient based on equilibrium temperature concept, assumed as approximately 8.0 Btu/hr ft². (9.6)

ρ = water density (assumed as constant at 62.4 lb/ft³).

C_p = specific heat of water (assumed as constant at 1.0 Btu/lb °F).

$x_{DTS,m}$ = location of the discharge of plant "m".

Since Eqs. (9.4) and (9.5) represent the approximate solution of a linear partial differential equation in fixed coordinates, with identical boundary conditions, the temperature rises $\Delta T_{i,m}$ in the discrete elements due to the individual plants can be summed to obtain the temperature rise in each discrete element due to the simultaneous operation of all plants; that is,

$$\Delta T_{PI,i} = \sum_{m=1}^{M_{PI}} \Delta T_{i,m} \quad (9.7)$$

This approach represents a very approximate formulation of the far-field thermal impact of all M_{PL} number of power plants on the river.

Hence, considering the natural temperature distribution $\bar{T}_{NAT}$, Eq. (9.3), and the temperature rise due to plant operations $\Delta\bar{T}_{PL}$, Eqs. (9.4) and (9.5), the approximate temperatures in the discrete elements $\bar{T}_i$ can be formally expressed as

$$\bar{T}_i = \bar{T}_{NAT} + \Delta\bar{T}_{PL} \quad (9.8)$$

to complete the input temperature data to the computer simulation model.

In summary, the necessary input data to the striped bass young-of-the-year model for the temperature conditions in the discrete elements are determined by considering the approximate daily mean temperature in the river $\bar{T}_{EST}$, longitudinal variations due to natural conditions $\bar{T}_{NAT}$, and the temperature rise $\Delta\bar{T}_{PL}$ resulting from power plant operations.

It should again be emphasized that the assumed temperature distribution in the estuary is intended strictly for approximating temperature conditions in the discrete elements in order to determine the biological characteristics of the striped bass life-stage populations in the simulations of the 1973 data. It is not intended to be representative of the near-field thermal impact of power plant operations in the Hudson River.

9.4 SALINITY CONDITIONS IN THE ESTUARY

Since the general formulation of the model considers the dependence of the biological characteristics of the striped bass life stages on the salinity conditions in the estuary, an approximate method based on salt intrusion length was employed to generate the approximate input data for the salinity conditions in the discrete elements.

9.4.1 Empirical Formulation of Salt Intrusion Length

The available salinity distribution data [55] indicate that the extent of the salt intrusion upstream from the Battery can be represented by the salt intrusion length, which is defined as the distance from the Battery where the salinity drops to 0.1 ppt. The data also indicate that the salt intrusion length can be correlated with the net freshwater flow rate in the river as shown in Fig. 9.6.

The observed variation of the dimensionless length ratio f_{INT} of the salt intrusion length from the Battery x_{INT} to the length of the estuary L_{EST} can be expressed by an empirical formula with two parameters as

$$f_{INT} = x_{INT} / L_{EST} = 1 - x / L_{EST} = A[1000 / \bar{G}_{NET}]^b \quad (9.9)$$

where the parameters A and b are defined separately for two flow ranges for the net freshwater flow rate $\bar{G}_{NET}$ (cfs) as below and above 25,000 cfs; that is,

$$\text{for } \bar{G}_{NET} \geq 25,000 \text{ cfs, } A = 6.58, \quad b = 1; \quad (9.10)$$

$$\text{for } \bar{G}_{NET} < 25,000 \text{ cfs, } A = 0.855, \quad b = 0.366. \quad (9.11)$$

The simple empirical formula, Eqs. (9.9) - (9.11), agrees very well with the observed salt intrusion length data for all flow ranges, as shown in Fig. 9.6.

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Fig. 9.6. Salt intrusion length variation with net freshwater flow in the Hudson River. Source: Data supplied by U.S. Department of the Interior, Geological Survey, Albany, N.Y., July 1974.

9.4.2 Longitudinal Distribution of Salinity

The longitudinal distribution of tidal-averaged, cross-section-averaged salinity in the river is approximated by utilizing a modified form of the solution of tidal-averaged, one-dimensional constituent conservation equation based on the salinity S_{OCS} at the Battery (see Fig. 9.4), salt front value $S_{EST} = 0.1$ ppt, and the dimensionless salt intrusion length ξ_{EST} as

$$\bar{S}_1 = S_{OCS} - (S_{OCS} - S_{EST}) \frac{(1 - e^{-\beta \xi})}{(1 - e^{-\beta \xi_{EST}})} \quad (9.12)$$

where

$$\xi = (L_{EST} - x) / L_{EST} = 1 - x / L_{EST} \quad (9.13)$$

$$\beta = G_{NET} L_{EST} / E \bar{A}_{EST} = G_{NET} (L_{EST} / E \bar{A}_{EST}) = G_{NET} \beta^* \quad (9.14)$$

The parameter β^* was determined empirically by trial and error in simulations of the observed salinity distributions at different flow rates, as shown in Fig. 9.7.

Fig. 9.7. Comparison of the observed salinity data with the results from the approximate empirical formula employed in the model.

Hence the daily averaged salinities in the discrete elements S_i required as input data to the model were approximated according to the simple formulas Eqs. (9.12) - (9.14), by utilizing the daily net freshwater flow rates at Green Island (see Fig. 9.2).

In summary, the required input data about the physical conditions in the estuary were generated according to approximate formulations. Since the general formulation is completely independent of the input data, more accurate representations of the physical conditions in the river can be readily incorporated in the model. However, considering the possible inaccuracies involved in the biological data, further refinement of the input for the physical conditions is not warranted for the simulation of the 1973 striped bass young-of-the-year populations in the Hudson River.

10. SIMULATION OF THE STRIPED BASS YOUNG-OF-THE-YEAR POPULATION IN THE HUDSON RIVER DURING 1973

The general model was applied to simulate the striped bass young-of-the-year population in the Hudson River during 1973. The period simulated began on April 29, which approximately corresponded to the beginning of the spawning period, and continued for 24 weeks through October 13. The associated computer code STRIPE (see Appendix) of the model was employed with a time-step size of 4 hr. Results were output at 24-hr intervals as daily averaged population density distributions of each of the six life stages.

To determine the values for the important parameters of the model and to compare the simulations with the conditions in the river, QLM's reduction [24] of the 1973 data was used. The detailed results of the computer code STRIPE were appropriately averaged over time (seven days) and space (five discrete elements) to be consistent with the format of the available reduced population data, which were presented as weekly averaged longitudinal distributions of life-stage populations in 10-mile segments along the river. Furthermore, the three juvenile life stages in the model (Juvenile I, Juvenile II, and Juvenile III) were combined into a single juvenile life stage to be consistent with the 1973 data for the juvenile populations. The necessary averaging procedures were incorporated in the general computer program STRIPE (see Appendix).

The parameter values used in the simulations for the modeling of the biological characteristics of the life stages and for the transport fluxes are given in previous sections. Entrainment and impingement losses for the power plants which were actually operating during May through October 1973 (shown in Table 5.2) were included in the simulations of the 1973 conditions. The model was employed both without compensation (with constant effective values for apparent survival probabilities) and with compensation. To evaluate the influence of different rates of entrainment and impingement at the power plants, the model was applied with two plausible sets of values for the intake population density distribution factors f_{in}^i for the life stages. Neither the results of the employment of the model with and without compensation nor the evaluation of the influence of different entrainment and impingement effects is included in this report; sample results are presented and discussed in refs. 25-28.

The results of the computer simulations were compared with the 1973 data in graphs of weekly averaged and 10-mile segment-averaged longitudinal distributions and in graphs of weekly averaged and longitudinally totaled temporal distributions of the standing crops of the life stages.

10.1 LONGITUDINAL DISTRIBUTIONS OF WEEKLY AVERAGED AND 10-MILE SEGMENT-AVERAGED STANDING CROPS OF THE STRIPED BASS LIFE-STAGE POPULATIONS

The results for weekly averaged and 10-mile segment-averaged longitudinal distributions of striped bass young-of-the-year life-stage populations are presented here for simulations with compensation (as discussed in Sects. 3.4 and 3.6) and with values for the intake population density distribution factors f_{in}^i (as presented in Table 5.1).

Starting with the week May 6-12 and continuing for 11 weeks (through the week July 15-21), the striped bass young-of-the-year exist as multiple life-stage populations in the Hudson River, as shown in Figs. 10.1-10.11. Reasonable agreement, both from qualitative and quantitative considerations, between the computer simulations and the observed data was achieved for different life stages during different weeks. Acceptable comparisons are shown for eggs during the weeks May 6-12 (Fig. 10.1).

Fig. 10.1. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week May 6-12. Source: Field data taken from ref. 24

May 27-June 2 (Fig. 10.4), and June 10-16 (Fig. 10.6); for yolk-sac larvae during the weeks May 13-19 (Fig. 10.2) and May 20-26 (Fig. 10.3); and for post-yolk-sac larvae during the weeks June 17-23 (Fig. 10.7), July 1-7 (Fig. 10.9), and July 8-14 (Fig. 10.10).

Considering the problems involved in the sampling program and the simplifying approximations involved in both the reduction of the population data and the development of the simulation model, it is unrealistic to expect consistently acceptable agreement between the simulations and the data for all life-stage populations throughout the period of the simulations. Poor comparisons are shown for eggs during the week May 20-26 (Fig. 10.3); for yolk-sac larvae during the weeks May 27-June 2 (Fig. 10.4) and June 10-16 (Fig. 10.6); and for post-yolk-sac larvae during the weeks May 27-June 2 (Fig. 10.4), June 10-16 (Fig. 10.6), and June 24-30 (Fig. 10.8). The particular discrepancies in Fig. 10.6, for both yolk-sac larvae and post-yolk-sac larvae, indicate more of a confrontation than a comparison between the computer simulations and the observed data. The existence of approximately an order of magnitude difference at certain locations in the river and at certain times rules out the possibility of minor problems in the modeling which could be corrected by proper modification of the parameter values according to the observed longitudinal distributions of the life-stage populations. Indeed, these large discrepancies strongly suggest either major deficiencies in modeling which may be attributed to the neglect of one or more controlling biological or physical phenomena in the formulation, or to major problems in the sampling and reduction of the 1973 data [25-28].

Fig. 10.2. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week May 13-19. Source: Field data taken from ref. 24.

Fig. 10.3. Comparison of the computer simulation and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week May 20-26. Source: Field data taken from ref. 24.

Fig. 10.4. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week May 27-June 2. Source: Field data taken from ref. 24.

Fig. 10.5. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week June 3-9. Source: Field data taken from ref. 24

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Fig. 10.6. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions for the life-stage populations in the Hudson River during the week June 10-16. Source: Field data taken from ref. 24.

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Fig. 10.7. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week June 17-23. Source: Field data taken from ref. 24.

A major problem in both sampling and modeling of the striped bass young-of-the-year population in the Hudson River is the inability to account for the populations of the early life stages (i.e., eggs and yolk-sac larvae) which may accumulate in the local depressions in the river. These areas of high population density may be out of reach of the sampling gear during certain periods; hence, they may not be represented in the data obtained during certain weeks. Conversely, during certain weeks the sampling program may include these local depressions with high population densities for the early life stages, and thus the results of the sampling may indicate relatively high populations for these life stages in these river segments. Although the general formulation of the model has the capability to approximately include this effect, in the simulations of the 1973 data this feature of the model was not implemented, and the results were obtained without considering the possible storage effects of the deep local depressions for the early life stages. The severe discrepancies between the simulations and the observed data for yolk-sac and post-yolk-sac larvae (see Fig. 10.6) strongly suggest that the accumulation of the early life-stage populations in the local depressions is important from the point of view of both sampling and modeling. An alternative or additional explanation for the severe discrepancies is horizontal patchiness in the distribution of yolk-sac and post-yolk-sac larvae (see Chap. 5, refs. 25-28).

The computer simulations predict the existence of substantive populations of both post-yolk-sac larvae and juveniles in the estuary earlier than the 1973 data indicate (see Figs. 10.3-10.5). This discrepancy suggests that the parameter values assigned to the growth rate coefficients for the yolk-sac larvae and post-yolk-sac larvae (see Table 3.5) were too high. It must be noted that the optimum growth

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Fig. 10.8. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week June 24-30. Source: Field data taken from ref. 24

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Fig. 10.9. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week July 1-7. Source: Field data taken from ref. 24

Fig. 10.10. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week July 8-14. Source: Field data taken from ref. 24

Fig. 10.11. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of the life-stage populations in the Hudson River during the week July 15-21. Source: Field data taken from ref. 24

rate coefficients were calculated as the inverse of the durations of the life stages (see Table 3.1) as estimated from hatchery and laboratory data [42-44], rather than from direct empirical determinations by simulation. Alternatively, this discrepancy could also be due to sampling problems in catching post-yolk-sac larvae and juvenile populations.

After July 22, the striped bass young-of-the-year population in the Hudson River exists as a single juvenile life stage, and the earlier life stages are no longer present. The computer simulations and the 1973 data for the weekly averaged and 10-mile segment-averaged longitudinal distributions of the juvenile life-stage populations are shown in Figs. 10.12-10.15 for the 12 weeks from July 22 through October 13. The computer simulations for the juvenile life stages agree well with the observed data, except for two consecutive weeks, September 9-15 and September 16-22 (Fig. 10.14).

The predicted results accurately indicate the locations of high concentrations of juveniles when compared with the 1973 data (Figs. 10.12, 10.13, and 10.15). Furthermore, the simulated and observed

Fig. 10.12. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of juvenile life-stage populations in the Hudson River for the three weeks July 22 through August 11. Source: Field data taken from ref. 24.

Fig. 10.13. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of juvenile life-stage populations in the Hudson River for the three weeks August 12 through September 1. Source: Field data taken from ref. 24.

Fig. 10.14. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of juvenile life-stage populations in the Hudson River for the three weeks September 2-22. Source: Field data taken from ref. 24.

Fig. 10.15. Comparison of the computer simulations and the 1973 data for weekly and 10-mile segment-averaged longitudinal distributions of juvenile life-stage populations in the Hudson River for the three weeks September 23 through October 13. Source: Field data taken from ref. 24

standing crops are of approximately the same magnitude, except for the two weeks mentioned above (Fig. 10.14). It should be emphasized that the discrepancies between the simulations and the data for these two weeks are more likely due to problems with the 1973 sampling program and subsequent data reduction than to deficiencies in the model. This point will be considered further in the next section in relation to the temporal distribution of the juvenile standing crop. It is interesting that the best agreement between the simulations and the data can be achieved for the juveniles—the life stage which has the greatest mobility and ability to resist the physical flow conditions which control the longitudinal distributions of the earlier life stages. This result indicates the appropriateness of the migratory transport formulation based on the gradients of the shoaling parameter and the population densities (Sect. 4.3.2).

10.2 TEMPORAL DISTRIBUTIONS OF WEEKLY AVERAGED AND LONGITUDINALLY TOTALED STANDING CROPS OF THE STRIPED BASS LIFE-STAGE POPULATIONS

Weekly averaged standing crops of the life stages for the entire river were obtained by summing the weekly averaged populations of the life stages in the fifteen 10-mile segments of the river. Comparisons of the computer-simulated and observed temporal distributions are presented in Fig. 10.16 for each of the striped bass young-of-the-year life stages and in Fig. 10.17 for all life stages combined. The general agreement between the simulations and the 1973 data is acceptable, except for several of the sharp peaks appearing in the 1973 data but not in the simulations. These discrepancies in the temporal distributions are also evident in the longitudinal distributions, as discussed in the previous section. Considering that egg disposition had already stopped before the occurrence of the earliest peak in the data, it is biologically impossible for the total standing crop to increase in the estuary. Hence the various peaks that appear in the temporal distributions for post-yolk-sac larvae and juveniles appear to be due to sampling variability and/or the method of reducing the data. Apart from these "spike discrepancies," the simulations of the observed temporal distributions are acceptable, particularly for the later life stages (post-yolk-sac larvae and juveniles) (Fig. 10.16).

In summary, the comparisons of the computer simulations and the 1973 data indicate reasonable agreement both for the longitudinal distributions and the temporal distributions. The simulations of the juvenile standing crop, in particular (except for two weeks), show good agreement with the 1973 data. The comparisons also indicate that the discrepancies between the simulations and the 1973 data may be due more to problems in sampling and data reduction than to approximations and assumptions involved in the formulation of the model.

ORNL DNG 75-16138

Fig. 10.16. Comparison of simulated and observed 1973 weekly standing crop values for each of the young-of-the-year life stages (Juvenile I, II, and III combined).

ORNL DWS 75-1439R1

Fig. 10.17. Comparison of simulated and observed 1973 weekly standing crop values for all young-of-the-year.

11. CONCLUSIONS AND RECOMMENDATIONS

The development of the daily transient (tidal-averaged), longitudinally one-dimensional (cross-section-averaged) computer simulation model for the striped bass young-of-the-year in the Hudson River illustrated that the mathematical foundations of the transport theories associated with the physical phenomena can be readily expanded to incorporate the important physiological and behavioral characteristics of the life stages of a biological population.

The longitudinal convective transport of the striped bass life-stage populations was formulated based on the net freshwater flow in the estuary (consistent with the tidal-averaged assumption of the general model). Simulation of the observed 1973 longitudinal distributions of the life-stage populations indicated that the downstream transport of the early life stages (eggs, yolk-sac larvae, and post-yolk-sac larvae) was significantly slower than the net freshwater flow in the Hudson River. It was evident that even these early life stages do not behave as uniformly distributed passive organisms. Rather, they must exhibit significant vertical and/or lateral variations in their distributions with relatively higher concentrations occurring near the bottom and/or near the shores, where the downstream flow conditions are relatively lower than in the main channel of the river.

This result is important in assessing the impact of power plant operations on the young-of-the-year populations. Since these early life stages are transported downstream slower than the net freshwater flow, as they pass a given power plant they are susceptible to entrainment at the intakes for longer durations than one would expect for passive organisms moving with the net freshwater flow. Furthermore, nonuniform vertical and/or lateral distributions of these early life stages can influence the rate of entrainment, depending on the locations, structural details, and the flow rates at the intakes, as well as the bathymetry and the flow conditions in the river.

In the present model these three-dimensional effects were approximated by considering convective defect transport fluxes and "f" factors, which represent the ratios of the intake population densities to the cross-section-averaged population densities in the river (consistent with the one-dimensional assumption of the general computer simulation model). The convective defect transport fluxes were determined based on simulations of the 1973 longitudinal distributions, and the "f" factors were estimated based on the limited data about the life-stage population densities in the intake flows. Although the present tidal-averaged, one-dimensional model attempts to incorporate these distributional effects, it must be realized that the vertical and lateral density variations of the early life stages and the hydrodynamic conditions in the estuary can never be completely described within the general scope of a one-dimensional (cross-section-averaged) formulation. From a theoretical point of view at least, such a complete description would require a three-dimensional transport model for the striped bass young-of-the-year in the Hudson River.

Certain of the physiological and behavioral characteristics of the striped bass young-of-the-year life stages were considered in detail in the present model. The transfer of populations from earlier to later life stages was formulated in terms of apparent survival probabilities and growth and mortality rates. The possible existence of various mechanisms for biological compensation was included by considering multiplicative factors which can separately vary the apparent survival probabilities and growth and mortality rates as a function of the population densities of the life stages. Temperature and salinity dependences were also included. The information necessary to calculate time-varying, tidal-averaged, longitudinal distributions for temperature and salinity was included as input data to the model. Due to lack of data the full capabilities of the model to consider the apparent survival probabilities and growth and mortality rates as functions of population density, temperature, and salinity were not actually implemented. Further laboratory and field studies are required.

The migration of the juvenile life stages to the shoal areas along the estuary was formulated according to a novel, gradient-type model which represents the net balance between the effects of shoaling preference and overcrowding. The simulation of the longitudinal distributions of weekly averaged juvenile standing crops agreed very well with the 1973 data. Thus, the migration of the striped bass juvenile life stages can be modeled without restrictive formulations based on the observed longitudinal distributions.

The rates of reduction by entrainment and impingement at the power plants were formulated by considering (a) the ratios of the population densities of the entrainable life stages (eggs, yolk-sac larvae, post-yolk-sac larvae, and early juveniles) entering the intakes to the average densities in the river ("f" factors), (b) avoidance factors (for juveniles) based on temperature- and salinity-dependent mobility characteristics, (c) geometric factors for the intakes and the discharges, and (d) the temperature-dependent survival probabilities of the entrainable life stages upon passage through the cooling water systems of the power plants. Parameter values or a range of values were selected, based on available data at the various power plants; the data, in some instances, were rather limited.

The comparisons of the preliminary numerical solutions from the model with the 1973 data clearly indicated that the model is acceptable both from qualitative and quantitative considerations for simulating the longitudinal and temporal distributions of the life-stage population densities in the estuary. Several of the discrepancies between the simulations and the observed data suggest inadequacies and inconsistencies in the 1973 data.

In conclusion, the present computer simulation model represents a general, daily transient (tidal-averaged), longitudinally one-dimensional (cross-section-averaged) transport model for the striped bass young-of-the-year life stages in the Hudson River. It can be readily employed as a reliable tool for predicting the yearly reduction in the striped bass young-of-the-year population due to the entrainment and impingement damage at the intakes of the power plants on the Hudson River.

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APPENDIX

LISTING OF COMPUTER PROGRAM STRIPE, SAMPLE BIOLOGICAL CONDITIONS AND PLANT CONDITIONS, AND SAMPLE OUTPUT

LISTING OF COMPUTER PROGRAM STRIPS

[illegible]

```

      JH DAY=JH DAY+MMNDAY(1)
1310 CONTINUE
      JH DAY=JH DAY+MMNDAY
      IDAYTY=JH DAY-NSPDAY
      T=THRDAY
      READ(5,1003)INTIME,NHRTF,OTIME
1003 FORMAT(6A,15.2A,15.2A,F0.2)
      NT=INTIME
      NT=NHRTF
      OT=OTIME
      IT=0
      NOTDAY=0
      CALL ESTCON
      CALL OUTPUT
      IN 2000 IT=1,NT
      TS=T
      IT=IT+1
      MAYNOT=NOTDAY
      THRDAY=T-OT-24,=DAYNOT
      IF(THRDAY.LE.24,863 TO 2100
      THRDAY=THRDAY-24,
      NOTDAY=NOTDAY+1
      MMNDAY=MMNDAY+1
      IDAYTY=IDAYTY+1
      JH DAY=JH DAY+1
      IF(MMNDAY.LE.MMNDAY(MONTH)GO TO 2100
      MMNDAY=MMNDAY-MMNDAY(MONTH)
      MONTH=MONTH+1
      IF(MONTH.LE.12)GO TO 2100
      MONTH=MONTH-12
      INYFAR=INYFAR+1
      IF(LEAPYR.FJ.4) JH DAY=JH DAY-1
      JH DAY=JH DAY-365
      MMNDAY(2)=20
      IF(LEAPYR.FJ.4) MMNDAY(2)=29
2100 CONTINUE
      CALL PTCINFO
      CALL ESTCON
      CALL SOLVEFETS,DTI
      IF(ITH.(T,NT)GO TO 2000
      IT=0
      CALL OUTPUT
2000 CONTINUE
C ***** SPECIAL OUTPUT PHASE *****
      KRUN=2
      CALL OUTPUT
9999 STOP
      END

```

```

SUBROUTINE ESTCON
C ESTCON READS THE PARAMETERS OF THE DISCRETE ELEMENTS AND CALCULATES UPDATED
C FLOW RATES, TEMPERATURES, AND SALINITIES DURING THE CALCULATION PHASE
COMMON/CTRL/KRIP,NP,NINTC,NX,NC,NTC,NTW,T
COMMON/CALDAT/AMONTH(12),MMNDAY(12),LEAPYR
COMMON/DATIME/IDAYTY,JULDAY,INYEAR,IMONTH,IMNDAY,THRDAY
COMMON/GFCR5/XC(77),ACC(77),DMC(77),NSC(77),GMC(77),ASC(77)
COMMON/GFCR1M/XI(76),DXI(76),ACR(76),DMR(76),ASR(76),GMR(76),MSR(76)
COMMON/CONFAC/VLXT(176),GENFAC(76),TMPEAC(76),SINFAC(76)
COMMON/CONPER/LVGPFR(366),GENPFR(366),TMPPFR(366),SINPFR(366)
COMMON/CINFLM/GFR(76),VLT(76),TMP(76),SIN(76)
COMMON/CINCRS/GFC(77),VIC(77),TMC(77),SIC(77)
COMMON/PIYPR/NOPPR,ENGPR(11),NP(11),IEGPR(1,13),
1 GFLVTE(1,13),GFLDIS(1,13),DTMPC(1,13),
2 NFMDPR,NPLANT,DTMPT(76)

```

```

      IF (KRUN.GT.0) GOTO 2
C  READ AND CALCULATE GEOMETRY OF THE ESTUARY *****
      MNIN=0.0001
      FTAREA=1.00E+10
      READ(5,1001) NC
1001  FORMAT(104.13)
      NX=NC-1
      NXC=NC+1
      DO 1100 IC=1,NC
      READ(5,1101) XC(1C),ACC(1C),IMC(1C),NSC(1C),GMC(1C)
1101  FORMAT(6X,54.1X,E14.6)
1100  CONTINUE
      RSC(1)=NSC(1)/DMC(1)
      DO 1200 IX=1,NX
      ICIM=IX
      ICIP=IX+1
      DX(1)=XC(1CIP)-XC(1CIM)
      DX(IX)=DX(1)
      A(1)=XC(1CIM)+0.5*DX(1)
      ACR(1)=0.5*(ACC(1CIM)+ACC(1CIP))
      ACR(IX)=ACR(1)
      DM(1)=0.5*(DMC(1CIM)+DMC(1CIP))
      DM(IX)=DM(1)
      BSR(1)=0.5*(BSC(1CIM)+BSC(1CIP))
      BSR(IX)=BSR(1)
      GMR(1)=0.5*(GMC(1CIM)+GMC(1CIP))
      GMR(IX)=GMR(1)
      RSC(1CIP)=BSC(1CIP)/DM(1CIP)
      RSM(IX)=BSR(1)/DM(1)
1200  CONTINUE
C  *****
C
C  READ ESTUARY FLOW, TEMPERATURE, AND SALINITY CONDITIONS *****
C
      DO 1300 IX=1,NXC
      READ(5,1301) VLXTID(IX),GFRFAC(IX),TMPFAC(IX),SINFAC(IX)
1301  FORMAT(8X,F13.6,4X,3(4X,F5.2))
      VLXTID(IX)=3600.*VLXTID(IX)
1300  CONTINUE
      READ(5,1002) NPER
1002  FORMAT(6X,14)
      DO 1400 IPER=1,NPER
      READ(5,1401) LNGPER(IPER),GFRPER(IPER),TMPPER(IPER),SINPER(IPER)
1401  FORMAT(5X,14,30X,F13.6,5X,F6.2,5X,F11.4)
      GFRPER(IPER)=3600.*GFRPER(IPER)
1400  CONTINUE
C  *****
C  *****
      VLC(1)=0.0
      DO 1500 IX=1,NX
      IXC=IX+1
      VLT(IX)=VLXTID(IX)
1500  CONTINUE
      DO 1600 IC=2,NX
      IXCI=IC-1
      IXCP=IC
      DXCI=DX(IXCI)
      DXCP=DX(IXCP)
      DXDEN=DXCI+DXCP
      VLC(1C)=(DXCI+VLT(IXCP)+DXCP+VLT(IXCI))/DXDEN
1600  CONTINUE
      VLC(NC)=VLXTID(NC)
      NDATA=0
      GO TO 9999
2  CONTINUE
      IF (NDATA.GT.0) GO TO 2001
C  IS THERE ENOUGH DATA TO SIMULATE THE DESIRED PERIOD *****
      DO 2000 IPER=1,NPER
      NDATA=NDATA+LNGPER(IPER)
2000  CONTINUE

```

.....

	SUBROUTINE SOLVER(TS,DT)	SOLV	10
C	SOLVER NUMERICALLY INTEGRATES THE POPULATION DIFFERENTIAL EQUATIONS USING A		
C	FOURTH ORDER RUNGE-KUTTA-GILL TECHNIQUE		
	COMMON/CONTROL/KRUN,MP,NINTC,NX,NC,NRC,NT,NTN,T	SOLV	20
	COMMON/PDSOL/PDN(7,76),FACPDN(7,76),ERRPDN(7,76)	SOLV	30
	COMMON/EGGSOL/EGG(76),FNCEGG(76),ERREGG(76)	SOLV	40
	DIPEASICA CDT(4),A(4),B(4),C(4),D(4)	SOLV	50
	IF(KRUN.GT.C)GC TO 2	SOLV	60
	PDPIN=1.E-12	SOLV	70
	CDT(1)=0.0	SOLV	80
	A(1)=C.5	SOLV	90
	B(1)=2.0	SOLV	100
	C(1)=3./2.	SOLV	110
	D(1)=C.5	SOLV	120
	CDT(2)=0.5	SOLV	130
	A(2)=1.-0.5**C.5	SOLV	140
	B(2)=1.0	SOLV	150
	C(2)=3.*(1.-C.5**C.5)	SOLV	160
	D(2)=1.-0.5**0.5	SOLV	170
	CDT(3)=0.5	SOLV	180
	A(3)=1.+C.5**C.5	SOLV	190
	B(3)=1.0	SOLV	200
	C(3)=3.*(1+0.5**0.5)	SOLV	210
	D(3)=1.+0.5**C.5	SOLV	220
	CDT(4)=1.0	SOLV	230
	A(4)=1./6.	SOLV	240
	B(4)=2.0	SOLV	250
	C(4)=C.5	SOLV	260
	D(4)=C.5	SOLV	270
	DO 1CCC IX=1,NX	SOLV	280
	DO 1CCC KP=1,MP	SOLV	290
	ERRPCN(KP,IX)=C.0	SOLV	300
1100	CONTINUE	SOLV	310
	ERRREGG(IX)=C.C	SOLV	320
1000	CONTINUE	SOLV	330
	GO TO 9999	SOLV	340
2	CONTINUE	SOLV	350
	DO 2CCC IIRG=1,4	SOLV	360
	ARKG=A(IIRG)	SOLV	370
	BIRG=B(IIRG)	SOLV	380
	CRKG=C(IIRG)	SOLV	390
	DRKG=D(IIRG)	SOLV	400
	T=TS+CDT(IIRG)*DT	SOLV	410
	CALL SCLFAC	SOLV	420
	DO 210C IX=1,NX	SOLV	430
	DO 220C KP=1,MP	SOLV	440
	OK=DT*FACPDN(KP,IX)	SOLV	450
	OKPDN=OK-BIRG*ERRPDN(KP,IX)	SOLV	460
	PDN(KP,IX)=PDN(KP,IX)+ARKG*OKPDN	SOLV	470
	IF(PDA(KP,IX).LE.PCNPIN) PCN(KP,IX)=0.0	SOLV	480
	ERRPDN(KP,IX)=ERRPDN(KP,IX)+CRKG*OKPDA-DRKG*OK	SOLV	490
2200	CONTINUE	SOLV	500
	OK=DT*FNCEGG(IX)	SOLV	510
	OKEGG=OK-BIRG*ERRREGG(IX)	SOLV	520
	EGG(IX)=EGG(IX)+ARKG*OKEGG	SOLV	530
	ERRREGG(IX)=ERRREGG(IX)+CRKG*OKEGG-DRKG*OK	SOLV	540
2100	CONTINUE	SOLV	550
2000	CONTINUE	SOLV	560
9999	RETURN	SOLV	570
	END	SOLV	580

	SUBROUTINE SOLFAC	SOL F	10
C	SOLFAC FURNISHES SOLVER WITH UPDATED SPANNING AND LIFE-STAGE POPULATION RATES		
	COMMON/CONTROL/KRUN,MP,NINTC,NX,NC,NRC,NT,NTN,T	SOL F	20
	COMMON/GEOCR S/RC(77),ACR(77),DNC(77),RSC(77),GNC(77),RSC(77)	SOL F	30
	COMMON/GEOLN/R(76),DN(76),ACR(76),DNC(76),RSC(76),GNC(76),RSC(76)	SOL F	40

COMMON/CONFLN/GFCI(76),VLTI(76),TNP(76),SLNI(76)	50
COMMON/CONCRS/GFCI(77),VLC(77),TNC(77),SLCI(77)	60
COMMON/PONSL/PDM(76),FNCPDM(76),FRRPDM(76)	70
COMMON/FGGSL/FGGI(76),FNEGGI(76),FRRGGI(76)	80
COMMON/CONPT/PTFGGI(76),PTSPW(76),PTGRW(76),PTMRE(76),PTMRE(76)	90
COMMON/CONEND/PDMUP(77),PDMUP(77),PDMUP(77),PDMUP(77)	100
COMMON/CONTRP/PTATDI(77),PTATDI(77),PTATDI(77)	110
COMMON/CONSTR/GFLSUR,POGSUR(77)	120
COMMON/CONTRD/GFLBFI(76),POGAFDI(76),PTRAEDI(76)	130
COMMON/CONTRA/TRA(77),GFLTRA(77),PMTRA(77)	140
COMMON/PLTTPR/NOFFER,INGIPR(11),NPIOPR(11),IPIOPR(1,13)	150
1 GFLINT(1,13),GFLDIS(1,13),OTMPCN(1,13)	160
2 NEWTPR,NPLANT,OTMPT(76)	170
IF(KRUN.GT.0)GO TO 2	180
ON 1000 IX=1,NX	190
ON 1100 KP=1,NP	200
FNCPON(KP,IX)=C.O	210
1100 CONTINUE	220
FNEGGI(IX)=0.0	230
1000 CONTINUE	240
GO TO 9999	250
2 CONTINUE	260
CALL ENDCON	270
CALL NINCEN	280
CALL TRPRT	290
ON 2000 IX=1,NX	300
ICIM=IX	310
ICIPM=IX+1	320
OXI(1)=OXI(IX)	330
ACR(1)=ACR(IX)	340
ACRIM=ACR(1)C(IX)	350
ACRIPM=ACR(1)C(IPM)	360
ASX(1)=ASX(IX)	370
WAR(1)=WAR(IX)	380
GFRIM=GFC(1)C(IX)	390
GFRIPM=GFC(1)C(IPM)	400
ON 2100 KP=1,NP	410
PON(1)=PON(KP,IX)	420
IF(IX.GT.1)GO TO 2101	430
PONIM=PONUPX(KP)	440
PONIP=PON(KP,IX+1)	450
GO TO 2200	460
2101 IF(IX.EQ.NX)GO TO 2102	470
PONIM=PON(KP,IX-1)	480
PONIP=PON(KP,IX+1)	490
GO TO 2200	500
2102 CONTINUE	510
PONIM=PON(KP,IX-1)	520
PONIP=PON(KP,IX+1)	530
2200 CONTINUE	540
IF(GFRIM.GT.0.01G) TO 2201	550
PONTM=PON(1)	560
GO TO 2202	570
2201 PONTM=PON(1)	580
2202 CONTINUE	590
IF(GFRIPM.LT.0.01G) TO 2203	600
PONTM=PON(1)	610
GO TO 2204	620
2203 PONTM=PONIP	630
2204 CONTINUE	640
IF(KP.GT.1)GO TO 2205	650
PTGEN=PTFGGI(IX)	660
GO TO 2210	670
2205 PTGEN=PTGRW(KP-1,IX)	680
2210 CONTINUE	690
FNCPT="PTGEN-PTGRW(KP,IX)-PTMRE(KP,IX)	700
FNCNV=(1.0/(OXI(1)+ACR(1)))+(GFRIM/(PONTM-PON(1))	710
-GFRIPM/(PONTM-PONIP))	720
PTIM=PTATDI(KP,ICIM)+PTDEF(KP,ICIM)+PTMRE(KP,ICIM)	730
PTIPM=PTATDI(KP,ICIPM)+PTDEF(KP,ICIPM)+PTMRE(KP,ICIPM)	740

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FNC TRP=(1./DXII)*ACR(II)*ACR(INH*PYTRIN)-ACR(PH*PYTRIN)      SOL F 750
FNC SUR=(1./ACR(II)*GRILL)*GFL SUR*(PMS SUR(KP)-PDI(II))      SOL F 760
FNC RED=(1./ACR(II)*GRILL)*GFL RED(IX)*(PDGBEN(KP,IX)-PDI(II)) SOL F 770
1      *PTRAFN(KP,IX)      SOL F 780
C SUM UP ALL RATES FOR LIFE-STAGE POPULATIONS TO DETERMINE NET TIME RATE OF
C CHANGE IN EACH DISCRETE ELEMENT *****
FNC PDNI(KP,IX)=FNC PRT+FNC CHV+FNC TRP+FNC SUR+FNC RED      SOL F 790
C *****
7100 CONTINUE      SOL F 800
C DETERMINE TIME RATE OF SPawning IN EACH DISCRETE ELEMENT *****
FNC EGG(IX)=PRTEGG(IX)*DXII*ACR(II)      SOL F 810
C *****
2000 CONTINUE      SOL F 820
C CHECK WHETHER TRIBUTARIES OR OPERATING PLANTS EFFECT NET TIME RATE OF LIFE
C STAGE POPULATION CHANGE *****
IF(NTRB.GT.0) CALL TRBCON      SOL F 830
IF(INPLANT.GT.0) CALL PLTCOM11      SOL F 840
C *****
DO 4000 IX=1,NX      SOL F 850
FNC PDNI(KP,IX)=0.0      SOL F 860
4000 CONTINUE      SOL F 870
9999 RETURN      SOL F 880
END      SOL F 890

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SUBROUTINE BIOCON      AINC 10
C BIOCON READS AND WRITES THE BIOLOGICAL PARAMETERS AND FURNISHES SOLUTION WITH
C THE UPDATED BIOLOGICAL FACTORS THAT EFFECT THE LIFE-STAGE POPULATIONS
COMMON/CONTRL/KRUN,NP,NINTC,NX,NC,NXC,NT,NTM,T      AINC 20
COMMON/DATIME/IDAYDY,JULDAY,INYEAR,IMONTH,IMNDAY,THRDAY      AINC 30
COMMON/CONFLN/GFRI(76),VLT(76),TNP(76),SLNE(76)      AINC 40
COMMON/PDNSTL/PDI(7,76),FNC PDI(7,76),ERRPDI(7,76)      AINC 50
COMMON/EGGSOL/EGGI(76),FNC EGG(76),ERR EGG(76)      AINC 60
COMMON/GRUPOS/PDNAME(7,4),MINDAY(7),MAXDAY(7),NSPDAY      AINC 70
COMMON/CONPRT/PRTEGG(76),PRTSPW(7,76),PRTGRI(7,76),PRTHRI(7,76)      AINC 80
COMMON/CONSPW/IKPSWI(7),RNPSPW(7),PCRSPW(7),PHXSPW(7),      AINC 90
1 THNSPW(7),TOLSPW(7),TTHNSPW(7),TTHXSPW(7),      AINC 100
2 SHNSPW(7),SOLSPW(7),STHNSPW(7),STHXSPW(7)      AINC 110
COMMON/CONSRV/CONPSRV(7),PCRSRV(7),PHXSRV(7),      AINC 120
1 THNSRV(7),TOLSRV(7),TTHNSRV(7),TTHXSRV(7),      AINC 130
2 SHNSRV(7),SOLSRV(7),STHNSRV(7),STHXSrv(7)      AINC 140
COMMON/CONGRW/IKPGRI(7),RPGRI(7),PCRGRI(7),PHXGRI(7),      AINC 150
1 THNGRI(7),TOLGRI(7),TTHNGRI(7),TTHXGRI(7),      AINC 160
2 SHNGRI(7),SOLGRI(7),STHNGRI(7),STHXGRI(7)      AINC 170
COMMON/CONMOR/IKPMOR(7),RPMOR(7),PCRMOR(7),PHXPMOR(7),      AINC 180
1 THNPMOR(7),TOLPMOR(7),TTHNPMOR(7),TTHXPMOR(7),      AINC 190
2 SHNPMOR(7),SOLPMOR(7),STHPMOR(7),STHXPOR(7)      AINC 200
COMMON/CONMJB/IKPMJB(7),VFLMJB(7),DYVMJB(7),      AINC 210
1 POPMJB(7),PCRMJB(7),PHXPMJB(7),      AINC 220
2 THNPMJB(7),TOLPMJB(7),TTHPMJB(7),TTHXPMJB(7),      AINC 230
3 SHNPMJB(7),SOLPMJB(7),STHPMJB(7),STHXPMB(7)      AINC 240
DIMENSION PDNRES(7,76)      AINC 250
IF(KRUN.GT.0)GO TO 2      AINC 260
CHNMOR=10.0      AINC 270
C READ AND WRITE LIFE-STAGE BIOLOGICAL CONDITIONS *****
READ(5,1001)NP,NSPDAY      AINC 280
1001 FORMAT(4X,I3,4X,I4)      AINC 290
DO 1100 KP=1,NP      AINC 300
READ(5,1101)(PDNAME(KP,INAME),INAME=1,4),MINDAY(KP),MAXDAY(KP)      AINC 310
1101 FORMAT(6X,4A4,6X,2(I3,I5))      AINC 320
1100 CONTINUE      AINC 330
READ(5,1201)(IKPSWI(KP),KP=1,NP)      AINC 340
1201 FORMAT(12(2X,I2))      AINC 350
DO 1200 KP=1,NP      AINC 360
IF(IKPSWI(KP).LE.0)GO TO 1200      AINC 370
READ(5,1202)RNPSPW(KP),PCRSPW(KP),PHXSPW(KP),      AINC 380
1 THNSPW(KP),TOLSPW(KP),TTHNSPW(KP),TTHXSPW(KP),      AINC 390
2 SHNSPW(KP),SOLSPW(KP),STHNSPW(KP),STHXPW(KP)      AINC 400

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1202 FORMAT(3X,3(2X,E13.6)/3X,4(1X,F6.1),1X,4(1X,E11.4))
1200 CONTINUE
      DO 1300 KP=1,NP
        READ(5,1302)CGPSRV(KP),PCRSRV(KP),PMKSRV(KP),
          1      TPMSRV(KP),TOLSRV(KP),TOMSRV(KP),TMASRV(KP),
          2      SMNSRV(KP),SOLSRV(KP),SOMSRV(KP),SMKSRV(KP)
1302 FORMAT(5X,F7.4,6X,2(2X,E13.6)/3X,4(1X,F6.1),1X,4(1X,E11.4))
1300 CONTINUE
      READ(5,1401)((IKPGRN(KP),KP=1,NP)
1401 FORMAT(12(2X,12))
      DO 1400 KP=1,NP
        IF((IKPGRN(KP).LE.0)GO TO 1400
        READ(5,1402)ROPGRN(KP),PCRGGRN(KP),PMKGRN(KP),
          1      TPNGRN(KP),TOLGRN(KP),TOMGRN(KP),TMAGRN(KP),
          2      SMNGRN(KP),SOLGRN(KP),SOMGRN(KP),SMKGRN(KP)
1402 FORMAT(3X,3(2X,E13.6)/3X,4(1X,F6.1),1X,4(1X,E11.4))
1400 CONTINUE
      READ(5,1501)((IKPMGR(KP),KP=1,NP)
1501 FORMAT(12(2X,12))
      DO 1500 KP=1,NP
        IF((IKPMGR(KP).LE.0)GO TO 1500
        READ(5,1502)ROPGRN(KP),PCRMGR(KP),PMKGRN(KP),
          1      TPMGRN(KP),TOLMGR(KP),TOMGRN(KP),TMAMGR(KP),
          2      SMMGRN(KP),SOLMGR(KP),SOMMGRN(KP),SMAMGRN(KP)
1502 FORMAT(3X,3(2X,E13.6)/3X,4(1X,F6.1),1X,4(1X,E11.4))
1500 CONTINUE
      READ(5,1601)((IKPMOB(KP),KP=1,NP)
1601 FORMAT(12(2X,12))
      DO 1600 KP=1,NP
        IF((IKPMOB(KP).LE.0)GO TO 1600
        READ(5,1602)VELMOB(KP),DTVMOB(KP),POPMOB(KP),PCRMOB(KP),PMKMOB(KP)
1602 FORMAT(5X,E13.6,2X,F7.2,2X,3(2X,E13.6))
        READ(5,1603)TNMMOB(KP),TOLMOB(KP),TOMMOB(KP),TMAMOB(KP),
          1      SPMMOB(KP),SOLMOB(KP),SOMMOB(KP),SMAMOB(KP)
1603 FORMAT(3X,4(1X,F6.1),1X,4(1X,E11.4))
1600 CONTINUE
      WRITE(6,1601)
1801 FORMAT(11H,30X,53H***** AGC GROUP BIOLOGICAL CONDITIONS *****
160000)
      WRITE(6,1602)
1802 FORMAT(11H,4X,29H**** SPANNING CONDITIONS ****)
      DO 1810 KP=1,NP
        IF((IKPSPN(KP).LE.0)GO TO 1810
        WRITE(6,1811)KP,(PNAME(KP),INAME),INAME=1,4),MINDAY(KP),MAXDAY(KP)
1811 FORMAT(11H,10X,9H**** KP =,13,5H ****,4X,4H****,4A4,4H****,4X,
19H**** FROM,15,7H DAY TO,15,9H DAY ****)
        WRITE(6,1812)ROPSPN(KP)
1812 FORMAT(11H,10X,31HOPTIMUM SPANNING RATE, ROPSPN =,E13.6,
19H (1/HOUR))
        WRITE(6,1813)PCRSPPN(KP)
1813 FORMAT(11H,10X,50HCRITICAL POPULATION DENSITY FOR SPANNING, PCRSPPN
1 =,E13.6,19H (NUMBER/FT**3))
        WRITE(6,1814)PMKSPN(KP)
1814 FORMAT(11H,10X,49HMAXIMUM POPULATION DENSITY FOR SPANNING, PMKSPN
1 =,E13.6,19H (NUMBER/FT**3))
        WRITE(6,1815)TPMSPPN(KP)
1815 FORMAT(11H,10X,38HMINIMUM SPANNING TEMPERATURE, TMNSPN =,F6.1,
18H (DEG F))
        WRITE(6,1816)TOLSPN(KP)
1816 FORMAT(11H,10X,44HLOWER OPTIMUM SPANNING TEMPERATURE, TOLSPN =,
1E13.6,8H (DEG F))
        WRITE(6,1817)TOMSPN(KP)
1817 FORMAT(11H,10X,45HHIGHER OPTIMUM SPANNING TEMPERATURE, TOMSPN =,
1F6.1,8H (DEG F))
        WRITE(6,1818)TMKSPN(KP)
1818 FORMAT(11H,10X,38HMAXIMUM SPANNING TEMPERATURE, TMKSPN =,F6.1,
18H (DEG F))
        WRITE(6,1819)SMNSPN(KP)
1819 FORMAT(11H,10X,35HMINIMUM SPANNING SALINITY, SMNSPN =,E11.4)
        WRITE(6,1820)SOLSPN(KP)

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BLOC 410
 BLOC 420
 BLOC 430
 BLOC 440
 BLOC 450
 BLOC 460
 BLOC 470
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 BLOC 670
 BLOC 680
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 BLOC 780
 BLOC 790
 BLOC 800
 BLOC 810
 BLOC 820
 BLOC 830
 BLOC 840
 BLOC 850
 BLOC 860
 BLOC 870
 BLOC 880
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 BLOC 900
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 BLOC 930
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 BLOC 950
 BLOC 960
 BLOC 970
 BLOC 980
 BLOC 990
 BLOC1000
 BLOC1010
 BLOC1020
 BLOC1030
 BLOC1040
 BLOC1050
 BLOC1060
 BLOC1070
 BLOC1080
 BLOC1090
 BLOC1100

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1826 FORMAT(1H .10X.41HLOWER OPTIMUM SPAWNING SALINITY. SOKSPW =.F11.4)A10C1110
      WRITE(6.1827)SOKSPW(KP)A10C11120
1827 FORMAT(1H .10X.42H HIGHER OPTIMUM SPAWNING SALINITY. SOKSPW =.A10C11130
      IF11.4)A10C11140
      WRITE(6.1828)SOKSPW(KP)A10C11150
1828 FORMAT(1H .10X.35HMAXIMUM SPAWNING SALINITY. SOKSPW =.F11.4)A10C11160
1810 CONTINUEA10C11170
      WRITE(6.1803)A10C11180
1803 FORMAT(1H0.4X.29H*** SURVIVAL CONDITIONS ***A10C11190
      ON 1830 KP=1.NPA10C1200
      WRITE(6.1831)KP.(PDNAME(KP).INAME).INAME=1.4).P1NDAY(KP).MAXDAY(KP)A10C1210
1831 FORMAT(1H0.10X.9H*** KP =.13.5H ***.4X.4H***.4A4.4H***.4X.A10C1220
      19H*** FROM.15.7H DAY TO.15.9H DAY ***A10C1230
      WRITE(6.1832)COPSRV(KP)A10C1240
1832 FORMAT(1H .10X.37H OPTIMUM SURVIVAL PERCENTAGE. COPSRV =.F7.4)A10C1250
      WRITE(6.1833)PCRSRV(KP)A10C1260
1833 FORMAT(1H .10X.50H CRITICAL POPULATION DENSITY FOR SURVIVAL. PCRSRV=A10C1270
      1=.E13.6.15H (NUMBER/FT**3))A10C1280
      WRITE(6.1834)PMXSRV(KP)A10C1290
1834 FORMAT(1H .10X.49H MAXIMUM POPULATION DENSITY FOR SURVIVAL. PMXSRV=A10C1300
      1=.E13.6.15H (NUMBER/FT**3))A10C1310
      WRITE(6.1835)TMSRV(KP)A10C1320
1835 FORMAT(1H .10X.38H MINIMUM SURVIVAL TEMPERATURE. TMSRV =.F6.1.A10C1330
      18H (DEG F))A10C1340
      WRITE(6.1836)TOLSRV(KP)A10C1350
1836 FORMAT(1H .10X.44H LOWER OPTIMUM SURVIVAL TEMPERATURE. TOLSRV =.A10C1360
      IF6.1.8H (DEG F))A10C1370
      WRITE(6.1837)TOMSRV(KP)A10C1380
1837 FORMAT(1H .10X.45H HIGHER OPTIMUM SURVIVAL TEMPERATURE. TOMSRV =.A10C1390
      IF6.1.8H (DEG F))A10C1400
      WRITE(6.1838)THXSRV(KP)A10C1410
1838 FORMAT(1H .10X.38H MAXIMUM SURVIVAL TEMPERATURE. THXSRV =.F6.1.A10C1420
      18H (DEG F))A10C1430
      WRITE(6.1845)SOKSRV(KP)A10C1440
1845 FORMAT(1H .10X.34H MINIMUM SURVIVAL SALINITY. SOKSRV =.F11.4)A10C1450
      WRITE(6.1846)SOLSRV(KP)A10C1460
1846 FORMAT(1H .10X.41H LOWER OPTIMUM SURVIVAL SALINITY. SOLSRV =.F11.4)A10C1470
      WRITE(6.1847)SOKSRV(KP)A10C1480
1847 FORMAT(1H .10X.42H HIGHER OPTIMUM SURVIVAL SALINITY. SOKSRV =.A10C1490
      IF11.4)A10C1500
      WRITE(6.1848)SOKSRV(KP)A10C1510
1848 FORMAT(1H .10X.35H MAXIMUM SURVIVAL SALINITY. SOKSRV =.F11.4)A10C1520
1830 CONTINUEA10C1530
      WRITE(6.1805)A10C1540
1805 FORMAT(1H0.4X.23H*** GROWTH CONDITIONS ***A10C1550
      ON 1850 KP=1.NPA10C1560
      IF1(KPCRGRV(KP)).LE.01GO TO 1850A10C1570
      WRITE(6.1851)KP.(PDNAME(KP).INAME).INAME=1.4).P1NDAY(KP).MAXDAY(KP)A10C1580
1851 FORMAT(1H0.10X.9H*** KP =.13.5H ***.4X.4H***.4A4.4H***.4X.A10C1590
      19H*** FROM.15.7H DAY TO.15.9H DAY ***A10C1600
      WRITE(6.1852)ROPGRV(KP)A10C1610
1852 FORMAT(1H .10X.29H OPTIMUM GROWTH RATE. ROPGRV =.F13.6.A10C1620
      19H (1/HOUR))A10C1630
      WRITE(6.1853)PCRGRV(KP)A10C1640
1853 FORMAT(1H .10X.48H CRITICAL POPULATION DENSITY FOR GROWTH. PCRGRV =A10C1650
      1=.E13.6.15H (NUMBER/FT**3))A10C1660
      WRITE(6.1854)PMXGRV(KP)A10C1670
1854 FORMAT(1H .10X.47H MAXIMUM POPULATION DENSITY FOR GROWTH. PMXGRV =.A10C1680
      1E13.6.15H (NUMBER/FT**3))A10C1690
      WRITE(6.1855)TMGRV(KP)A10C1700
1855 FORMAT(1H .10X.36H MINIMUM GROWTH TEMPERATURE. TMGRV =.F6.1.A10C1710
      18H (DEG F))A10C1720
      WRITE(6.1856)TOLGRV(KP)A10C1730
1856 FORMAT(1H .10X.42H LOWER OPTIMUM GROWTH TEMPERATURE. TOLGRV =.A10C1740
      IF6.1.8H (DEG F))A10C1750
      WRITE(6.1857)TOMGRV(KP)A10C1760
1857 FORMAT(1H .10X.43H HIGHER OPTIMUM GROWTH TEMPERATURE. TOMGRV =.A10C1770
      IF6.1.8H (DEG F))A10C1780
      WRITE(6.1858)THXGRV(KP)A10C1790
1858 FORMAT(1H .10X.36H MAXIMUM GROWTH TEMPERATURE. THXGRV =.F6.1.A10C1800
      18H (DEG F))A10C1810

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WRITE(6,1865)SMNGR(KP)
1865 FORMAT(1H,10X,3HMINIMUM GROWTH SALINITY, SMNGR =,F11.4)
WRITE(6,1866)SMGR(KP)
1866 FORMAT(1H,10X,3HLOWER OPTIMUM GROWTH SALINITY, SMGR =,F11.4)
WRITE(6,1867)SMGR(KP)
1867 FORMAT(1H,10X,4HLOWER OPTIMUM GROWTH SALINITY, SMGR =,F11.4)
WRITE(6,1868)SMGR(KP)
1868 FORMAT(1H,10X,3HMAXIMUM GROWTH SALINITY, SMGR =,F11.4)
1850 CONTINUE
WRITE(6,1867)
1867 FORMAT(1H,4X,26H** MORTALITY CONDITIONS **
DO 1870 KP=1,NP
IF (KP.NE.1) LEAVE TO 1870
WRITE(6,1871)KP, (PDNAME(KP,NAME), NAME=1.4), PINDAY(KP), MAXDAY(KP)
1871 FORMAT(1H,10X,9H*** KP =,I3.5H ***.4X,6H***.4X,6H***.4X,
10H*** FROM,15.7H DAY TO,15.7H DAY ***
WRITE(6,1872)RPMNR(KP)
1872 FORMAT(1H,10X,3HOPTIMUM MORTALITY RATE, RPMNR =,F13.6,
10H (1/HOUR))
WRITE(6,1873)PCRMNR(KP)
1873 FORMAT(1H,10X,5HCritical POPULATION DENSITY FOR MORTALITY, PCRMNR =,F13.6,15H (NUMBER/F003))
WRITE(6,1874)PXMNR(KP)
1874 FORMAT(1H,10X,5HMAXIMUM POPULATION DENSITY FOR MORTALITY, PXMNR =,F13.6,15H (NUMBER/F003))
WRITE(6,1875)TMMNR(KP)
1875 FORMAT(1H,10X,3HMINIMUM MORTALITY TEMPERATURE, TMMNR =,F6.1,
10H (DEG F))
WRITE(6,1876)TOLMNR(KP)
1876 FORMAT(1H,10X,4HLOWER OPTIMUM MORTALITY TEMPERATURE, TOLMNR =,
F6.1,10H (DEG F))
WRITE(6,1877)TOMMNR(KP)
1877 FORMAT(1H,10X,4HLOWER OPTIMUM MORTALITY TEMPERATURE, TOMMNR =,
F6.1,10H (DEG F))
WRITE(6,1878)TMMNR(KP)
1878 FORMAT(1H,10X,3HMAXIMUM MORTALITY TEMPERATURE, TMMNR =,F6.1,
10H (DEG F))
WRITE(6,1885)SMNMNR(KP)
1885 FORMAT(1H,10X,3HMINIMUM MORTALITY SALINITY, SMNMNR =,F11.4)
WRITE(6,1886)SOLMNR(KP)
1886 FORMAT(1H,10X,4HLOWER OPTIMUM MORTALITY SALINITY, SOLMNR =,
F11.4)
WRITE(6,1887)SOLMNR(KP)
1887 FORMAT(1H,10X,3HLOWER OPTIMUM MORTALITY SALINITY, SOLMNR =,
F11.4)
WRITE(6,1888)SOLMNR(KP)
1888 FORMAT(1H,10X,3HMAXIMUM MORTALITY SALINITY, SOLMNR =,F11.4)
1870 CONTINUE
WRITE(6,1901)
1901 FORMAT(1H,30X,51H***** AGE GROUP MORTALITY CONDITIONS *****
1000)
DO 1910 KP=1,NP
IF (KP.NE.1) LEAVE TO 1910
WRITE(6,1911)KP, (PDNAME(KP,NAME), NAME=1.4), PINDAY(KP), MAXDAY(KP)
1911 FORMAT(1H,10X,9H*** KP =,I3.5H ***.4X,6H***.4X,6H***.4X,
10H*** FROM,14.7H DAY TO,14.7H DAY ***
VFSMNR=VELMNR(KP)/3600.
WRITE(6,1912)VFSMNR
1912 FORMAT(1H,10X,4HAPPROXIMATE MAXIMUM SWIMMING SPEED, VFSMNR =,
F6.2,6H (FPS))
WRITE(6,1913)DTVMNR(KP)
1913 FORMAT(1H,10X,6HAPPROXIMATE MAXIMUM SUSTAINED DURATION AT MAXIMUM
10H SPEED, DTVMNR =,F7.2,7H (HOUR))
WRITE(6,1914)PCNMNR(KP)
1914 FORMAT(1H,10X,4HOPTIMUM POPULATION DENSITY FOR MOBILITY, PCNMNR =,F13.6,15H (NUMBER/F003))
WRITE(6,1915)PCNMNR(KP)
1915 FORMAT(1H,10X,5HCritical POPULATION DENSITY FOR MOBILITY, PCNMNR =,F13.6,15H (NUMBER/F003))
WRITE(6,1916)PXMNR(KP)

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1916 FORMAT(1H,10X,30MAXIMUM POPULATION DENSITY FOR MOBILITY, PNMNR BINC2520
      I =,E13.6,15H (NUMBER/FT**3)) BINC2530
      WRITE(6,1925)TMINR(KP) BINC2540
1925 FORMAT(1H,10X,30MINIMUM SWIMMING TEMPERATURE, TMINR =,F6.1, BINC2550
      10H (DEG F)) BINC2560
      WRITE(6,1926)TMINR(KP) BINC2570
1926 FORMAT(1H,10X,40NUMBER OPTIMUM SWIMMING TEMPERATURE, TOLNR =, BINC2580
      IF6.1,0H (DEG F)) BINC2590
      WRITE(6,1927)TMINR(KP) BINC2600
1927 FORMAT(1H,10X,45HIGHER OPTIMUM SWIMMING TEMPERATURE, TMINR =, BINC2610
      IF6.1,0H (DEG F)) BINC2620
      WRITE(6,1928)TMINR(KP) BINC2630
1928 FORMAT(1H,10X,30MAXIMUM SWIMMING TEMPERATURE, TMINR =,F6.1, BINC2640
      10H (DEG F)) BINC2650
      WRITE(6,1935)SMINR(KP) BINC2660
1935 FORMAT(1H,10X,35MINIMUM SWIMMING SALINITY, SMINR =,E11.4) BINC2670
      WRITE(6,1936)SMINR(KP) BINC2680
1936 FORMAT(1H,10X,40NUMBER OPTIMUM SWIMMING SALINITY, SOLNR =,F11.4) BINC2690
      WRITE(6,1937)SMINR(KP) BINC2700
1937 FORMAT(1H,10X,45HIGHER OPTIMUM SWIMMING SALINITY, SMINR =, BINC2710
      IF11.4) BINC2720
      WRITE(6,1938)SMINR(KP) BINC2730
1938 FORMAT(1H,10X,35MAXIMUM SWIMMING SALINITY, SMINR =,F11.4) BINC2740
1910 CONTINUE BINC2750
C ***** BINC2760
      DO 1900 IX=1,NX BINC2770
      PRTEGG(IX)=0.0 BINC2780
      DO 1990 KP=1,NP BINC2790
      PDRRES(KP,IX)=0.0 BINC2800
      PRYSPW(KP,IX)=0.0 BINC2810
      PRGRW(KP,IX)=0.0 BINC2820
      PRTHOR(KP,IX)=0.0 BINC2830
1990 CONTINUE BINC2840
1900 CONTINUE BINC2850
      GO TO 9999 BINC2860
2 CONTINUE BINC2870
C TEST RESIDENT POPULATION, TEMPERATURE, AND SALINITY IN EACH ELEMENT TO
C CALCULATE UPDATED SPANNING, GROWTH, AND MORTALITY RATES ***** BINC2880
      DO 2000 IX=1,NX BINC2890
      TMP(IX)=TMR(IX) BINC2900
      SLN(IX)=SLN(IX) BINC2910
      EGGPR=0.0 BINC2920
      IF(1DAYDY.GE.150)GO TO 2109 BINC2930
      DO 2100 KP=1,NP BINC2940
      IF(KPSPW(KP).LE.0)GO TO 2190 BINC2950
      PDR(IX)=PDR(KP,IX) BINC2960
      IF(PDR(IX).LE.0.0)GO TO 2190 BINC2970
      IF(PDR(IX).GT.PCRSPW(KP))GO TO 2111 BINC2980
      CORPDR=1.0 BINC2990
      GO TO 2118 BINC3000
2111 IF(PDR(IX).GE.PHXSPW(KP))GO TO 2190 BINC3010
      CORPDR=(PDR(IX)-PHXSPW(KP))/(PCRSPW(KP)-PHXSPW(KP)) BINC3020
2118 CONTINUE BINC3030
      IF(TMP(IX).LE.TMXSPW(KP))GO TO 2190 BINC3040
      IF(TMP(IX).GE.TOLSPW(KP))GO TO 2121 BINC3050
      CORTMP=(TMP(IX)-TMXSPW(KP))/(TOLSPW(KP)-TMXSPW(KP)) BINC3060
      GO TO 2128 BINC3070
2121 IF(TMP(IX).GT.TMXSPW(KP))GO TO 2122 BINC3080
      CORTMP=1.0 BINC3090
      GO TO 2128 BINC3100
2122 IF(TMP(IX).GE.TMXSPW(KP))GO TO 2190 BINC3110
      CORTMP=(TMP(IX)-TMXSPW(KP))/(TMXSPW(KP)-TMXSPW(KP)) BINC3120
2128 CONTINUE BINC3130
      IF(SLN(IX).LE.SMXSPW(KP))GO TO 2190 BINC3140
      IF(SLN(IX).GE.SOLSPW(KP))GO TO 2131 BINC3150
      CORSLN=(SLN(IX)-SMXSPW(KP))/(SOLSPW(KP)-SMXSPW(KP)) BINC3160
      GO TO 2138 BINC3170
2131 IF(SLN(IX).GT.SMXSPW(KP))GO TO 2132 BINC3180
      CORSLN=1.0 BINC3190
      GO TO 2138 BINC3200

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2132	IF(SL N111,GE,SNKSPW(KP))GO TO 2195	B INC 3190
	CNRSLN=(SL N111-SNKSPW(KP))/(SNKSPW(KP)-SNKSPW(KP))	B INC 3200
2136	CONTINUE	B INC 3210
	CNRSP=CONPOMCORTPOCNRSLN	B INC 3270
	PRTSW(KP,IX)=CNRSP*PRNPSPW(KP)+POMN11	B INC 3230
	EGGPRT=EGGPRT+PRTSW(KP,IX)	B INC 3240
	GO TO 2100	B INC 3250
2190	PRTSW(KP,IX)=0.0	B INC 3260
2100	CONTINUE	B INC 3270
2109	PRTEGG(IX)=EGGPRT	B INC 3280
	ON 2200 KP=1,ND	B INC 3290
	POMN11=POM(KP,IX)	B INC 3300
	IF(POMN11-IF,0.0)GO TO 2290	B INC 3310
	IF(POMN11-GT,PCRSV(KP))GO TO 2211	B INC 3320
	CNRPN=1.0	B INC 3330
	GO TO 2212	B INC 3340
2211	IF(POMN11,GE,PNKSRV(KP))GO TO 2219	B INC 3350
	CNRPN=(POMN11-PNKSRV(KP))/(PNKSRV(KP)-PNKSRV(KP))	B INC 3360
2212	CONTINUE	B INC 3370
	IF(TOP111,LF,TMNSRV(KP))GO TO 2219	B INC 3380
	IF(TOP111,GE,TOLSRV(KP))GO TO 2213	B INC 3390
	CNRTP=(TOP111-TMNSRV(KP))/(TOLSRV(KP)-TMNSRV(KP))	B INC 3400
	GO TO 2214	B INC 3410
2213	IF(TOP111,GT,TMNSRV(KP))GO TO 2215	B INC 3420
	CNRTP=1.0	B INC 3430
	GO TO 2214	B INC 3440
2215	IF(TOP111,GE,TMNSRV(KP))GO TO 2219	B INC 3450
	CNRTP=(TOP111-TMNSRV(KP))/(TMNSRV(KP)-TMNSRV(KP))	B INC 3460
2216	CONTINUE	B INC 3470
	IF(SL N111,LF,SNKSRV(KP))GO TO 2219	B INC 3480
	IF(SL N111,GE,SNL SRV(KP))GO TO 2216	B INC 3490
	CNRSLN=(SL N111-SNKSRV(KP))/(SNL SRV(KP)-SNKSRV(KP))	B INC 3500
	GO TO 2218	B INC 3510
2216	IF(SL N111,GT,SNKSRV(KP))GO TO 2217	B INC 3520
	CNRSLN=1.0	B INC 3530
	GO TO 2218	B INC 3540
2217	IF(SL N111,GE,SNKSRV(KP))GO TO 2219	B INC 3550
	CNRSLN=(SL N111-SNKSRV(KP))/(SNKSRV(KP)-SNKSRV(KP))	B INC 3560
2218	CONTINUE	B INC 3570
	CNRSAV=CONPOMCORTPOCNRSLN	B INC 3580
	GO TO 2220	B INC 3590
2219	CNRSAV=0.0	B INC 3600
2220	CONTINUE	B INC 3610
	IF(IPGRW(KP),LF,0)GO TO 2229	B INC 3620
	IF(POMN11,GT,PCGRW(KP))GO TO 2221	B INC 3630
	CNRPN=1.0	B INC 3640
	GO TO 2222	B INC 3650
2221	IF(POMN11,GE,PNKGRW(KP))GO TO 2229	B INC 3660
	CNRPN=(POMN11-PNKGRW(KP))/(PNKGRW(KP)-PNKGRW(KP))	B INC 3670
2222	CONTINUE	B INC 3680
	IF(TOP111,LF,TMNGRW(KP))GO TO 2229	B INC 3690
	IF(TOP111,GE,TOLGRW(KP))GO TO 2223	B INC 3700
	CNRTP=(TOP111-TMNGRW(KP))/(TOLGRW(KP)-TMNGRW(KP))	B INC 3710
	GO TO 2224	B INC 3720
2223	IF(TOP111,GT,TMNGRW(KP))GO TO 2225	B INC 3730
	CNRTP=1.0	B INC 3740
	GO TO 2224	B INC 3750
2225	IF(TOP111,GE,TMNGRW(KP))GO TO 2229	B INC 3760
	CNRTP=(TOP111-TMNGRW(KP))/(TMNGRW(KP)-TMNGRW(KP))	B INC 3770
2226	CONTINUE	B INC 3780
	IF(SL N111,LF,SNKGRW(KP))GO TO 2229	B INC 3790
	IF(SL N111,GE,SNLGRW(KP))GO TO 2226	B INC 3800
	CNRSLN=(SL N111-SNKGRW(KP))/(SNLGRW(KP)-SNKGRW(KP))	B INC 3810
	GO TO 2228	B INC 3820
2226	IF(SL N111,GT,SNKGRW(KP))GO TO 2227	B INC 3830
	CNRSLN=1.0	B INC 3840
	GO TO 2228	B INC 3850
2227	IF(SL N111,GE,SNKGRW(KP))GO TO 2229	B INC 3860
	CNRSLN=(SL N111-SNKGRW(KP))/(SNKGRW(KP)-SNKGRW(KP))	B INC 3870

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2228 CONTINUE
      CORR=CONPDC=CONTPDCNLSL
      GO TO 2230
2229 CORR=0.0
2230 CONTINUE
      IF (BLPWR(KP).LE.0.0) GO TO 2239
      IF (PDI111.GT.PCNRN(KP)) GO TO 2231
      CORR=1.0
      GO TO 2232
2231 IF (PDI111.GE.PMNR(KP)) GO TO 2239
      CORR=1.0C4NTR=PDI111-PCNRN(KP)/(PMNR(KP)-PCNRN(KP))
2232 CONTINUE
      IF (TPI111.LE.TMNR(KP)) GO TO 2239
      IF (TPI111.GE.TOLNR(KP)) GO TO 2233
      CORR=1.0C4NTR=TPI111-TOLNR(KP)/(TMNR(KP)-TOLNR(KP))
      GO TO 2234
2233 IF (TPI111.GT.TMNR(KP)) GO TO 2235
      CORR=1.0
      GO TO 2234
2235 IF (TPI111.GE.TMNR(KP)) GO TO 2239
      CORR=1.0C4NTR=TPI111-TMNR(KP)/(TMNR(KP)-TOLNR(KP))
2236 CONTINUE
      IF (SLI111.LE.SMNR(KP)) GO TO 2239
      IF (SLI111.GE.SOLNR(KP)) GO TO 2236
      CORR=1.0C4NTR=SLI111-SOLNR(KP)/(SMNR(KP)-SOLNR(KP))
      GO TO 2238
2236 IF (SLI111.GT.SMNR(KP)) GO TO 2237
      CORR=1.0
      GO TO 2238
2237 IF (SLI111.GE.SMNR(KP)) GO TO 2239
      CORR=1.0C4NTR=SLI111-SMNR(KP)/(SMNR(KP)-SOLNR(KP))
2238 CONTINUE
      CORR=CONPDC=CONTPDCNLSL
      GO TO 2240
2239 CORR=CONPDC=3
      IF (BLPWR(KP).LE.0.0) CORR=0.0
2240 CONTINUE
      IF (KP.GT.1) GO TO 2241
      PRGEN=PRFGG(IX)
      GO TO 2245
2241 PRGEN=PRGRWKP-1.14)
2245 CONTINUE
      I.:PRGEN.LE.0.0) GO TO 2242
      PNRRES(KP,IX)=PDI111
      GO TO 2280
2242 IF (PDI111.GT.PNRRES(KP,IX)) PNRRES(KP,IX)=PDI111
2280 CONTINUE
      PNRGR=PNRRES(KP,IX)
      PNRDR=PNRRES(KP,IX)
      PRGRWKP(IX)=CONPDCNTRPGRWKP+PCNRSVCPNRSV(KP)+PNRGR
      PRDRWKP(IX)=CONPDCNTRPDRWKP+1.-CONPDCNTRPDRWKP+PNRDR
      GO TO 2280
2290 CONTINUE
      PNRRES(KP,IX)=0.0
      PRGRWKP(IX)=0.0
      PRDRWKP(IX)=0.0
2200 CONTINUE
2000 CONTINUE
C *****
9999 RETURN
      END

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SUBROUTINE ENDCON
C ENDCON DETERMINES THE LIFE-STAGE POPULATION CONTRIBUTIONS AT THE ENDS OF THE
C ESTUARY
C COMMON/CONTRL/KRUN,MP,NINTC,NX,NC,NRC,NT,NTW,T

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FENDC 10

FENDC 20

[illegible][illegible]

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CTR1D=CCCCCCCC(CFRNT000,50)
CTRDEF=CCCCDEF(CFRNT000,50)
DO 1100 KP=1,NP
  RFA015=.11011416ACCF(KP),SURFON(KP),RMSH(KP),RMSHND(KP)
1101 FORMAT(4X,17,44,3X,21,F5,21)
1100 CONTINUE
  ETRY1D(I)=0.0
  CCSHND(I)=0.0
  CCRHND(I)=0.0
  DO 1000 IC=1,NH
    ETRY1D(IC)=CTR1D*VLC(I,IC)HND(I,IC)
    IXCND=IC-1
    IXCND=IC
    ON(CND)=ON(IXCND)
    ON(CPD)=ON(IXCND)
    ONDEN=ON(ICND)+ON(ICPD)
    ALXTID=VLC(I,IC)DVTIDEP/PI
    CCSHND(IC)=2.0*ALXTID/ALX(I,IC)+((1.0*ON(CND)-RSH(I,ICND))/RSH(I,ICPD))
    CCRHND(IC)=ALXTID
1000 CONTINUE
  ETRY1D(NE)=CTR1D*VLC(NE,NE)HND(NE)
  ALXTID=VLC(NE,NE)DVTIDEP/PI
  CCSHND(NE)=ALXTID/ALX(NE,NE)+((1.0*ON(CND)-RSH(NE,ICND))/RSH(NE,ICPD))
  CCRHND(NE)=ALXTID
  CFLSH=0.0
  DO 1200 KP=1,NP
    PDCSH(KP)=0.0
1200 CONTINUE
  DO 1300 IX=1,NX
    CFLSHD(IX)=0.0
    DO 1400 KP=1,NP
      PDCSHD(KP,IX)=0.0
      PTRSHD(KP,IX)=0.0
1400 CONTINUE
1300 CONTINUE
  WRITE(6,1501)
1501 FORMAT(1H,30X,57H***** AGE GROUP TRANSPORT CONDITIONS *****TAPN
1000)
  WRITE(6,1502)
1502 FORMAT(1H,4X,94H*** CALCULATED DISPERSION TRANSPORT, PTRSH CALCU
1ED BY NEMO-SCALE TURBULENCE (IF THE TERM FDBV)
  WRITE(6,1503)
1503 FORMAT(1H,4X,107H*** TRANSPORT EFFECTS DUE TO CROSS-SECTIONAL VARI
1ATIONS OF AGE GROUP POPULATION DENSITY DISTRIBUTIONS)
  WRITE(6,1504)
1504 FORMAT(1H,10X,47HVERTICAL VARIATION EFFECT, PTRSH, CALCULATED)
  WRITE(6,1505)
1505 FORMAT(1H,4X,112H*** DEFECT TYPE TRANSPORT, PTRSH DETERMINED ACCOR
1DING TO A CUBIC VARIATION IN DEPTH FOR VERTICAL DISTRIBUTIONS)
  WRITE(6,1506)
1506 FORMAT(1H,10X,34H*** LATERAL VARIATION EFFECT, PTRSH = 0)
  DO 1500 KP=1,NP
    WRITE(6,1507)KP,(PNAME(KP,INAME),INAME=1,4),PNDAY(KP),RNDAY(KP)TAPN
1507 FORMAT(1H,10X,90H*** KP =,13,5H 0000,4X,41H***,4H,41H***,4X,
19H*** FROM,15,7H DAY TO,15,9H DAY 0000)
    WRITE(6,1508)SURFON(KP)
1508 FORMAT(1H,10X,107HPERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT
1 THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, SURFON =,F5,21)TAPN
1500 CONTINUE
  WRITE(6,1601)
1601 FORMAT(1H,4X,110H*** NEGATIVE TRANSPORT, PTRSH DETERMINED ACCOR
1DING TO SHOALING AND CROWDING EFFECTS BASED ON GRADIENT FORMS)
  DO 1600 KP=1,NP
    IF(PICAGE(KP)).LE.01GO TO 1600
    WRITE(6,1602)KP,(PNAME(KP,INAME),INAME=1,4),PNDAY(KP),RNDAY(KP)TAPN
1602 FORMAT(1H,10X,90H*** KP =,13,5H 0000,4X,41H***,4H,41H***,4X,
19H*** FROM,15,7H DAY TO,15,9H DAY 0000)
    WRITE(6,1603)RMSH(KP)
1603 FORMAT(1H,10X,60HWEIGHTING PARAMETER FOR SHOALING TENDENCY OF THE
1 AGE GROUP, RMSH =,F5,21)
    WRITE(6,1604)RMSHND(KP)

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1044 FORMAT(10X,10HWEIGHTING PARAMETER FOR THE TENDENCY TO MOVE ANIMAL 980
1AY FROM CRIMINAL CONVICTIONS FOR THE AGE GROUP. RECORD =.F5.7) TAPN 990
1600 CONTINUE TAPN1000
C ***** TAPN1010
GO TO 9999 TAPN1010
2 CONTINUE TAPN1020
UN 7100 KP=1.0P TAPN1030
PTRTRM=-ETATID(1)/(PDM(KP,1)-PDMUP(KP,1)/NDEB TAPN1040
PTRTID(KP,1)=PTRTRM TAPN1050
PTRDEF(KP,1)=0.0 TAPN1060
PTRMIG(KP,1)=0.0 TAPN1070
2100 CONTINUE TAPN1080
C TESTS MIGRATION AND STABILITY FLAGS, RESIDENT POPULATION, TEMPERATURE, AND
C SALINITY IN EACH ELEMENT TO CALCULATE FACTORS OF THE OVERALL LONGITUDINAL
C TRANSPORT PHENOMENON ***** TAPN1090
TN 7000 IC=2.0X TAPN1100
TAP IC=TN(IC) TAPN1110
SALIC=SI(CIC) TAPN1120
IXC=IC-1 TAPN1130
IXCP=IC TAPN1140
NXC=0N(IXC) TAPN1150
NXC=0N(IXCP) TAPN1160
NXC=0N(IXC+NXC) TAPN1170
CN 2266 KP=1.0P TAPN1180
PDMIC=PDM(KP,IXC) TAPN1190
PDMICP=PDM(KP,IXCP) TAPN1200
PDMIC=(IXC+NXC)*PDMICP+NXC*(PDM(KP,1)/NDEB) TAPN1210
IF(PDMIC,GT,0.0) TN 2205 TAPN1220
PTRTID(KP,IC)=0.0 TAPN1230
PTRDEF(KP,IC)=0.0 TAPN1240
PTRMIG(KP,IC)=0.0 TAPN1250
GO TN 2200 TAPN1260
2205 CONTINUE TAPN1270
PTRTRM=-2.0*ETATID(IC)/(PDMICP-PDMIC)/NDEB TAPN1280
PTRTID(KP,IC)=PTRTRM TAPN1290
PDMTC=PDMIC TAPN1300
VFCIC=GF(CIC)/ACC(IC) TAPN1310
IF(VFCIC,LT,0.0) PDMTC=PDMICP TAPN1320
PTRDEF(KP,IC)=-CTRDEF=VFCIC*(PDM(KP,1)-PDMTC) TAPN1330
IF(MIGAGE(KP),LT,0.0) GO TN 2290 TAPN1340
IF(PDM(KP,1),LT,0.0) GO TN 2290 TAPN1350
IF(PDMIC,GE,PDM(KP,1)) GO TN 2211 TAPN1360
CORPDM=PDMIC/PDM(KP,1) TAPN1370
GO TN 2210 TAPN1380
2211 IF(PDMIC,GT,PDM(KP,1)) GO TN 2212 TAPN1390
CORPDM=1.0 TAPN1400
GO TN 2210 TAPN1410
2212 IF(PDMIC,GE,PDM(KP,1)) GO TN 2290 TAPN1420
CORPDM=(PDMIC-PDM(KP,1))/(PDM(KP,1)-PDM(KP,1)) TAPN1430
2210 CONTINUE TAPN1440
IF(TAPIC,LT,TM(KP,1)) GO TN 2290 TAPN1450
IF(TAPIC,GE,TM(KP,1)) GO TN 2271 TAPN1460
CTRTP=(TAPIC-TM(KP,1))/(TM(KP,1)-TM(KP,1)) TAPN1470
GO TN 2220 TAPN1480
2271 IF(TAPIC,GT,TM(KP,1)) GO TN 2272 TAPN1490
CTRTP=1.0 TAPN1500
GO TN 2220 TAPN1510
2222 IF(TAPIC,GE,TM(KP,1)) GO TN 2290 TAPN1520
CTRTP=(TAPIC-TM(KP,1))/(TM(KP,1)-TM(KP,1)) TAPN1530
2220 CONTINUE TAPN1540
CORSL=1.0 TAPN1550
IF(SLIC,LT,SM(KP,1)) GO TN 2230 TAPN1560
IF(SLIC,GE,SM(KP,1)) GO TN 2231 TAPN1570
CORSL=1.-0.50*(SLIC-SM(KP,1))/(SM(KP,1)-SM(KP,1)) TAPN1580
GO TN 2230 TAPN1590
2231 IF(SLIC,GT,SM(KP,1)) GO TN 2232 TAPN1600
CORSL=0.5 TAPN1610
GO TN 2230 TAPN1620
2232 IF(SLIC,GE,SM(KP,1)) GO TN 2230 TAPN1630
CORSL=1.-0.50*(SLIC-SM(KP,1))/(SM(KP,1)-SM(KP,1))

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2250 CONTINUE                                TAPN1660
CUMND=CUMND+PCND*RTAPCND*SLN              TAPN1665
VLAND=CUMND*VELAND*RTAPCND                TAPN1670
VCSND=0.5*VLAND*(DUMND(KP)/TDPFR) + VCSND*(KP)*CCSND(ICE) TAPN1680
PCSND=VCSND*PCND*ICE                      TAPN1690
VCRND=0.5*VLAND*(DUMND(KP)/TDPFR) + VCRND*(KP)*CCRND(ICE)/DUMND(KP) TAPN1700
PCRND=-2.0*VCRND*(PCND*ICE)              TAPN1710
PTRND(ICE)=PCSND+PCRND                   TAPN1720
GO TO 2200                                TAPN1730
2290 PTRND(ICE)=0.0                        TAPN1740
2700 CONTINUE                                TAPN1750
2000 CONTINUE                                TAPN1760
TAPICH=TAC(ICE)                          TAPN1770
SLNICH=SLC(ICE)                          TAPN1780
DUMND=DUMND(ICE)                         TAPN1790
DN 2300 KP=1, NP                          TAPN1800
PCND=PCND(KP, NP)                        TAPN1810
PCND=PCND(KP)                             TAPN1820
PCND=0.5*(PCND+PCND(KP))                 TAPN1830
IF(PCND<0.0) GO TO 2305                  TAPN1840
PTRND(ICE, VC)=0.0                       TAPN1850
PTRDEF(ICE, VC)=0.0                      TAPN1860
PTRND(ICE, VC)=0.0                       TAPN1870
GO TO 2300                                TAPN1880
2305 CONTINUE                                TAPN1890
PTRTR=-EVALDUMND(KP)-PCND(KP, NP)/DUMND TAPN1900
PTRD(ICE, VC)=PTRTR                      TAPN1910
PCND=PCND(KP)                             TAPN1920
VFC=VFC(ICE)/ACC(ICE)                   TAPN1930
IF(VFC<1.0) PCND=PCND(KP)               TAPN1940
PTRDEF(ICE, VC)=PTRDEF(ICE, VC)+PCND(KP) TAPN1950
IF(PTRND(ICE, VC)<0.0) GO TO 2340         TAPN1960
IF(PTRND(ICE, VC)>0.0) GO TO 2390         TAPN1970
IF(PCND<0.0) GO TO 2311                  TAPN1980
CUMND=PCND(KP)/PTRND(ICE)                TAPN1990
GO TO 2310                                TAPN2000
2311 IF(PCND<0.0) GO TO 2312              TAPN2010
CORPND=1.0                               TAPN2020
GO TO 2310                                TAPN2030
2312 IF(PCND<0.0) GO TO 2390              TAPN2040
CORPND=(PTRND(ICE, VC)-PTRND(ICE, VC))/PTRND(ICE, VC) TAPN2050
CONTINUE                                TAPN2060
IF(TAPICH<0.0) GO TO 2340                TAPN2070
IF(TAPICH<0.0) GO TO 2371                TAPN2080
CUMND=(TAPICH-DUMND(KP))/DUMND(KP)-DUMND(KP) TAPN2090
GO TO 2320                                TAPN2100
2321 IF(TAPICH<0.0) GO TO 2322            TAPN2110
CORPND=1.0                               TAPN2120
GO TO 2320                                TAPN2130
2322 IF(TAPICH<0.0) GO TO 2390            TAPN2140
CUMND=(TAPICH-DUMND(KP))/DUMND(KP)-DUMND(KP) TAPN2150
CONTINUE                                TAPN2160
CORSLN=1.0                               TAPN2170
IF(SLNICH<0.0) GO TO 2330                TAPN2180
IF(SLNICH<0.0) GO TO 2331                TAPN2190
CORSLN=1.0-0.5*(SLNICH-SLNND(KP))/(SLNND(KP)-SLNND(KP)) TAPN2200
GO TO 2330                                TAPN2210
2331 IF(SLNICH<0.0) GO TO 2332            TAPN2220
CORSLN=0.5                               TAPN2230
GO TO 2330                                TAPN2240
2332 IF(SLNICH<0.0) GO TO 2330            TAPN2250
CORSLN=1.0-0.5*(SLNICH-SLNND(KP))/(SLNND(KP)-SLNND(KP)) TAPN2260
CONTINUE                                TAPN2270
CUMND=CUMND+CORSLN*PCND*RTAPCND*SLN      TAPN2280
VLAND=CUMND*VELAND*RTAPCND                TAPN2290
VCSND=0.5*VLAND*(DUMND(KP)/TDPFR) + VCSND*(KP)*CCSND(ICE) TAPN2300
PCSND=VCSND*PCND*ICE                      TAPN2310
VCRND=0.5*VLAND*(DUMND(KP)/TDPFR) + VCRND*(KP)*CCRND(ICE)/DUMND(KP) TAPN2320
PCRND=-VCRND*(PCND*ICE)                  TAPN2330
PTRND=PCSND+PCRND                         TAPN2340

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      IF (PTRONS.LT.0.) PTRONS=0.
      PIRMI(KP,PC)=PIKDS
      GO TO 2300
2300 PIRMI(KP,IC)=0.0
2300 CONTINUE
9999 RETURN
      END

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SUBROUTINE PLTCUNPLPLMC)
COMMON/CG,TAL/KRUS,MP,NINTC,NM,NC,NEC,NT,NTB,I
COMMON/DATIME/IDAYGY,JULDAY,IYECAR,IACATM,IMGLAY,IMECAY
COMMON/GEDELN/GE(76),DEL(76),ACAT(76),ONDI(76),SDI(76),JPR(76),XSN(76)
COMMON/CONELP/CFR(76),VLT(76),TRP(76),SL(76)
COMMON/PDASCL/PUN( 7,76),FNCPU( 7,76),CRAP( 7,76)
COMMON/EGGSL/EGG(76),FCL( 6,76),LREGL(76)
COMMON/GRUPLS/PDNAME( 7,4),NINDV( 7),NAGAVE( 7),NSPDAY
COMMON/CONPDB/INPROB( 7),VCL( 6,76),DTUP( 7),
1      PUPROB( 7),PLR( 6,76),PPR( 7),
2      INPROB( 7),TAL( 6,76),TJMR( 7),INR( 7),
3      SRR( 7),SLR( 6,76),SCH( 7),SRR( 7)
COMMON/CONPL/PLTCT,PLVAP(13,4),LPI(13),LPL(13),
1      APLINT(13),APLDES(13),GCL(13),GLES(13)
COMMON/PLTSR/CINCHI( 7),CINAV( 7),CHUS( 7),
1      TACH( 7),TPACH( 7)
COMMON/PLTOPR/UPPER,L'NOPR( 1),NPLOPR( 1,13),
1      GFLINT( 1,13),GFLDST( 1,13),GIMP( 1,13),
2      NENOPR,NPLANT,DTMPLT(76)
COMMON/CONFIL/TIDPR,CCCTIL,CFR( 7),CTH( 7),PLPSR
IF (KUS.GT.0) GO TO 2
DISUL=.5
NEPSR=.12
R.ACIS,IGIINPLTOI
1001 FORMAT(1X,15)
DO 150 I=1,NPLTOT
  READ(5,1101)PLNAME(IOMPLT),INAME(1,4),LPI(IOMPLT),
1      LPL(IOMPLT),APLINT(IOMPLT),APLDES(IOMPLT),
2      GCL(IOMPLT),GLES(IOMPLT)
1101 FORMAT(4X,4A,2X,2I2X,E13.6),2X,2I2X,F5.2)
1100 CONTINUE
DO 1200 KP=1,NP
  READ(5,1201)CINPDB(KP),CINAV(KP),CHUSV(KP),FNCPU(KP),TRNGEN(KP)
1201 FORMAT(1X,3I4X,F5.2),4X,2I4X,F6.2)
1200 CONTINUE
READ(5,1301)PHYCAR,NUPPR
1301 FORMAT(4X,15,8X,14)
DO 1300 IUPPR=1,NUPPR
  READ(5,1301)LNOPR(IUPPR),NPLOPR(IUPPR)
1301 FORMAT(4X,14,4X,13)
IF (NPLCPH(IUPPR).LE.0) GO TO 1300
NPLANT=NPLOPR(IUPPR)
DO 1310 IPLANT=1,NPLANT
  READ(5,1311)IPLOPR(IUPPR,IPLANT),GFLINT(IUPPR,IPLANT),
1      GFLDST(IUPPR,IPLANT),CTMPLT(IUPPR,IPLANT)
1311 FORMAT(1X,13,4X,2I2X,E13.6),4X,F6.2)
1310 CONTINUE
1300 CONTINUE
WRITE(6,1401)
1401 FORMAT(1H1,2X,76H0000000000 AGC GROUP PLANT AVOIDANCE AND SURVIVAL)
1L CHARACTERISTICS 0000000000)
DO 1400 KP=1,NP
  WRITE(6,1402)KP,(PDNAME(KP,INAME),INAME=1,4)

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1527 FORMAT(1X,'10% SENSORS TEMPERATURE RISE, DTMPCD =,F6.2,      PLTC1250
      1X,'(DEG F))                                          PLTC1260
1510 CONTINUE                                          PLTC1270
1500 CONTINUE                                          PLTC1280
C *****
      JN 1600 IX=1.4X                                          PLTC1290
      DTMP T(IX)=0.0                                          PLTC1300
1600 CONTINUE                                          PLTC1310
      NPI DAY=0                                          PLTC1320
      NFNPR=0                                          PLTC1330
      GO TO 9999                                          PLTC1340
2) CONTINUE                                          PLTC1350
      IF (NPI DAY.GT.0) GO TO 4                                          PLTC1360
      IF (NPI DAY.GT.0) GO TO 2001                                          PLTC1370
C IS THERE ENOUGH DAILY DATA TO SIMULATE THE DESIRED PLANT OPERATIONAL PERIOD?
      JN 2010 IOPPER=1,NOPPER                                          PLTC1380
      NPI DAY=NPI DAY+NGNPR(IOPPER)                                          PLTC1390
      IF (NPI DAY.GT.1000000) GO TO 2002                                          PLTC1400
2010 CONTINUE                                          PLTC1410
      GO TO 9999                                          PLTC1420
C *****
2001 CONTINUE                                          PLTC1430
      IF (IOPPER.IF.NPI DAY) GO TO 9000                                          PLTC1440
C DEFINE NEW PLANT OPERATIONAL PERIOD *****
      IOPPER=IOPPER+1                                          PLTC1450
      NPI DAY=NPI DAY+NGNPR(IOPPER)                                          PLTC1460
2002 CONTINUE                                          PLTC1470
      NFNPR=1                                          PLTC1480
      NPI DAY=NPI DAY+1                                          PLTC1490
C *****
      IF (NPI DAY.GT.0) GO TO 2009                                          PLTC1500
      JN 2020 IX=1.4X                                          PLTC1510
      DTMP T(IX)=0.0                                          PLTC1520
2020 CONTINUE                                          PLTC1530
      GO TO 9999                                          PLTC1540
2009 CONTINUE                                          PLTC1550
C CALCULATE DISCHARGE TEMPERATURE FROM OTHER PLANTS IN CERTAIN ELEMENTS *****
      JN 2100 IPLANT=1,NPLANT                                          PLTC1560
      IOPPLT=IPLANT-IOPPER+1                                          PLTC1570
      IXDIS=IOPDIS(IOPPLT)                                          PLTC1580
      DISTMP=DISDIL*(GFLDIS(IOPPER,IPPLT)/GFLDIS)                                          PLTC1590
1) DTMPCD(IOPPER,IPPLT)                                          PLTC1600
      DTMP T(IXDIS)=DTMP T(IXDIS)+DISTMP                                          PLTC1610
      JN 2110 IXD=1.10                                          PLTC1620
      IXUP=IXDIS-IXD                                          PLTC1630
      IF (IXUP.LE.0) GO TO 2115                                          PLTC1640
      XNDP=XI(IXUP)-XI(IXDIS)                                          PLTC1650
      FTRDUP=CTRTRDUP(IXUP)+XNDP(IXUP)                                          PLTC1660
      VFLDUP=GFL(IXUP)/ACR(IXUP)                                          PLTC1670
      DNDUP=DND(IXUP)                                          PLTC1680
      CEXDUP=(VFLDUP/(2.*FTRDUP))*SORT(1.,+4.,MCPSUMFTRDUP/                                          PLTC1690
      (DNDUP*(VFLDUP**2)))**1.)+1.)+XNDP                                          PLTC1700
      DTMP T(IXUP)=DTMP T(IXUP)+DISTMP*(FTRDUP/XNDP)                                          PLTC1710
2115 CONTINUE                                          PLTC1720
      IXDN=IXDIS+IXD                                          PLTC1730
      IF (IXDN.GT.0) GO TO 2110                                          PLTC1740
      XNDN=XI(IXDN)-XI(IXDIS)                                          PLTC1750
      FTRDND=CTRTRDUP(IXDN)+XNDN(IXDN)                                          PLTC1760
      VFLDND=GFL(IXDN)/ACR(IXDN)                                          PLTC1770
      DNDND=DND(IXDN)                                          PLTC1780
      CFXDND=(VFLDND/(2.*FTRDND))*SORT(1.,+4.,MCPSUMFTRDND/                                          PLTC1790
      (DNDND*(VFLDND**2)))**1.)+1.)+XNDN                                          PLTC1800
      DTMP T(IXDN)=DTMP T(IXDN)+DISTMP*(1./FTRDND)                                          PLTC1810
2110 CONTINUE                                          PLTC1820
2100 CONTINUE                                          PLTC1830
C *****
      GO TO 9999                                          PLTC1840
4) CONTINUE                                          PLTC1850
C TEST TEMPERATURE, SALINITY, AND MOBILITY CONDITIONS TO CALCULATE LIFE-SPAN

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C   RATE IN THE PLANT INTAKE AND DISCHARGE ELEMENTS *****
IX: 4000 IPLANT=1,NPLANT
IDNPLT=IPL3PRI(IOPPER,IPLANT)
IXINT=IXPINT(IDNPLT)
IXDIS=IXDIS(IDNPLT)
IXINT=DX(IXINT)
ACRINT=ACR(IXINT)
OXDIS=OX(IXDIS)
ACRDIS=ACR(IXDIS)
TMPINT=TMP(IXINT)
SLNINT=SLN(IXINT)
VELINT=GFLINT(IOPPER,IPLANT)/APLINT(IDNPLT)
TMPDIS=TMPINT+TMPCD(IOPPER,IDNPLT)
ON 4100 KP=1,NP
IF(KPMOB(KP).LE.0)GO TO 4117
IF(TMPINT.LE.TMMOB(KP))GO TO 4117
IF(TMPINT.GE.TOLMOB(KP))GO TO 4111
CORTMP=(TMPINT-TMMOB(KP))/(TOLMOB(KP)-TMMOB(KP))
GO TO 4114
4111 IF(TMPINT.GT.TMMOB(KP))GO TO 4112
CORTMP=1.0
GO TO 4114
4112 IF(TMPINT.GE.TMMOB(KP))GO TO 4117
CORTMP=(TMPINT-TMMOB(KP))/(TOLMOB(KP)-TMMOB(KP))
4114 CONTINUE
CORSLN=1.0
IF(SLNINT.LE.SMMOB(KP))GO TO 4118
IF(SLNINT.GE.SOLMOB(KP))GO TO 4115
CORSLN=1.-0.5*(SLNINT-SMMOB(KP))/(SOLMOB(KP)-SMMOB(KP))
GO TO 4118
4115 IF(SLNINT.GT.SMMOB(KP))GO TO 4116
CORSLN=0.5
GO TO 4118
4116 IF(SLNINT.GE.SMMOB(KP))GO TO 4118
CORSLN=1.-0.5*(SLNINT-SMMOB(KP))/(SOLMOB(KP)-SMMOB(KP))
GO TO 4118
4117 CORMOB=0.0
GO TO 4119
4118 CONTINUE
CORMOB=CORTMP*CORSLN*VELMOB(KP)/VELINT
IF(CORMOB.GT.1.0) CORMOB=1.0
4119 CONTINUE
CORINT=GFOINT(IPLANT)*CINPONI(KP)*(1.-CINAVD(KP)*CORMOB)
PONINT=CORINT*PON(KP,IXINT)
IF(TMPDIS.GT.TMXCND(KP))GO TO 4122
CORTMP=1.0
GO TO 4129
4122 IF(TMPDIS.GE.TMXCND(KP))GO TO 4123
CORTMP=(TMPDIS-TMXCND(KP))/(TMXCND(KP)-TMXCND(KP))
GO TO 4129
4123 CORTMP=0.0
4129 CONTINUE
CORDIS=GENDISI(IPLANT)*CORTMP
PONDIS=CNDISV(KP)*CORDIS*PONINT
FNCPON(KP,IXINT)=FNCPON(KP,IXINT)+(1./IXINT)*ACRINT
) *GFLINT(IOPPER,IPLANT)*(PONINT-PON(KP,IXINT))
FNCPON(KP,IXDIS)=FNCPON(KP,IXDIS)+(1./IXDIS)*ACRDIS
) *GFLDIS(IOPPER,IPLANT)*(PONDIS-PON(KP,IXDIS))
4100 CONTINUE
4000 CONTINUE
C *****
GO TO 9999
2999 WRITE(6,2991)IDAYIV,NPLDAY
2991 FORMAT(1H0,93H***** NOT ENOUGH DAILY DATA FOR PLANT OPERATION*****
) CONDITIONS ***** DAYS FOR Y-D-Y, IDAYIV =.14,2X,20H***** LAST DATA
2DAY, NPLDAY =.14)
CALL EXIT
9000 NENOPR=0
9999 RETURN
END

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SUBROUTINE TRACON
C TRACON FURNISHES SOLUTION WITH THE TRIUTARY CONTRIBUTIONS TO THE LIFE STAGE
C POPULATION RATES
COMMON/CONTROL/KRUN, NP, NINTC, NX, NC, NXC, NT, NTW, T
COMMON/CALDAT/AMONTH(12,3), NMDAY(12), LFAPYR
COMMON/DATIME/IDAYJY, JMDAY, INYFAR, IMONTH, IMNDAY, THRDAY
COMMON/GENCRS/XC(77), ACC(77), DM(77), ASC(77), GMC(77), RSC(77)
COMMON/GENELM/X(76), DX(76), ACR(76), DM(76), ASR(76), GMR(76), RSH(76)
COMMON/CONFEM/GFR(76), VLT(76), TMP(76), SLN(76)
COMMON/PONSDI/PONI(7,76), FNCPONI(7,76), FRRPONI(7,76)
COMMON/EGGSOL/EGGI(76), FNCGGI(76), FRRGGI(76)
COMMON/CONTRB/NTRA, ITRA(7), GFLTRA(7), PDNTRA(7,7)
IF(KRUN-GT,0)GO TO 2
NTRA=1
ITRB(1)=1
DO 1010 KP=1, NP
PDNTRA(KP,1)=0.0
1010 CONTINUE
GO TO 9999
2 CONTINUE
GFLTRA(1)=GFR(1)
DO 2000 IITRA=1, NTRA
ITRB=ITRA(IITRA)
DITRB=DX(ITRB)
ACITRB=ACR(ITRB)
DO 2010 KP=1, NP
FNCPONI(KP, IITRB)=FNCPONI(KP, IITRB)+(1./(DITRB*ACITRB))
*GFLTRA(IITRB)*(PDNTRA(KP, IITRB)-PDN(KP, IITRB))
2010 CONTINUE
2000 CONTINUE
9999 RETURN
END

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SUBROUTINE OUTPUT
C OUTPUT TESTS CERTAIN FLAGS (IWRITE, ISTORE, IPUNCH) TO DECIDE WHAT TYPE OF
C OUTPUT TO GIVE
COMMON/CONTROL/KRUN, NP, NINTC, NX, NC, NXC, NT, NTW, T
COMMON/CALDAT/AMONTH(12,3), NMDAY(12), LFAPYR
COMMON/DATIME/IDAYJY, JMDAY, INYFAR, IMONTH, IMNDAY, THRDAY
COMMON/GENCRS/XC(77), ACC(77), DM(77), ASC(77), GMC(77), RSC(77)
COMMON/GENELM/X(76), DX(76), ACR(76), DM(76), ASR(76), GMR(76), RSH(76)
COMMON/CONFEM/GFR(76), VLT(76), TMP(76), SLN(76)
COMMON/CONCRS/GFC(77), VLC(77), TMC(77), SLC(77)
COMMON/PONSDI/PONI(7,76), FNCPONI(7,76), FRRPONI(7,76)
COMMON/EGGSOL/EGGI(76), FNCGGI(76), FRRGGI(76)
COMMON/GRUPSP/ONAME(7,4), MINDAY(7), MAXDAY(7), NSPDAY
COMMON/CONFUP/PONIF(X(7), PDNUPSI(7), PDNONSI(7), PDNONXI(7))
COMMON/PUTOUT/IWRITE, ISTORE, IPUNCH, XMP(76), TOTPONI(7), SFRPONI(7)
COMMON/CYPLDT/INTAPE, IPDIST, IPNDIS, IPDGIS, IPNTIN, IPDTIN, IPNTOT
IF(KRUN-1)1, 2, 3
1 CONTINUE
UPSI4H=0.5
DNX=NX
DMSIPH=DNX*0.5
XMPHAT=X(NC)
XMP(1)=(XC(1)-XMPHAT)/5280.
DO 1100 IXC=2, NC
IX=IXC-1
XMP(IX)=(X(IX)-XMPHAT)/5280.
1100 CONTINUE
XMP(NXC)=0.0
IF(IWRITE.LE,0)GO TO 1900
WRITE(6,1001)
1001 FORMAT(1H1, 24X, 7H***** TIDAL AVERAGED GEOMETRIC PROPERTIES
IF THE ELEMENTS *****
WRITE(6,1002)

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1002 FORMAT(1H0,1X,7MELEMENT,1X,12HLOCATION(MFT),3X,10HLENGTH(FT),4X,      OUTPUT 320
14HDEPTH(FT),5X,11HAREA(FT**2),1X,14HVOLUME(FT**3),1X,      OUTPUT 330
21H AVERAGE WIDTH(FT),1X,12H SURFACE WIDTH(FT),2X,11H SMOOT RATIO)      OUTPUT 340
WRITE(6,1003)      OUTPUT 350
1003 FORMAT(1H ,3X,2HIX,7X,5HX(1X),8X,6HX(1X),8X,7HDMB(1X),7X,      OUTPUT 360
17HACR(1X),7X,7HVCRI(1X),9X,7HACRI(1X),10X,7HRSR(1X),10X,7HRSN(1X),/ )      OUTPUT 370
DO 1200 IX=1,NX      OUTPUT 380
DX(IX)=DX(IX)      OUTPUT 390
DMB(IX)=DMB(IX)      OUTPUT 400
ACR(IX)=ACR(IX)      OUTPUT 410
VCR(IX)=DX(IX)*ACR(IX)      OUTPUT 420
RCR(IX)=ACR(IX)/DMB(IX)      OUTPUT 430
WRITE(6,1201)IX,X(IX),DX(IX),DMB(IX),ACR(IX),VCR(IX),      OUTPUT 440
RCR(IX),RSR(IX),RSN(IX)      OUTPUT 450
1201 FORMAT(1H ,2X,I3,3X,E13.6,1X,E13.6,1X,F13.6,1X,E13.6,1X,F13.6,2X,      OUTPUT 460
1E13.6,5X,E13.6,4X,E13.6,4X,F13.6)      OUTPUT 470
1200 CONTINUE      OUTPUT 480
1900 CONTINUE      OUTPUT 490
IF(ISTJRF.GT.0) CALL STJFR      OUTPUT 500
GO TO 9999      OUTPUT 510
2 CONTINUE      OUTPUT 520
CALL PROCON      OUTPUT 530
IF(1WRITE.LE.0) GO TO 2900      OUTPUT 540
WRITE(6,2001)IDAYNY,JULDAY,THURDAY,1MNDAY,      OUTPUT 550
1 (AMONTH(1MONTH,1NAME),1NAME=1,3),1MYEAR      OUTPUT 560
2001 FORMAT(1H1,2X,48H***** DAYS AFTER START OF SPANNING YEAR, 1DAYNY =,      OUTPUT 570
14,2X,25H***** JULIAN DAY, JULDAY =,14,2X,11H***** DATE :,F4.2,      OUTPUT 580
25H HOUR,13,344,15)      OUTPUT 590
WRITE(6,2002)      OUTPUT 600
2002 FORMAT(1H0,20X,72H***** TIDAL AVERAGED PHYSICAL CONDITIONS 1MNDAY      OUTPUT 610
6 THE ELEMENTS ***** )      OUTPUT 620
WRITE(6,2003)      OUTPUT 630
2003 FORMAT(1H0,1X,7MELEMENT,2X,12HLOCATION(MFT),2X,76H FRESH WATER FLOW      OUTPUT 640
1RAT(F/CF5),2X,24H MAXIMUM TIDAL SPEED(FPS),2X,18H TEMPERATURE(DEC F),      OUTPUT 650
23X,12H SALINITY( )      OUTPUT 660
WRITE(6,2004)      OUTPUT 670
2004 FORMAT(1H ,3X,2HIX,8X,5HX(1X),15X,7H GFR(1X),20X,7H VLT(1X),16X,      OUTPUT 680
17H TMP(1X),11X,7H SLN(1X),/)      OUTPUT 690
DO 2010 IX=1,NX      OUTPUT 700
GFR(IX)=GFR(IX)/3600,      OUTPUT 710
VLT(IX)=VLT(IX)/3600,      OUTPUT 720
WRITE(6,2011)IX,X(IX),GFR(IX),VLT(IX),TMP(IX),SLN(IX)      OUTPUT 730
2011 FORMAT(1H ,2X,I3,4X,E13.6,8X,E13.6,14X,F13.6,10X,F13.6,5X,F13.6)      OUTPUT 740
2010 CONTINUE      OUTPUT 750
WRITE(6,2005)      OUTPUT 760
2005 FORMAT(1H0,8X,103H***** TOTAL NUMBER OF SPANNED EGGS AND POPULATION      OUTPUT 770
BLATION DENSITY OF AGE GROUPS IN THE ELEMENTS ***** )      OUTPUT 780
WRITE(6,2021)(PDNAME(KP,1),PDNAME(KP,2),PDNAME(KP,3),      OUTPUT 790
1 PDNAME(KP,4),KP=1,5)      OUTPUT 800
2021 FORMAT(1H0,1X,7MELEMENT,2X,12HLOCATION(MFT),2X,12H SPANNED EGGS,2X,      OUTPUT 810
15(4A4))      OUTPUT 820
WRITE(6,2022)(KP,KP=1,5)      OUTPUT 830
2022 FORMAT(1H ,3X,2HIX,8X,5HX(1X),9X,7HEGG(1X),4X,5(2X,4H PDN(13,      OUTPUT 840
14H,1X),3X),/)      OUTPUT 850
TOTEGG=0.0      OUTPUT 860
WRITE(6,2023)UPSTIM,XMP(1),(PDNUPSI(KP),KP=1,5)      OUTPUT 870
2023 FORMAT(1H ,F5.1,4X,E13.6,1X,I3X,2X,5(1X,E13.6,2X))      OUTPUT 880
DO 2020 IX=1,NX      OUTPUT 890
IXC=IX+1      OUTPUT 900
WRITE(6,2024)IX,XMP(IX),EGG(IX),(PDN(KP,IX),KP=1,5)      OUTPUT 910
2024 FORMAT(1H ,2X,I3,4X,E13.6,641X,E13.6,2X))      OUTPUT 920
TOTEGG=TOTEGG+EGG(IX)      OUTPUT 930
2020 CONTINUE      OUTPUT 940
WRITE(6,2023)ONSPIN,XMP(NXC),(PDNONSI(KP),KP=1,5)      OUTPUT 950
IF(1NPLAST.LE.5) GO TO 2105      OUTPUT 960
NPSTRT=0      OUTPUT 970
2100 NPSTRT=NPSTRT+6      OUTPUT 980
NPLAST=NPSTRT+5      OUTPUT 990
IF(1NPLAST.LE.NP) GO TO 2102      OUTPUT 1000
NPLAST=NP      OUTPUT 1010

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	SUBROUTINE INITIAL	INIT	10
C	INITAL READS THE STARTING TIME AND INITIAL EGG AND LIFE-STAGE DENSITIES AT		
C	THE STARTING TIME		
	COMMON/CONTRL/ARUN, NP, NINTC, NX, NC, NRC, NY, NTW, T	INIT	20
	COMMON/CALDAT/AMONTH(12), NMNDAY(12), IEAPYR	INIT	30
	COMMON/DATIME/IDAY, Y, JULDAY, INYFAR, IYMONTH, IMNDAY, THURDAY	INIT	40
	COMMON/PDMSOL/PDNI (7, 76), FNC PDNI (7, 76), FRF PDNI (7, 76)	INIT	50
	COMMON/EGGSOL/EGGI (76), FNC EGGI (76), FRF EGGI (76)	INIT	60
	READ(5, 1001) INYFAR, (IEAPYR, IYMONTH, IMNDAY, THURDAY	INIT	70
1001	FORMAT(10X, 15, 2X, 12, 4X, 15, 2X, 13, 2X, 6, 7)	INIT	80
	ON 3100 IX=1, NX	INIT	90
	READ(5, 3101) EGGI (IX), (PDNI (KP, IX), KP=1, NP)	INIT	100
3101	FORMAT(8X, 5(1X, F13, 6)/8X, 5(1X, F13, 6))	INIT	110
3100	CONTINUE	INIT	120
	CRPDNI=2.2	INIT	130
	ON 3900 IX=1, NX	INIT	140
	PDNI (7, IX)=CRPDNI*PDNI (7, IX)	INIT	150
3900	CONTINUE	INIT	160
	RETURN	INIT	170
	END	INIT	180

[illegible]

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2055 CONTINUE                                STOR 720
      GC TC 2210                             STOR 730
2060 CONTINUE                                STOR 740
      IASLG=C.O                               STOR 750
      DC 2000 IX=2,NX,5                       STOR 760
      IXSEG=IASLG+1                           STOR 770
      DO 2100 KP=1,6                           STOR 780
        PNASG(KP,IXSEG,ITDAY)=PCN(KP,IX)*VCR(IX)+PLN(KP,IX+1)*VCR(IX+1)+ STOR 790
        EPDN(KP,IX+2)*VC<(IX+2)+PDN(KP,IX+3)*VCR(IX+3)+PLN(KP,IX+4)*VCR(IX+4)+ STOR 800
        64)                                     STOR 810
        PDNSG(KP,IXSEG,ITDAY)=PNASG(KP,IXSEG,ITDAY)/VAC(IXSEG) STOR 820
2100 CONTINUE                                STOR 830
      WRITE(6,2101) ITDAY,IXSEG,(PNASG(KP,IXSEG,ITDAY),KP=1,6) STOR 840
2101 FORMAT(1H ,IX,12,7X,12,7X,7(E13.6,3X)) STOR 850
2000 CONTINUE                                STOR 860
      WRITE(6,2102) (KP,KP=1,6)              STOR 870
2102 FORMAT(1H0,77,6H ITDAY,3X,5H IASLG,6(7X,1HPDASEG,11,1H),77) STOR 880
      NUP=IASLG                               STOR 890
      DO 2200 IXSEG=1,NUP                     STOR 900
        WRITE(6,2101) ITDAY,IXSEG,(PDNSG(KP,IXSEG,ITDAY),KP=1,6) STOR 910
2200 CONTINUE                                STOR 920
2210 CONTINUE                                STOR 930
      DC 2250 KP=1,6                           STOR 940
      IF(IPCIST.GT.0.AND.IPNDIS.LT.1.AND.IPCUIS.LT.1.AND.PDNPA(KP).NE. STOR 950
      6PUNPLT) CALL CPLCTS(SMILES,PDNAVG,PNAVC,SC-LE1,KP,ITAVG) STOR 960
2250 CONTINUE                                STOR 970
      IF(IPCIST.GT.0.AND.IPNDIS.LT.1.AND.IPCUIS.LT.1) GO TO 999 STOR 980
      IF(ITDAY.LT.7) GC TC 9999               STOR 990
      ITAVG=ITAVG+1                           STOR1000
      LTWLC=ITAVG                             STOR1010
      WRITE(6,2301) (KP,KP=1,6)              STOR1020
2301 FORMAT(1H1,5H ITAVG,3X,5H IXSEG,6(7X,7HPNAVG,11,1H),7X,6HPNJUV, STOR1030
      677)                                     STOR1040
      PNMMA(1)=C.O                             STOR1050
      PNMMA(2)=C.O                             STOR1060
      PNMMA(3)=C.O                             STOR1070
      PNMMA(4)=C.O                             STOR1080
      PNMMA(5)=C.O                             STOR1090
      PNMMA(6)=C.O                             STOR1100
      DC 2350 IXSEG=1,NUP                     STOR1110
      PNAJUV(IXSEG)=C.O                       STOR1120
      PDNJUV(IXSEG)=C.O                       STOR1130
2350 CONTINUE                                STOR1140
      DC 2400 IXSEG=1,NUP                     STOR1150
      DO 2500 KP=1,6                           STOR1160
        PNAVG(KP,IXSEG,ITAVG)=(PNASG(KP,IXSEG,1)+PNASG(KP,IXSEG,2)+ STOR1170
        6PNASG(KP,IXSEG,3)+PNASG(KP,IXSEG,4)+PNASG(KP,IXSEG,5)+PNASG(KP,IXSEG,6)+ STOR1180
        6,IXSEG,6)+PNASG(KP,IXSEG,7))/7.0 STOR1190
        PNNTOT(KP,ITAVG)=PNNTOT(KP,ITAVG)+PNAVC(KP,IXSEG,ITAVG) STOR1200
        PNMMA(KP)=APAX1(PNMMA(KP),PNAVG(KP,IXSEG,ITAVG)) STOR1210
        PTIPAX(KP)=APAX1(PNMMA(KP),PTIPAX(KP)) STOR1220
        PDNAVG(KP,IXSEG,ITAVG)=(PCASEG(KP,IXSEG,1)+PCNSLG(KP,IXSEG,2)+ STOR1230
        6PDNSG(KP,IXSEG,3)+PDNSLG(KP,IXSEG,4)+PDNSLG(KP,IXSEG,5)+PDNSG(KP,IXSEG,6)+ STOR1240
        6,IXSEG,6)+PCNSG(KP,IXSEG,7))/7.0 STOR1250
        PADMAX(KP,ITAVG)=APAX1(PACMAX(KP,ITAVG),PDNAVG(KP,IXSEG,ITAVG)) STOR1260
        IF(PADMAX(KP,ITAVG).EQ.PDNAVG(KP,IXSEG,ITAVG)) IASMAX(KP,ITAVG)= STOR1270
        6IXSEG STOR1280
        IF(KP.LT.4) GC TC 2500                STOR1290
        PNAJUV(IXSEG)=PNAVG(KP,IXSEG,ITAVG)+PNAJUV(IXSEG) STOR1300
        PDNJUV(IXSEG)=PDNAVG(KP,IXSEG,ITAVG)+PDNJUV(IXSEG) STOR1310
2500 CONTINUE                                STOR1320
      PNJTCT(ITAVG)=PNNJUV(IXSEG)+PNJTCT(ITAVG) STOR1330
      WRITE(6,2101) ITAVG,IXSEG,(PNAVG(KP,IXSEG,ITAVG),KP=1,6), STOR1340
      6PNAJUV(IXSEG) STOR1350
2400 CONTINUE                                STOR1360
      PTOTAL(ITAVG)=PNNTOT(1,ITAVG)+PNNTOT(2,ITAVG)+PNNTOT(3,ITAVG)+ STOR1370
      6PNNTOT(4,ITAVG)+PNNTOT(5,ITAVG)+PNNTOT(6,ITAVG) STOR1380
      WRITE(6,2103) (PNNTCT(KP,ITAVG),KP=1,6),PNJTCT(ITAVG) STOR1390
2103 FORMAT(1H0,19X,7(E13.6,3X))           STOR1400
      WRITE(6,2501) (KP,KP=1,6)             STOR1410

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      DC 20CC IASEG=1,ANP                                STOR142C
      WRITE(6,21C1) ITAVG,IXSEG,(PDNAVG(KP,IXSEG,ITAVG),KP=1,6), STOR1430
      (PDNAVG(IASEG))                                       STOR1440
2501 FORMAT(1H,////,6H ITAVG,3X,5H IASEG,6(7X,7HPDNAVG(1,1,1H)),7X,6H STOR1450
      (PDNAVG,///))                                       STOR1460
2600 CONTINUE                                           STOR1470
      WRITE(6,21C3) (PADMAX(KP,ITAVG),KP=1,6)             STOR1480
      WRITE(6,21C4) (IXSPAX(KP,ITAVG),KP=1,6)            STOR1490
21C4 FORMAT(1H,24X,6(13,13X))                          STOR1500
      DO 23CC KP=1,6                                       STOR1510
      PADPXX(KP)=APAX1(PACPXX(KP),PADMAX(KP,ITAVG))      STOR1520
      IF(PACPXX(KP).EQ.PADMAX(KP,ITAVG)) IXSPXX(KP)=IXSPAX(KP,ITAVG) STOR1530
      IF(PACPXX(KP).EQ.PADMAX(KP,ITAVG)) IXCXX(KP)=ITAVG STOR1540
      IF((IPCCIS.GT.0.CR.(PNCIS.GT.0).AND.PNAPAX(KP).GT.PLFACT) STOR1550
      CALL DPLCTS(SPILES,PDNAVG,PNAVG,SCALE1,KP,ITAVG)    STOR1560
2300 CONTINUE                                           STOR1570
      ITDAY=C                                             STOR1580
      GO TO 9999                                           STOR1590
3 CONTINUE                                              STOR1600
      IF(IPCIST.GT.0.AND.IPCDIS.LT.1.AND.IPDUS.LT.1) GO TO 9999 STOR1610
      WRITE(6,30C1)                                       STOR1620
30C1 FORMAT(1H,73H***** MAX(MUP 5-ELEMENT AVERAGES PER CUBIC FOOT OVER STOR1630
      & THE TIME CYCLE *****))                         STOR1640
      DO 3200 KP=1,6                                       STOR1650
      WRITE(6,30C2) KP,PACPXX(KP),IXSPXX(KP),IXCPXX(KP) STOR1660
3200 CONTINUE                                           STOR1670
3002 FORMAT(1H,15H***** PDNAVG(1,1,4H) = ,E13.6,12H FOR SEGMENT,1), STOR1680
      (12H DURING WEEK,1))                                STOR1690
      WRITE(6,31C1)                                       STOR1700
31C1 FORMAT(1H,5HITAVG,5X,9HPNNTOT(1),6X,9HPNNTOT(2),6X,9HPNNTOT(3),6X,9HPNNTOT(4),6X,9HPNNTOT(5),6X,9HPNNTOT(6),7X,6HPNNTOT,9X,6HPNNTOTAL STOR1710
      &,///))                                              STOR1720
      DO 33CC ITAVG=1,LTWEEK                               STOR1730
      WRITE(6,32C1) ITAVG,(PNNTCT(KP,ITAVG),KP=1,6),PNJCTCT(ITAVG), STOR1740
      (PTCTAL(ITAVG))                                     STOR1750
3300 CONTINUE                                           STOR1760
32C1 FORMAT(1H,1X,12,5X,E13.6,7(2X,E13.6))             STOR1770
      IXBEG=1                                             STOR1780
      IXEND=15                                           STOR1790
      DO 30CC KP=1,6                                       STOR1800
      IF(IPNTIM.GT.0.OR.(IPOTIM.GT.0.CR.(IPNTCT.GT.0)) STOR1810
      CALL IPLOTS(PNAVG,PDNAVG,PNNTOT,SCALE1,SCALE2,YMAX1,SCALE1,KP, STOR1820
      (IXBEG,IXEND))                                     STOR1830
3000 CONTINUE                                           STOR1840
9999 RETURN                                             STOR1850
      END                                                 STOR1860

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      SUBROUTINE DPLOTS(SMILES,PDNAVG,PNAVG,SCALE1,KP,ITAVG) DPLO 10
C ***** PCULATIONS ARE PLOTTED AGAINST DISTANCE FROM BATTERY ***DPLO 20
C IF IPOIST GT 0 AND IPCDIS LT 1 AND IPNCIS LT 1, PDN PLOTS ARE GIVEN DPLO 30
C IF IPCDIS GT 0, PDNAVG PLOTS ARE GIVEN FOR EACH ITAVG (WEEK) DPLO 40
C IF IPNCIS GT 0, PNAVG PLOTS ARE GIVEN FOR EACH ITAVG (WEEK) DPLO 50
C *****DPLO 60
      LOGICAL*1 A,BLANK,SYMB,ISYP(6)                    CPLO 70
      COMMON/CONTRL/KRUN,NP,NINTC,NX,NC,NXC,NT,NTH,T DPLO 80
      COMMON/CALDAT/APONTH(12,3),NMDAY(12),LEAPYR DPLO 90
      COMMON/DATIME/IDAYOY,JULDAY,INYEAR,INCNTN,INMDAY,THRDAY DPLO 100
      COMMON/PONSOL/PONI(7,76),FNCPODI(7,76),ERRPDI(7,76) DPLO 110
      COMMON/GRGUPS/PONAME(7,4),MINDAY(7),MAXDAY(7),NSPDAY DPLO 120
      COMMON/CGNEND/PONUPX(7),PCNUPS(7),PCNONS(7),PONONX(7) DPLO 130
      COMMON/PUTGUT/INWRITE,ISTORE,IPUNCH,XMP(78),TCTPDI(7),SERPDI(7) DPLO 140
      COMMON/CNPLOT/INTAPE,IPOIST,IPNDIS,IPDDIS,IPNTIM,IPDTIM,IPNTOT DPLO 150
      COMMON/RANGES/XPIN,XMAX,XRANGE,YPIN,YMAX,YRANGE DPLO 160
      COMMON/LIMITS/PDNNAX,PNNX,LTWEEK DPLO 170
      COMMON/PLDATA/DUM(78),XPLOT(78),NCL(7),NR(8),A(51,120) DPLO 180
      DIMENSION PNAVG(6,15,24),PDNAVG(6,15,24),SMILES(75) DPLO 190

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DIMENSION TITLE1(6),TITLE2(7),TITLE3(11)
DATA TITLE1/24P NUMBER PER CUBIC FEET */
DATA TITLE2/20P 5-ELEMENT AVERAGE NUMBER * /
DATA TITLE3/44P 5-ELEMENT AVERAGE NUMBER PER CUBIC FEET * /
DATA NC1/26/,NCD/13/,NM1/1/,NM2/7/
DATA BLANK/1P /,ISYM/1P/,IPY,1P/,1P0,1P2,1P3/
IF(NM1.GT.0)GO TO 2
1 CONTINUE=
NS=75
APIN=-152.0
XMAX=C.
NRCW=E
NCC=1
DO 11CC IRCW=1,NRCW
NR(IIRC)=NR1+(IIRC-1)*NRD
1100 CONTINUE=
NCL(1)=27
DO 12CC ICCL=2,NCL
NCL(ICCL)=NCL1+(ICCL-1)*NCL
1200 CONTINUE=
GO TO 5599
2 CONTINUE=
SCAFCT=1.0E+03
IF(IPY.GE.3)SCAFCT=1.0E+04
DO 21CC I=1,51
DO 21CC J=1,120
2100 A(I,J)=BLANK
SYMB=(SYM(KP))
IF(IIPNCIS.GT.0)GO TO 2500
IF(IIPCCIS.GT.0)GO TO 2900
YMAX=PNMAX*SCAFCT
DUP(I)=PDUP(KP)*SCAFCT
DUP(IAC)=PDUCAS(KP)*SCAFCT
UU 22CC IX=2,AC
IC=IX-1
XPLCT(IC)=XPP(IC)
DUP(IX)=PDUP(KP,IC)*SCAFCT
2200 CONTINUE=
XPLCT(NC)=XPP(NC)
APLCT(IAC)=XPP(IAC)
CALL PLOT(NRCW,NCOL)
CALL CLVNT(NRCW,NCOL)
CALL FLCTAY(IAC,NRCW,NCOL,SYMB)
WRITE(6,2201)TITLE1,SCAFCT
2201 FORMAT(1H1,/,/,51X,6A4,1P0.1,/)
DO 2400 I=1,51
WRITE(6,2202)(A(I,J),J=1,120)
2400 CONTINUE=
2202 FORMAT(1H ,12CA1)
WRITE(6,2203)
2203 FORMAT(1H ,26X,4HTRCY,67X,7HBATTERY)
WRITE(6,2206)
2206 FORMAT(1H ,40X,29HDISTANCE FROM BATTERY (PILES),/)
WRITE(6,2204)(PDNAME(KP,INAME),INAME=1,4),I
2204 FORMAT(1H0,11HAGE GROUP :,4A4,11H AT TIME = ,E10.3,4H HRS)
WRITE(6,2207)ICAYGY,JULDAY,THRDAY,IMNCAY,
1 (APGNTH(IIPCNTH,INAME),INAME=1,3),INYEAR
2207 FORMAT(1H0,2X,4H**** DAYS AFTER START OF SPANNING YEAR, 1GAYGY =,
114,2X,25H**** JULIAN DAY, JULDAY =,14,2X,11H**** DATE :,F6.2,
25H HOUR,13,3A4,15)
GO TO 5599
2500 YMAX=PNMX*SCALE1
IXSEG=0
DO 2600 IX=2,AX,5
IXSEG=IXSEG+1
DUP(IX-1)=PNNAVG(KP,IXSEG,ITAVG)*SCALE1
DUP(IX)=PNNAVG(KP,IXSEG,ITAVG)*SCALE1
DUP(IX+1)=PNNAVG(KP,IXSEG,ITAVG)*SCALE1
DUP(IX+2)=PNNAVG(KP,IXSEG,ITAVG)*SCALE1
DUP(IX+3)=PNNAVG(KP,IXSEG,ITAVG)*SCALE1

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CPL0 880
CPL0 890

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2600 CONTINUE
      DC 2700 IX=1,NS
      XPLCT(IX)=SPILES(IX)
2700 CONTINUE
      CALL PLCT(ARCH,NCUL)
      CALL CNVRT(ARCH,NCCL)
      CALL PLCTXY(NS,ARCH,NCCL,SYMB)
      WRITE(6,2701)TITLE2,SCALE1
2701 FORMAT(1H1,/,/,49A,74A,1PE2.1,/)
      DC 2800 I=1,51
      WRITE(6,2802)(A(I,J),J=1,120)
2800 CONTINUE
      WRITE(6,2803)
      WRITE(6,2806)
      WRITE(6,2805)(PCNAPE(KP,INAME),INAME=1,4),ITAVG
2805 FORMAT(1H ,11HAGE GROUP : ,4A4,1CH FOR WEEK ,13)
      WRITE(6,2807)ICAYCY,JULDAY,IMHDAY,IPNCAY,
      1 (AMONTH(IPMONTH,INAME),INAME=1,3),INYEAR
      IF(IPEEIS.LT.1)GO TO 9999
2900 YMAX=PCNAPE*SCAFCT
      IXSEG=0
      DO 2950 I=1,51
      DO 2950 J=1,120
2950 A(I,J)=41AAK
      DC 2910 IX=2,AX,5
      IXSEG=IXSEG+1
      DUM(IX-1)=PCNAVG(KP,IXSEG,ITAVG)*SCAFCT
      DUM(IX)=PCNAVG(KP,IXSEG,ITAVG)*SCAFCT
      DUM(IX+1)=PCNAVG(KP,IXSEG,ITAVG)*SCAFCT
      DUM(IX+2)=PCNAVG(KP,IXSEG,ITAVG)*SCAFCT
      DUM(IX+3)=PCNAVG(KP,IXSEG,ITAVG)*SCAFCT
2910 CONTINUE
      DC 2920 IX=1,NS
      XPLCT(IX)=SPILES(IX)
2920 CONTINUE
      CALL PLCT(ARCH,NCUL)
      CALL CNVRT(ARCH,NCCL)
      CALL PLCTXY(NS,ARCH,NCCL,SYMB)
      WRITE(6,2921)TITLE3,SCAFCT
2921 FORMAT(1H1,/,/,41X,11A4,1PE8.1,/)
      DO 2930 I=1,51
      WRITE(6,2902)(A(I,J),J=1,120)
2930 CONTINUE
      WRITE(6,2903)
      WRITE(6,2906)
      WRITE(6,2905)(PCNAPE(KP,INAME),INAME=1,4),ITAVG
      WRITE(6,2907)ICAYCY,JULDAY,IMHDAY,IPNCAY,
      1 (AMONTH(IPMONTH,INAME),INAME=1,3),INYEAR
9999 RETURN
      END

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SUBROUTINE TPLOTS(IPNNAVG,PCNAVG,PNNTOT,SCALE1,SCALE2,YMAXT,SCALET,TPLO 10
(KP,XBEG,?ENC) TPLO 20
C ***** POPULATIONS ARE PLOTTED AGAINST THE WHOLE TIME PERIOD *****TPLO 30
C IF IPNTIM GT C, PNNAVG FOR EACH AGE GROUP IS PLOTTED BY SEGMENT TPLO 40
C IF IPDTIM GT C, PCNAVG FOR EACH AGE GROUP IS PLOTTED BY SEGMENT TPLO 50
C IF IPNTGT GT C, THE TCTAL NUMBER OF JUVENILES IS PLOTTED TPLO 60
C IF IPNTOT GT C, THE TOTAL OF ALL AGE GROUPS IS PLOTTED TPLO 70
C *****TPLO 80
LOGICAL*1 A,BLANK,SYMB,ISYP(8) TPLO 90
COMMON/GRUPS/PCNAPE( 7,4),MINDAY( 7),MAXDAY( 7),NSPDAY TPLO 100
COMMON/CNPLT/INTAPE,IPDIST,IPNDIS,IPDIS,IPNTIN,IPCTIN,IPNTOT TPLO 110
COMMON/LIMITS/PCNMAX,PNMX,LTIMEK TPLO 120
COMMON/PCPTOT/PNJTCT(24),PTOTAL(24) TPLO 130
COMMON/RANGES/XMIN,XMAX,XRANGE,YPIN,YMAX,YRANGE TPLO 140
COMMON/PLDATA/DUM(78),XPLDT(78),NCL(7),NR(8),A(51,120) TPLO 150

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DIMENSION PNAVG(6,15,24),PNA(6,15,24)
DIMENSION PNAIT(6,24)
DIMENSION IPLOTX(15)
DATA IPLOTX/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15/
DIMENSION TITLE(14),TITLE2(6),TITLE3(7),TITLE4(7),TITLE5(9)
DATA AC1/22,ACU/16,ARI/17,ANC/17
DATA CLANK/1P,ISYM/1P,IPV,IMP,IMI,IMZ,IMS,IMJ,IMI/
DATA TITLE1/18,AVERAGE SUPERN 0/
DATA TITLE2/32,AVERAGE SUPERN PER CUBIC FEET 0 /
DATA TITLE3/26,TOTAL NUMBER FOR AGE GROUP 0/
DATA TITLE4/26,TOTAL NUMBER OF JUVENILES 0 /
DATA TITLE5/26, TOTAL NUMBER FOR ALL AGE GROUPS 0 /
DIMENSION XFILE(515)
DATA XFILE5/-145,-135,-125,-115,-105,-95,-85,-75,-65,
6-55,-45,-35,-25,-15,-5./
DATA ICCUNT/7/
IF (ICOUNT.GT.0) GO TO 3000
ICOUNT=ICOUNT+1
YMAX1=PNA*SCALE1
YMAX2=PNA*SCALE2
XPI=0.0
XPA=24.0
NRGW=2
NCCL=1
DO 3100 INCW=1,NRGW
AP(INCW)=AP1+(INCW-1)*K40
3100 CONTINUE
DO 3200 JCCL=1,NCCL
ACL(JCCL)=ACL1+(JCCL-1)*NCCL
3200 CONTINUE
DO 3300 ITAVG=1,LTWEEK
XPLT(ITAVG)=ITAVG
3300 CONTINUE
3000 CONTINUE
SYN=ISYM(KP)
IF (IPDTIP.LT.1) GO TO 3300
DO 3400 IS=1,AGEG,IXEND
DO 3500 J=1,120
DO 3600 J=1,120
A(I,J)=BLANK
IXSEG=IPLOTX(15)
DO 3250 ITAVG=1,LTWEEK
DUM(ITAVG)=PNAVG(KP,IXSEG,ITAVG)*SCALE1
3250 CONTINUE
YMAX=YMAX1
CALL PLOT(NRGW,NCCL)
CALL CONVRT(NRGW,NCCL)
CALL PLOTXY(LTWEEK,NRGW,NCCL,SYN)
WRITE(6,3251)TITLE1,SCALE1
3251 FORMAT(1H1,/,55X,4A4,1PE6.1,/)
DO 3350 I=1,51
WRITE(6,3252)(A(I,J),J=1,120)
3350 CONTINUE
3252 FORMAT(1H ,120A1)
3253 FORMAT(1H ,67X,5PWEEKS,/)
WRITE(6,3253)
WRITE(6,3254)IPONAME(KP,INAME),INAME=1,4,XFILES(IXSEG)
3254 FORMAT(1H ,11PAGE GROUP :,4A4,F6.2,19P MILES FROM BATTERY)
3400 CONTINUE
3360 IF (IPDTIP.LT.1) GO TO 3510
DO 3500 IS=1,AGEG,IXEND
DO 3370 I=1,51
DO 3370 J=1,120
3370 A(I,J)=BLANK
IXSEG=IPLOTX(15)
DO 3450 ITAVG=1,LTWEEK
DUM(ITAVG)=PDNAV(KP,IXSEG,ITAVG)*SCALE2
3450 CONTINUE
YMAX=YMAX2
CALL PLOT(NRGW,NCCL)

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CALL CLCVRTINRCW,NCCL)	TPLO 360
CALL PLCTAYILTNEEK,NROW,NCCL,SYMB)	TPLO 370
WRITE(6,3452)TITLE2,SCALE2	TPLO 380
3452 FORMAT(1H1,/,47A,6A4,1PEB.1,/,)	TPLO 390
DO 3460 I=1,51	TPLO 400
WRITE(6,3252)(A(I,J),J=1,120)	TPLO 410
3460 CONTINUE	TPLO 420
WRITE(6,3253)	TPLO 430
WRITE(6,3254)(PCNAPE(KP,INAME),INAME=1,4),APILES(1XSCG)	TPLO 440
3500 CONTINUE	TPLO 450
3510 IF(1PNTOT.LT.1)GO TO 9999	TPLO 460
DO 3520 I=1,51	TPLO 470
DO 3520 J=1,120	TPLO 480
3520 A(I,J)=BLANK	TPLO 490
DO 3600 ITAVG=1,LTHEEK	TPLO 500
DUM(ITAVG)=PAATLT(KP,ITAVG)*SCALE1	TPLO 510
3600 CONTINUE	TPLO 520
YMAX=YMAX1	TPLO 530
CALL PLCT(NROW,NCCL)	TPLO 540
CALL CCNVRT(NROW,NCCL)	TPLO 550
CALL PLCTAYILTNEEK,NROW,NCCL,SYMB)	TPLO 560
WRITE(6,3601)TITLE3,SCALE1	TPLO 570
3601 FORMAT(1H1,/,47A,6A4,1PEB.1,/,)	TPLO 580
DO 3650 I=1,51	TPLO 590
WRITE(6,3252)(A(I,J),J=1,120)	TPLO 600
3650 CONTINUE	TPLO 610
WRITE(6,3253)	TPLO 620
WRITE(6,3651)(PCNAPE(KP,INAME),INAME=1,4)	TPLO 630
3651 FORMAT(1H1,/,47A,6A4,1PEB.1,/,)	TPLO 640
IF(KP.LT.6)GO TO 9999	TPLO 650
DO 3655 I=1,51	TPLO 660
DO 3655 J=1,120	TPLO 670
3655 A(I,J)=BLANK	TPLO 680
DO 3700 ITAVG=1,LTHEEK	TPLO 690
DUM(ITAVG)=PNJTOT(ITAVG)*SCALE1	TPLO 700
3700 CONTINUE	TPLO 710
SYMB=1SYMB(7)	TPLO 720
CALL PLCT(NROW,NCCL)	TPLO 730
CALL CCNVRT(NROW,NCCL)	TPLO 740
CALL PLCTAYILTNEEK,NROW,NCCL,SYMB)	TPLO 750
WRITE(6,3701)TITLE4,SCALE1	TPLO 760
3701 FORMAT(1H1,/,47A,6A4,1PEB.1,/,)	TPLO 770
DO 3750 I=1,51	TPLO 780
WRITE(6,3252)(A(I,J),J=1,120)	TPLO 790
3750 CONTINUE	TPLO 800
WRITE(6,3253)	TPLO 810
DO 3755 I=1,51	TPLO 820
DO 3755 J=1,120	TPLO 830
3755 A(I,J)=BLANK	TPLO 840
DO 3800 ITAVG=1,LTHEEK	TPLO 850
DUM(ITAVG)=PTOTAL(ITAVG)*SCALE1	TPLO 860
3800 CONTINUE	TPLO 870
SYMB=1SYMB(8)	TPLO 880
YMAX=YMAX1+1.5	TPLO 890
CALL PLCT(NROW,NCCL)	TPLO 900
CALL CCNVRT(NROW,NCCL)	TPLO 910
CALL PLCTAYILTNEEK,NROW,NCCL,SYMB)	TPLO 920
WRITE(6,3801)TITLE5,SCALE1	TPLO 930
3801 FORMAT(1H1,/,45X,9A4,1PEB.1,/,)	TPLO 940
DO 3850 I=1,51	TPLO 950
WRITE(6,3252)(A(I,J),J=1,120)	TPLO 960
3850 CONTINUE	TPLO 970
WRITE(6,3253)	TPLO 980
9999 RETURN	TPLO 990
END	


```

SUBROUTINE PLOT(A,M)
C ** THIS SUBROUTINE PLACES THE PLOT BOUNDARY CHARACTERS IN A **
LOGICAL*1 A,SYPRCH,SYPCCL
COMMON/PLDATA/CLM(78),XPLC(78),NCL(7),NR(8),A(51,120)
DATA SYPRCH/1H-/,SYPCCL/1H1/
NR1=NR(1)
NRA=NR(2)
NC1=NCL(1)
NCP=NCL(4)
IRCH=NR1
DO 110 J=NC1,NCP
110 A(IRCH,J)=SYPRCH
IRCH=NRA
DO 120 J=NC1,NCP
120 A(IRCH,J)=SYPRCH
JCOL=NC1
DO 130 I=NR1,NRA
130 A(I,JCOL)=SYPCCL
JCOL=NCP
DO 140 I=NR1,NRA
140 A(I,JCOL)=SYPCCL
RETURN
END

```

PLOT 10
PLOT 20
PLOT 30
PLOT 40
PLOT 50
PLOT 60
PLOT 70
PLOT 80
PLOT 90
PLOT 100
PLOT 110
PLOT 120
PLOT 130
PLOT 140
PLOT 150
PLOT 160
PLOT 170
PLOT 180
PLOT 190
PLOT 200
PLOT 210
PLOT 220
PLOT 230

```

SUBROUTINE PLOTXY(NN,N,M,E)
C ** THIS ROUTINE PLACES THE SCALED X,Y VALUES INTO ARRAY A **
LOGICAL*1 A,E
COMMON/RANGES/XPIN,XMAX,XRANGE,YPIN,YPAX,YRANGE
COMMON/PLDATA/CLM(78),XPLC(78),NCL(7),NR(8),A(51,120)
XN=NR(4)-NR(1)
YM=NCL(4)-NCL(1)
DO 100 I=1,NN
RXI=((XPLC(I))-XPIN)/XRANGE)*YM
CYI=((CLM(I))-YPIN)/YRANGE)*XN
KR1=RXI+.4999999
KCI=CYI+.4999999
IX=NCL(1)+KR1
LC=NR(4)-KCI
A(LC,IX)=E
100 CONTINUE
RETURN
END

```

PLXY 10
PLXY 20
PLXY 30
PLXY 40
PLXY 50
PLXY 60
PLXY 70
PLXY 80
PLXY 90
PLXY 100
PLXY 110
PLXY 120
PLXY 130
PLXY 140
PLXY 150
PLXY 160
PLXY 170
PLXY 180

SAMPLE BIOLOGICAL CONDITIONS AND PLANT CONDITIONS

***** AGE GROUP BIOLOGICAL CONDITIONS *****

**** SPAWNING CONDITIONS ****

**** KP = 7 **** **** DUMMY SPAWNING **** **** FROM 365 DAY TO 9999 DAY ****
 OPTIMUM SPAWNING RATE, ROPSPW = 0.240000E 02 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR SPAWNING, PCRSBW = 0.100000E 01 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR SPAWNING, PMSBW = 0.100000E 04 (NUMBER/PT**3)
 MINIMUM SPAWNING TEMPERATURE, TMSBW = 54.0 (DEG F)
 LOWER OPTIMUM SPAWNING TEMPERATURE, TOLSPW = 0.580000E 02 (DEG F)
 HIGHER OPTIMUM SPAWNING TEMPERATURE, TONSPW = 62.0 (DEG F)
 MAXIMUM SPAWNING TEMPERATURE, THSPW = 66.0 (DEG F)
 MINIMUM SPAWNING SALINITY, SMSBW = -0.2000E 01
 LOWER OPTIMUM SPAWNING SALINITY, SOLSPW = -0.1000E 01
 HIGHER OPTIMUM SPAWNING SALINITY, SONSPW = 0.1000E 01
 MAXIMUM SPAWNING SALINITY, SHSPW = 0.2000E 01

**** SURVIVAL CONDITIONS ****

**** KP = 1 **** **** EGG **** **** FROM 0 DAY TO 2 DAY ****
 OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.3600
 CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.100000E 02 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR SURVIVAL, PMSRV = 0.100000E 03 (NUMBER/PT**3)
 MINIMUM SURVIVAL TEMPERATURE, TMSRV = 10.0 (DEG F)
 LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
 HIGHER OPTIMUM SURVIVAL TEMPERATURE, TONSRV = 90.0 (DEG F)
 MAXIMUM SURVIVAL TEMPERATURE, THSRV = 99.0 (DEG F)
 MINIMUM SURVIVAL SALINITY, SMSRV = -0.2000E 01
 LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = -0.1000E 01
 HIGHER OPTIMUM SURVIVAL SALINITY, SONSRV = 0.1000E 01
 MAXIMUM SURVIVAL SALINITY, SHSRV = 0.2000E 01

**** KP = 2 **** **** YOLK SAC **** **** FROM 3 DAY TO 8 DAY ****
 OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.6000
 CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.350000E-01 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR SURVIVAL, PMSRV = 0.710000E-02 (NUMBER/PT**3)
 MINIMUM SURVIVAL TEMPERATURE, TMSRV = 10.0 (DEG F)
 LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
 HIGHER OPTIMUM SURVIVAL TEMPERATURE, TONSRV = 40.0 (DEG F)
 MAXIMUM SURVIVAL TEMPERATURE, THSRV = 99.0 (DEG F)
 MINIMUM SURVIVAL SALINITY, SMSRV = -0.2000E 01
 LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = -0.1000E 01
 HIGHER OPTIMUM SURVIVAL SALINITY, SONSRV = 0.1000E 01
 MAXIMUM SURVIVAL SALINITY, SHSRV = 0.2000E 01

**** KP = 3 **** **** LARVA **** **** FROM 9 DAY TO 10 DAY ****
 OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.7600
 CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.240000E-01 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR SURVIVAL, PMSRV = 0.560000E-02 (NUMBER/PT**3)
 MINIMUM SURVIVAL TEMPERATURE, TMSRV = 10.0 (DEG F)
 LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
 HIGHER OPTIMUM SURVIVAL TEMPERATURE, TONSRV = 40.0 (DEG F)
 MAXIMUM SURVIVAL TEMPERATURE, THSRV = 99.0 (DEG F)
 MINIMUM SURVIVAL SALINITY, SMSRV = -0.2000E 01
 LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = -0.1000E 01
 HIGHER OPTIMUM SURVIVAL SALINITY, SONSRV = 0.1000E 01
 MAXIMUM SURVIVAL SALINITY, SHSRV = 0.2000E 01

**** KP = 4 **** **** JUVENILE I **** **** FROM 11 DAY TO 70 DAY ****
 OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.9133
 CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.900000E-04 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR SURVIVAL, PMSRV = 0.180000E-02 (NUMBER/PT**3)
 MINIMUM SURVIVAL TEMPERATURE, TMSRV = 10.0 (DEG F)

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LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
HIGHER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 90.0 (DEG F)
MAXIMUM SURVIVAL TEMPERATURE, THRSRV = 99.0 (DEG F)
MINIMUM SURVIVAL SALINITY, SOLSRV = 0.2000E 01
LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
HIGHER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
MAXIMUM SURVIVAL SALINITY, SHRSRV = 0.2000E 01

**** RP = 5 ****      **** JUVENILE II ****      **** FROM 71 DAY TO 191 DAY ****
OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.9333
CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.580000E-04 (NUMBER/PT003)
MAXIMUM POPULATION DENSITY FOR SURVIVAL, PRHSRV = 0.120000E-02 (NUMBER/PT003)
MINIMUM SURVIVAL TEMPERATURE, THRSRV = 10.0 (DEG F)
LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
HIGHER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 90.0 (DEG F)
MAXIMUM SURVIVAL TEMPERATURE, THRSRV = 99.0 (DEG F)
MINIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
HIGHER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
MAXIMUM SURVIVAL SALINITY, SHRSRV = 0.2000E 01

**** RP = 6 ****      **** JUVENILE III ****      **** FROM 194 DAY TO 165 DAY ****
OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 0.9666
CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.220000E-04 (NUMBER/PT003)
MAXIMUM POPULATION DENSITY FOR SURVIVAL, PRHSRV = 0.450000E-03 (NUMBER/PT003)
MINIMUM SURVIVAL TEMPERATURE, THRSRV = 10.0 (DEG F)
LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
HIGHER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 90.0 (DEG F)
MAXIMUM SURVIVAL TEMPERATURE, THRSRV = 99.0 (DEG F)
MINIMUM SURVIVAL SALINITY, SOLSRV = 0.2000E 01
LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
HIGHER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
MAXIMUM SURVIVAL SALINITY, SHRSRV = 0.2000E 01

**** RP = 7 ****      **** DUMY SPANNING ****      **** FROM 165 DAY TO 999 DAY ****
OPTIMUM SURVIVAL PERCENTAGE, COPSRV = 1.0000
CRITICAL POPULATION DENSITY FOR SURVIVAL, PCRSRV = 0.101000E 02 (NUMBER/PT003)
MAXIMUM POPULATION DENSITY FOR SURVIVAL, PRHSRV = 0.100000E 03 (NUMBER/PT003)
MINIMUM SURVIVAL TEMPERATURE, THRSRV = 10.0 (DEG F)
LOWER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 20.0 (DEG F)
HIGHER OPTIMUM SURVIVAL TEMPERATURE, TOLSRV = 90.0 (DEG F)
MAXIMUM SURVIVAL TEMPERATURE, THRSRV = 99.0 (DEG F)
MINIMUM SURVIVAL SALINITY, SOLSRV = 0.2000E 01
LOWER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
HIGHER OPTIMUM SURVIVAL SALINITY, SOLSRV = 0.1000E 01
MAXIMUM SURVIVAL SALINITY, SHRSRV = 0.2000E 01

** GROWTH CONDITIONS **

**** RP = 1 ****      **** EGG ****      **** FROM 0 DAY TO 2 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.347222E-01 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCGRW = 0.100000E 02 (NUMBER/PT003)
MAXIMUM POPULATION DENSITY FOR GROWTH, PRGRW = 0.100000E 01 (NUMBER/PT003)
MINIMUM GROWTH TEMPERATURE, THGRW = 50.0 (DEG F)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 75.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 85.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = 95.0 (DEG F)
MINIMUM GROWTH SALINITY, SOLGRW = 0.2000E 01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000E 01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000E 01
MAXIMUM GROWTH SALINITY, SHGRW = 0.2000E 00

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**** KP = 2 ****      YOLK SAC      **** FROM      1 DAY TO      0 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.699999-02 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCRDW = 0.100000-02 (NUMBER/PT0001)
MAXIMUM POPULATION DENSITY FOR GROWTH, PMGDW = 0.100000-01 (NUMBER/PT0001)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 10.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 20.0 (DEG F)
MAXIMUM GROWTH TEMPERATURE, THGRW = 999.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = -0.2000-01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
MAXIMUM GROWTH SALINITY, SMGRW = 0.2000-01

**** KP = 3 ****      LARVA      **** FROM      9 DAY TO      10 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.199999-02 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCRDW = 0.100000-02 (NUMBER/PT0001)
MAXIMUM POPULATION DENSITY FOR GROWTH, PMGDW = 0.100000-01 (NUMBER/PT0001)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 10.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 20.0 (DEG F)
MAXIMUM GROWTH TEMPERATURE, THGRW = 999.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = -0.2000-01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
MAXIMUM GROWTH SALINITY, SMGRW = 0.2000-01

**** KP = 4 ****      JUVENILE I      **** FROM      11 DAY TO      10 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.101666-02 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCRDW = 0.100000-02 (NUMBER/PT0001)
MAXIMUM POPULATION DENSITY FOR GROWTH, PMGDW = 0.100000-01 (NUMBER/PT0001)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 10.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 20.0 (DEG F)
MAXIMUM GROWTH TEMPERATURE, THGRW = 999.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = -0.2000-01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
MAXIMUM GROWTH SALINITY, SMGRW = 0.2000-01

**** KP = 5 ****      JUVENILE II      **** FROM      11 DAY TO      191 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.118749-01 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCRDW = 0.100000-02 (NUMBER/PT0001)
MAXIMUM POPULATION DENSITY FOR GROWTH, PMGDW = 0.100000-01 (NUMBER/PT0001)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 10.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 20.0 (DEG F)
MAXIMUM GROWTH TEMPERATURE, THGRW = 999.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = -0.2000-01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
MAXIMUM GROWTH SALINITY, SMGRW = 0.2000-01

**** KP = 6 ****      JUVENILE III      **** FROM      194 DAY TO      165 DAY ****
OPTIMUM GROWTH RATE, ROPGRW = 0.292249-01 (1/MONR)
CRITICAL POPULATION DENSITY FOR GROWTH, PCRDW = 0.100000-02 (NUMBER/PT0001)
MAXIMUM POPULATION DENSITY FOR GROWTH, PMGDW = 0.100000-01 (NUMBER/PT0001)
LOWER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 10.0 (DEG F)
HIGHER OPTIMUM GROWTH TEMPERATURE, TOLGRW = 20.0 (DEG F)
MAXIMUM GROWTH TEMPERATURE, THGRW = 999.0 (DEG F)
MINIMUM GROWTH TEMPERATURE, THGRW = -0.2000-01
LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
HIGHER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000-01
MAXIMUM GROWTH SALINITY, SMGRW = 0.2000-01

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MINIMUM GROWTH SALINITY, SMDROW = 0.2000E 01
 LOWER OPTIMUM GROWTH SALINITY, SOLGRW = 0.1000E 01
 HIGHER OPTIMUM GROWTH SALINITY, SOHGRW = 0.1000E 01
 MAXIMUM GROWTH SALINITY, SMDROW = 0.2000E 01

.. MORTALITY CONDITIONS ..

.... RP = 1
 EGG
 OPTIMUM MORTALITY RATE, MPMOR = 0.18722E-01 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCMROR = 0.100000E 02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMMROR = 0.100000E 01 (NUMBER/FT**3)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLMOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, THOMOR = 300.0 (DEG F)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 999.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, SMMOR = 0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLMOR = 0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SOHMR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMMOR = 0.2000E 01

.... RP = 2
 YOLK SAC
 OPTIMUM MORTALITY RATE, MPMOR = 0.69888E-02 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCMROR = 0.100000E 02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMMROR = 0.100000E 01 (NUMBER/FT**3)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLMOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, THOMOR = 300.0 (DEG F)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 999.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, SMMOR = 0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLMOR = 0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SOHMR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMMOR = 0.2000E 01

.... RP = 3
 LARVA
 OPTIMUM MORTALITY RATE, MPMOR = 0.18939E-02 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCMROR = 0.100000E 02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMMROR = 0.100000E 01 (NUMBER/FT**3)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLMOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, THOMOR = 300.0 (DEG F)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 999.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, SMMOR = 0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLMOR = 0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SOHMR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMMOR = 0.2000E 01

.... RP = 4
 JUVENILE Y
 OPTIMUM MORTALITY RATE, MPMOR = 0.10416E-02 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCMROR = 0.100000E 02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMMROR = 0.100000E 01 (NUMBER/FT**3)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLMOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, THOMOR = 300.0 (DEG F)
 MINIMUM MORTALITY TEMPERATURE, THMOR = 999.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, SMMOR = 0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLMOR = 0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SOHMR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMMOR = 0.2000E 01

**** KP = 5 **** **** JUVENILE II **** **** FROM 71 DAY TO 141 DAY ****
 OPTIMUM MORTALITY RATE, MOPROR = 0.138748E-03 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCRNOR = 0.100000E 02 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMROR = 0.100000E 03 (NUMBER/PT**3)
 MINIMUM MORTALITY TEMPERATURE, TMNROR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLNOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, TONNOR = 400.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, TMNROR = 999.0 (DEG F)
 MINIMUM MORTALITY SALINITY, SMNROR = -0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLNOR = -0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SONNOR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMNROR = 0.2000E 01

**** KP = 6 **** **** JUVENILE III **** **** FROM 144 DAY TO 165 DAY ****
 OPTIMUM MORTALITY RATE, MOPROR = 0.242248E-03 (1/HOUR)
 CRITICAL POPULATION DENSITY FOR MORTALITY, PCRNOR = 0.100000E 02 (NUMBER/PT**3)
 MAXIMUM POPULATION DENSITY FOR MORTALITY, PMROR = 0.100000E 03 (NUMBER/PT**3)
 MINIMUM MORTALITY TEMPERATURE, TMNROR = 10.0 (DEG F)
 LOWER OPTIMUM MORTALITY TEMPERATURE, TOLNOR = 20.0 (DEG F)
 HIGHER OPTIMUM MORTALITY TEMPERATURE, TONNOR = 400.0 (DEG F)
 MAXIMUM MORTALITY TEMPERATURE, TMNROR = 999.0 (DEG F)
 MINIMUM MORTALITY SALINITY, SMNROR = -0.2000E 01
 LOWER OPTIMUM MORTALITY SALINITY, SOLNOR = -0.1000E 01
 HIGHER OPTIMUM MORTALITY SALINITY, SONNOR = 0.1000E 01
 MAXIMUM MORTALITY SALINITY, SMNROR = 0.2000E 01

***** AGE GROUP MOBILITY CONDITIONS *****

**** KP = 5 **** JUVENILE I **** FROM 11 DAY TO 70 DAY ****
 APPROXIMATE MAXIMUM SWIMMING SPEED, VELMOB = 0.50 (PPS)
 APPROXIMATE MAXIMUM SUSTAINED DURATION AT MAXIMUM SPEED, DTMOB = 2.00 (HOUR)
 OPTIMUM POPULATION DENSITY FOR MOBILITY, POPOB = 0.0 (NUMBER/FT**3)
 CRITICAL POPULATION DENSITY FOR MOBILITY, PCMOB = 0.100000E-02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MOBILITY, PMOBI = 0.100000E-03 (NUMBER/FT**3)
 MINIMUM SWIMMING TEMPERATURE, TMOB = 30.0 (DEG F)
 LOWER OPTIMUM SWIMMING TEMPERATURE, TOLMOB = 50.0 (DEG F)
 HIGHER OPTIMUM SWIMMING TEMPERATURE, TOMOB = 80.0 (DEG F)
 MAXIMUM SWIMMING TEMPERATURE, THMOB = 95.0 (DEG F)
 MINIMUM SWIMMING SALINITY, SMOB = 0.1500E-03
 LOWER OPTIMUM SWIMMING SALINITY, SOLMOB = 0.1000E-02
 HIGHER OPTIMUM SWIMMING SALINITY, SOMOB = 0.3000E-02
 MAXIMUM SWIMMING SALINITY, SMOBI = 0.4000E-02

**** KP = 6 **** JUVENILE II **** FROM 71 DAY TO 193 DAY ****
 APPROXIMATE MAXIMUM SWIMMING SPEED, VELMOB = 1.00 (PPS)
 APPROXIMATE MAXIMUM SUSTAINED DURATION AT MAXIMUM SPEED, DTMOB = 4.00 (HOUR)
 OPTIMUM POPULATION DENSITY FOR MOBILITY, POPOB = 0.0 (NUMBER/FT**3)
 CRITICAL POPULATION DENSITY FOR MOBILITY, PCMOB = 0.100000E-02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MOBILITY, PMOBI = 0.100000E-03 (NUMBER/FT**3)
 MINIMUM SWIMMING TEMPERATURE, TMOB = 30.0 (DEG F)
 LOWER OPTIMUM SWIMMING TEMPERATURE, TOLMOB = 50.0 (DEG F)
 HIGHER OPTIMUM SWIMMING TEMPERATURE, TOMOB = 80.0 (DEG F)
 MAXIMUM SWIMMING TEMPERATURE, THMOB = 95.0 (DEG F)
 MINIMUM SWIMMING SALINITY, SMOB = 0.1500E-03
 LOWER OPTIMUM SWIMMING SALINITY, SOLMOB = 0.1000E-02
 HIGHER OPTIMUM SWIMMING SALINITY, SOMOB = 0.3000E-02
 MAXIMUM SWIMMING SALINITY, SMOBI = 0.4000E-02

**** KP = 6 **** JUVENILE III **** FROM 194 DAY TO 365 DAY ****
 APPROXIMATE MAXIMUM SWIMMING SPEED, VELMOB = 1.00 (PPS)
 APPROXIMATE MAXIMUM SUSTAINED DURATION AT MAXIMUM SPEED, DTMOB = 6.00 (HOUR)
 OPTIMUM POPULATION DENSITY FOR MOBILITY, POPOB = 0.0 (NUMBER/FT**3)
 CRITICAL POPULATION DENSITY FOR MOBILITY, PCMOB = 0.100000E-02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MOBILITY, PMOBI = 0.100000E-03 (NUMBER/FT**3)
 MINIMUM SWIMMING TEMPERATURE, TMOB = 30.0 (DEG F)
 LOWER OPTIMUM SWIMMING TEMPERATURE, TOLMOB = 50.0 (DEG F)
 HIGHER OPTIMUM SWIMMING TEMPERATURE, TOMOB = 80.0 (DEG F)
 MAXIMUM SWIMMING TEMPERATURE, THMOB = 95.0 (DEG F)
 MINIMUM SWIMMING SALINITY, SMOB = 0.1500E-03
 LOWER OPTIMUM SWIMMING SALINITY, SOLMOB = 0.1000E-02
 HIGHER OPTIMUM SWIMMING SALINITY, SOMOB = 0.3000E-02
 MAXIMUM SWIMMING SALINITY, SMOBI = 0.4000E-02

**** KP = 7 **** DUMMY SPANNING **** FROM 365 DAY TO 9999 DAY ****
 APPROXIMATE MAXIMUM SWIMMING SPEED, VELMOB = 1.00 (PPS)
 APPROXIMATE MAXIMUM SUSTAINED DURATION AT MAXIMUM SPEED, DTMOB = 12.00 (HOUR)
 OPTIMUM POPULATION DENSITY FOR MOBILITY, POPOB = 0.0 (NUMBER/FT**3)
 CRITICAL POPULATION DENSITY FOR MOBILITY, PCMOB = 0.100000E-02 (NUMBER/FT**3)
 MAXIMUM POPULATION DENSITY FOR MOBILITY, PMOBI = 0.100000E-03 (NUMBER/FT**3)
 MINIMUM SWIMMING TEMPERATURE, TMOB = 30.0 (DEG F)
 LOWER OPTIMUM SWIMMING TEMPERATURE, TOLMOB = 50.0 (DEG F)
 HIGHER OPTIMUM SWIMMING TEMPERATURE, TOMOB = 80.0 (DEG F)
 MAXIMUM SWIMMING TEMPERATURE, THMOB = 95.0 (DEG F)
 MINIMUM SWIMMING SALINITY, SMOB = 0.1500E-03
 LOWER OPTIMUM SWIMMING SALINITY, SOLMOB = 0.1000E-02
 HIGHER OPTIMUM SWIMMING SALINITY, SOMOB = 0.3000E-02
 MAXIMUM SWIMMING SALINITY, SMOBI = 0.4000E-02

***** AGE GROUP TRANSPORT CONDITIONS *****

*** CALCULATED DISPERSION TRANSPORT, PTRTDB CAUSED BY MESO-SCALE TURBULENCE OF THE TIDAL EDNY

*** TRANSPORT EFFECTS DUE TO CROSS-SECTIONAL VARIATIONS OF AGE GROUP POPULATION DENSITY DISTRIBUTIONS

VERTICAL VARIATION EFFECT, PTRVRT, CALCULATED

*** DEPECT TYPE TRANSPORT, PTRDEP DETERMINED ACCORDING TO A CUBIC VARIATION IN DEPTH FOR VERTICAL DISTRIBUTIONS

LATERAL VARIATION EFFECT, PTRLTR = 0

**** RP = 1 **** EGG **** FROM 0 DAY TO 2 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 1.80

**** RP = 2 **** YOLK SAC **** FROM 3 DAY TO 8 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 1.80

**** RP = 3 **** LARVA **** FROM 9 DAY TO 30 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 1.80

**** RP = 4 **** JUVENILE I **** FROM 31 DAY TO 70 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 0.0

**** RP = 5 **** JUVENILE II **** FROM 71 DAY TO 193 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 0.0

**** RP = 6 **** JUVENILE III **** FROM 194 DAY TO 365 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 0.0

**** RP = 7 **** DUMMY SPANNING **** FROM 365 DAY TO 9999 DAY ****
PERCENTAGE OF THE MEAN VALUE WHICH IS HIGHER AT THE BOTTOM AND LOWER AT THE SURFACE FROM THE MEAN, DVPDNI = 0.0

*** MIGRATORY TRANSPORT, PTRMIG DETERMINED ACCORDING TO SHOALING AND CROWDING EFFECTS BASED ON GRADIENT FORMS

**** RP = 4 **** JUVENILE I **** FROM 31 DAY TO 70 DAY ****
WEIGHTING PARAMETER FOR SHOALING TENDENCY OF THE AGE GROUP, RSHOL = 0.40
WEIGHTING PARAMETER FOR THE TENDENCY TO MOVE AWAY FROM CROWDED CONDITIONS FOR THE AGE GROUP, RCROWD = 0.20

**** RP = 5 **** JUVENILE II **** FROM 71 DAY TO 193 DAY ****
WEIGHTING PARAMETER FOR SHOALING TENDENCY OF THE AGE GROUP, RSHOL = 0.40
WEIGHTING PARAMETER FOR THE TENDENCY TO MOVE AWAY FROM CROWDED CONDITIONS FOR THE AGE GROUP, RCROWD = 0.20

**** RP = 6 **** JUVENILE III **** FROM 194 DAY TO 365 DAY ****
WEIGHTING PARAMETER FOR SHOALING TENDENCY OF THE AGE GROUP, RSHOL = 0.40
WEIGHTING PARAMETER FOR THE TENDENCY TO MOVE AWAY FROM CROWDED CONDITIONS FOR THE AGE GROUP, RCROWD = 0.20

**** RP = 7 **** DUMMY SPANNING **** FROM 365 DAY TO 9999 DAY ****
WEIGHTING PARAMETER FOR SHOALING TENDENCY OF THE AGE GROUP, RSHOL = 0.40
WEIGHTING PARAMETER FOR THE TENDENCY TO MOVE AWAY FROM CROWDED CONDITIONS FOR THE AGE GROUP, RCROWD = 0.20

***** AGE GROUP PLANT AVOIDANCE AND SURVIVAL CHARACTERISTICS *****

**** 1 **** EGG ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 0.50
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 0.0
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.20
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 2 **** YOLK SAC ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 0.50
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 0.0
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.20
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 3 **** LARVA ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 0.50
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 0.0
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.20
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 4 **** JUVENILE I ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 1.00
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 0.20
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.0
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 5 **** JUVENILE II ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 1.00
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 0.80
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.0
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 6 **** JUVENILE III ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 1.00
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 1.00
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.0
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

**** 7 **** DUNNY SPAWNING ****
 CROSS-SECTIONAL DISTRIBUTION FACTOR AS THE RATIO OF INTAKE DENSITY TO MEAN DENSITY FOR THE AGE GROUP, CINPDM = 1.00
 INTAKE AVOIDANCE FACTOR FOR THE AGE GROUP, CINAVD = 1.00
 OPTIMUM CONDENSOR SURVIVAL PERCENTAGE FOR THE AGE GROUP, CNDSEV = 0.0
 HIGHER OPTIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, TONCND = 90.00
 MAXIMUM TEMPERATURE LIMIT FOR THE CONDENSOR SURVIVAL OF THE AGE GROUP, THXCND = 95.00

***** PLANT OPERATIONAL CONDITIONS DURING SPECIFIED PERIODS *****

**** PERIOD, IOPPER = 1 ** FROM MONDAY = 91 MNYEAR = 1973 TO MONDAY = 90 MNYEAR = 1974 ** DURATION, LNGOPR = 365 DAYS ****

**** 1 ** PLANT NUMBER, IDNPLT = 1 ** ALBANY ****

INTAKE ELEMENT, IXPINT = 7
 INTAKE AREA, APLINT = 0.784000E 03 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEOINT = 1.00
 INTAKE FLOW RATE, GPLINT = -0.784000E 03 (CFS)
 INTAKE VELOCITY, VELINT = -0.100000E 01 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 7
 DISCHARGE AREA, APLDIS = 0.784000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.784000E 03 (CFS)
 DISCHARGE VELOCITY, VELDIS = 0.100000E 01 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCN = 11.00 (DEG F)

**** 2 ** PLANT NUMBER, IDNPLT = 2 ** DANKAMMER 1,2,3 ****

INTAKE ELEMENT, IXPINT = 44
 INTAKE AREA, APLINT = 0.163600E 03 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEOINT = 1.00
 INTAKE FLOW RATE, GPLINT = -0.409000E 03 (CFS)
 INTAKE VELOCITY, VELINT = -0.250000E 01 (FPS)
 DISCHARGE ELEMENT, IXPCIS = 44
 DISCHARGE AREA, APLDIS = 0.409000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.409000E 03 (CFS)
 DISCHARGE VELOCITY, VELDIS = 0.100000E 01 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 14.50 (DEG F)

**** 3 ** PLANT NUMBER, IDNPLT = 3 ** DANKAMMER 4 ****

INTAKE ELEMENT, IXPINT = 44
 INTAKE AREA, APLINT = 0.110800E 03 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEOINT = 1.00
 INTAKE FLOW RATE, GPLINT = -0.277000E 03 (CFS)
 INTAKE VELOCITY, VELINT = -0.250000E 01 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 44
 DISCHARGE AREA, APLDIS = 0.277000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.277000E 03 (CFS)
 DISCHARGE VELOCITY, VELDIS = 0.100000E 01 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 14.50 (DEG F)

**** 4 ** PLANT NUMBER, IDNPLT = 4 ** ROBERTSON 1,2 ****

INTAKE ELEMENT, IXPINT = 44
 INTAKE AREA, APLINT = 0.193066E 04 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEOINT = 1.00
 INTAKE FLOW RATE, GPLINT = -0.184800E 04 (CFS)
 INTAKE VELOCITY, VELINT = -0.740001E 00 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 44
 DISCHARGE AREA, APLDIS = 0.193066E 04 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.184800E 04 (CFS)
 DISCHARGE VELOCITY, VELDIS = 0.740001E 00 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 15.40 (DEG F)

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**** 5 ** PLANT NUMBER, IDNPLT = 6 ** INDIAN POINT 1 ****
INTAKE ELEMENT, IXPINT = 55
INTAKE AREA, APLINT = 0.886250E 03 (FT**2)
INTAKE GEOMETRIC FACTOR, GROINT = 1.00
INTAKE FLOW RATE, GPLINT = -0.709000E 03 (CFS)
INTAKE VELOCITY, VELINT = -0.800000E 00 (FPS)
DISCHARGE ELEMENT, IXPDIS = 55
DISCHARGE AREA, APLDIS = 0.100000E 04 (FT**2)
DISCHARGE GEOMETRIC FACTOR, GRODIS = 1.00
DISCHARGE FLOW RATE, GPLDIS = 0.709000E 03 (CFS)
DISCHARGE VELOCITY, VELDIS = 0.709000E 00 (FPS)
CONDENSER TEMPERATURE RISE, DTNPCD = 12.00 (DEG F)

**** 6 ** PLANT NUMBER, IDNPLT = 7 ** INDIAN POINT 2 ****
INTAKE ELEMENT, IXPINT = 55
INTAKE AREA, APLINT = 0.215333E 04 (FT**2)
INTAKE GEOMETRIC FACTOR, GROINT = 1.00
INTAKE FLOW RATE, GPLINT = -0.125000E 03 (CFS)
INTAKE VELOCITY, VELINT = -0.580496E -01 (FPS)
DISCHARGE ELEMENT, IXPDIS = 55
DISCHARGE AREA, APLDIS = 0.500000E 03 (FT**2)
DISCHARGE GEOMETRIC FACTOR, GRODIS = 1.00
DISCHARGE FLOW RATE, GPLDIS = 0.125000E 03 (CFS)
DISCHARGE VELOCITY, VELDIS = 0.250000E 00 (FPS)
CONDENSER TEMPERATURE RISE, DTNPCD = 14.60 (DEG F)

**** 7 ** PLANT NUMBER, IDNPLT = 8 ** INDIAN POINT 1 ****
INTAKE ELEMENT, IXPINT = 55
INTAKE AREA, APLINT = 0.215333E 04 (FT**2)
INTAKE GEOMETRIC FACTOR, GROINT = 1.00
INTAKE FLOW RATE, GPLINT = -0.193803E 04 (CFS)
INTAKE VELOCITY, VELINT = -0.900001E 00 (FPS)
DISCHARGE ELEMENT, IXPDIS = 55
DISCHARGE AREA, APLDIS = 0.500000E 03 (FT**2)
DISCHARGE GEOMETRIC FACTOR, GRODIS = 1.00
DISCHARGE FLOW RATE, GPLDIS = 0.193803E 04 (CFS)
DISCHARGE VELOCITY, VELDIS = 0.387600E 01 (FPS)
CONDENSER TEMPERATURE RISE, DTNPCD = 17.20 (DEG F)

**** 8 ** PLANT NUMBER, IDNPLT = 9 ** LOVETT 1,2,3,4 ****
INTAKE ELEMENT, IXPINT = 55
INTAKE AREA, APLINT = 0.330000E 03 (FT**2)
INTAKE GEOMETRIC FACTOR, GROINT = 1.00
INTAKE FLOW RATE, GPLINT = -0.430000E 03 (CFS)
INTAKE VELOCITY, VELINT = -0.130303E 01 (FPS)
DISCHARGE ELEMENT, IXPDIS = 55
DISCHARGE AREA, APLDIS = 0.430000E 03 (FT**2)
DISCHARGE GEOMETRIC FACTOR, GRODIS = 1.00
DISCHARGE FLOW RATE, GPLDIS = 0.430000E 03 (CFS)
DISCHARGE VELOCITY, VELDIS = 0.100000E 01 (FPS)
CONDENSER TEMPERATURE RISE, DTNPCD = 14.80 (DEG F)

**** 9 ** PLANT NUMBER, IDNPLT = 10 ** LOVETT 4 ****
INTAKE ELEMENT, IXPINT = 55
INTAKE AREA, APLINT = 0.181250E 03 (FT**2)
INTAKE GEOMETRIC FACTOR, GROINT = 1.00
INTAKE FLOW RATE, GPLINT = -0.290000E 03 (CFS)
INTAKE VELOCITY, VELINT = -0.160000E 01 (FPS)
DISCHARGE ELEMENT, IXPDIS = 55
DISCHARGE AREA, APLDIS = 0.300000E 03 (FT**2)

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DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.290000E 03 (CPS)
 DISCHARGE VELOCITY, VELDIS = 0.966667E 00 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 14.80 (DEG F)

**** 10 ** PLANT NUMBER, IDNPLT = 11 ** BOWLINE 1 ****
 INTAKE ELEMENT, IXPIET = 50
 INTAKE AREA, APLINT = 0.170000E 04 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEoint = 1.00
 INTAKE FLOW RATE, GPLINT = -0.855500E 03 (CPS)
 INTAKE VELOCITY, VELINT = -0.403235E 00 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 50
 DISCHARGE AREA, APLDIS = 0.960000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.855500E 03 (CPS)
 DISCHARGE VELOCITY, VELDIS = 0.994767E 00 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 13.40 (DEG F)

**** 11 ** PLANT NUMBER, IDNPLT = 12 ** BOWLINE 2 ****
 INTAKE ELEMENT, IXPIET = 50
 INTAKE AREA, APLINT = 0.170000E 04 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEoint = 1.00
 INTAKE FLOW RATE, GPLINT = -0.855500E 03 (CPS)
 INTAKE VELOCITY, VELINT = -0.403235E 00 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 50
 DISCHARGE AREA, APLDIS = 0.860000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.855500E 03 (CPS)
 DISCHARGE VELOCITY, VELDIS = 0.994767E 00 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 13.40 (DEG F)

**** 12 ** PLANT NUMBER, IDNPLT = 13 ** 40TH STREET ****
 INTAKE ELEMENT, IXPIET = 74
 INTAKE AREA, APLINT = 0.374000E 03 (FT**2)
 INTAKE GEOMETRIC FACTOR, GEoint = 1.00
 INTAKE FLOW RATE, GPLINT = -0.374000E 03 (CPS)
 INTAKE VELOCITY, VELINT = -0.100000E 01 (FPS)
 DISCHARGE ELEMENT, IXPDIS = 74
 DISCHARGE AREA, APLDIS = 0.374000E 03 (FT**2)
 DISCHARGE GEOMETRIC FACTOR, GEODIS = 1.00
 DISCHARGE FLOW RATE, GPLDIS = 0.374000E 03 (CPS)
 DISCHARGE VELOCITY, VELDIS = 0.100000E 01 (FPS)
 CONDENSER TEMPERATURE RISE, DTHPCD = 6.00 (DEG F)

***** TIDAL AVERAGE GEOMETRIC PROPERTIES OF THE ELEMENTS *****									
ELEMENT ID	LOCATION (PT) X (IN)	LENGTH (PT) PX (IN)	DEPTH (PT) DMS (IN)	AREA (PT*2) ACR (IN)	VOLUME (PT*3) VCH (IN)	AVERAGE WIDTH (PT) BCW (IN)	SURFACE WIDTH (PT) BSR (IN)	SHOAL RATIO RSH (IN)	
1	0.528000E 04	0.105000E 04	0.162000E 02	0.72249E 08	0.74249E 08	0.44593E 01	0.54500E 03	0.12407E 02	0.12407E 02
2	0.158400E 04	0.105000E 04	0.162000E 02	0.99637E 08	0.10521E 09	0.60000E 01	0.75000E 03	0.45746E 02	0.45746E 02
3	0.264000E 04	0.105000E 04	0.162000E 02	0.12091E 08	0.12771E 09	0.71241E 01	0.91500E 03	0.56689E 02	0.56689E 02
4	0.369600E 04	0.105000E 04	0.162000E 02	0.16796E 08	0.16616E 09	0.57871E 01	0.91500E 03	0.16160E 02	0.16160E 02
5	0.475200E 04	0.105000E 04	0.162000E 02	0.16018E 08	0.16916E 09	0.46445E 01	0.92250E 03	0.26770E 02	0.26770E 02
6	0.580800E 04	0.105000E 04	0.162000E 02	0.13904E 08	0.16681E 09	0.40188E 01	0.71625E 03	0.20810E 02	0.20810E 02
7	0.686400E 04	0.105000E 04	0.162000E 02	0.15185E 08	0.15993E 09	0.44155E 01	0.88374E 03	0.28591E 02	0.28591E 02
8	0.792000E 04	0.105000E 04	0.162000E 02	0.19792E 08	0.20900E 09	0.57810E 01	0.10180E 04	0.49427E 02	0.49427E 02
9	0.897600E 04	0.105000E 04	0.162000E 02	0.25308E 08	0.24840E 09	0.73003E 01	0.11415E 04	0.13328E 02	0.13328E 02
10	0.100320E 04	0.105000E 04	0.162000E 02	0.22341E 08	0.21592E 09	0.65004E 01	0.11400E 04	0.13197E 02	0.13197E 02
11	0.110880E 04	0.105000E 04	0.162000E 02	0.19157E 08	0.20230E 09	0.55705E 01	0.90000E 03	0.26170E 02	0.26170E 02
12	0.121440E 04	0.105000E 04	0.162000E 02	0.23220E 08	0.28420E 09	0.67593E 01	0.15000E 04	0.36681E 02	0.36681E 02
13	0.132000E 04	0.105000E 04	0.162000E 02	0.30615E 08	0.31751E 09	0.87788E 01	0.16750E 04	0.54784E 02	0.54784E 02
14	0.142560E 04	0.105000E 04	0.162000E 02	0.31540E 08	0.34214E 09	0.99038E 01	0.30750E 04	0.90815E 02	0.90815E 02
15	0.153120E 04	0.105000E 04	0.162000E 02	0.29124E 08	0.30755E 09	0.45282E 01	0.17475E 04	0.11713E 02	0.11713E 02
16	0.163680E 04	0.105000E 04	0.162000E 02	0.27548E 08	0.28204E 09	0.41277E 01	0.23250E 04	0.66780E 02	0.66780E 02
17	0.174240E 04	0.105000E 04	0.162000E 02	0.16274E 08	0.38105E 09	0.10864E 01	0.17500E 04	0.10246E 02	0.10246E 02
18	0.184800E 04	0.105000E 04	0.162000E 02	0.13540E 08	0.34214E 09	0.99038E 01	0.30750E 04	0.90815E 02	0.90815E 02
19	0.195360E 04	0.105000E 04	0.162000E 02	0.40090E 08	0.42181E 09	0.11868E 01	0.26250E 04	0.77472E 02	0.77472E 02
20	0.205920E 04	0.105000E 04	0.162000E 02	0.33787E 08	0.35479E 09	0.10516E 01	0.18750E 04	0.55497E 02	0.55497E 02
21	0.216480E 04	0.105000E 04	0.162000E 02	0.16990E 08	0.38061E 09	0.18076E 01	0.27000E 04	0.80187E 02	0.80187E 02
22	0.227040E 04	0.105000E 04	0.162000E 02	0.42446E 08	0.45995E 09	0.18487E 01	0.31000E 04	0.15135E 03	0.15135E 03
23	0.237600E 04	0.105000E 04	0.162000E 02	0.70721E 08	0.78681E 09	0.15821E 01	0.5500E 04	0.12616E 03	0.12616E 03
24	0.248160E 04	0.105000E 04	0.162000E 02	0.68908E 08	0.72748E 09	0.14592E 01	0.41250E 04	0.87391E 02	0.87391E 02
25	0.258720E 04	0.105000E 04	0.162000E 02	0.75455E 08	0.80201E 09	0.17540E 01	0.48750E 04	0.10518E 03	0.10518E 03
26	0.269280E 04	0.105000E 04	0.162000E 02	0.78783E 08	0.83201E 09	0.17540E 01	0.48750E 04	0.10518E 03	0.10518E 03
27	0.279840E 04	0.105000E 04	0.162000E 02	0.71084E 08	0.75045E 09	0.17536E 01	0.50250E 04	0.12196E 03	0.12196E 03
28	0.290400E 04	0.105000E 04	0.162000E 02	0.75164E 08	0.79354E 09	0.17536E 01	0.42750E 04	0.52325E 02	0.52325E 02
29	0.300960E 04	0.105000E 04	0.162000E 02	0.97400E 08	0.10306E 10	0.19442E 01	0.38250E 04	0.76192E 02	0.76192E 02
30	0.311520E 04	0.105000E 04	0.162000E 02	0.12522E 08	0.13149E 10	0.12574E 01	0.57500E 04	0.15178E 03	0.15178E 03
31	0.322080E 04	0.105000E 04	0.162000E 02	0.12648E 08	0.18009E 10	0.10157E 01	0.56250E 04	0.12879E 03	0.12879E 03
32	0.332640E 04	0.105000E 04	0.162000E 02	0.11537E 08	0.12201E 10	0.21817E 01	0.46500E 04	0.84190E 02	0.84190E 02
33	0.343200E 04	0.105000E 04	0.162000E 02	0.99419E 08	0.10560E 10	0.14806E 01	0.40500E 04	0.49178E 02	0.49178E 02
34	0.353760E 04	0.105000E 04	0.162000E 02	0.97748E 08	0.10316E 10	0.13387E 01	0.38500E 04	0.47805E 02	0.47805E 02
35	0.364320E 04	0.105000E 04	0.162000E 02	0.57454E 08	0.11231E 10	0.18249E 01	0.37500E 04	0.44042E 02	0.44042E 02
36	0.374880E 04	0.105000E 04	0.162000E 02	0.10484E 08	0.10402E 10	0.13781E 01	0.25875E 04	0.33269E 02	0.33269E 02
37	0.385440E 04	0.105000E 04	0.162000E 02	0.11117E 08	0.11739E 10	0.10728E 01	0.21750E 04	0.20881E 02	0.20881E 02
38	0.396000E 04	0.105000E 04	0.162000E 02	0.12367E 08	0.13006E 10	0.14731E 01	0.26750E 04	0.30947E 02	0.30947E 02
39	0.406560E 04	0.105000E 04	0.162000E 02	0.11874E 08	0.12480E 10	0.15308E 01	0.26250E 04	0.33838E 02	0.33838E 02
40	0.417120E 04	0.105000E 04	0.162000E 02	0.10827E 08	0.11413E 10	0.11528E 01	0.28500E 04	0.15608E 02	0.15608E 02
41	0.427680E 04	0.105000E 04	0.162000E 02	0.10879E 08	0.11508E 10	0.16024E 01	0.28875E 04	0.12611E 02	0.12611E 02
42	0.438240E 04	0.105000E 04	0.162000E 02	0.13901E 08	0.14679E 10	0.22891E 01	0.31740E 04	0.50599E 02	0.50599E 02
43	0.448800E 04	0.105000E 04	0.162000E 02	0.17472E 08	0.18805E 10	0.25910E 01	0.42000E 04	0.76873E 02	0.76873E 02
44	0.459360E 04	0.105000E 04	0.162000E 02	0.15751E 08	0.16637E 10	0.25910E 01	0.48500E 04	0.13991E 03	0.13991E 03
45	0.469920E 04	0.105000E 04	0.162000E 02	0.16051E 08	0.16923E 10	0.25270E 01	0.51000E 04	0.42142E 02	0.42142E 02
46	0.480480E 04	0.105000E 04	0.162000E 02	0.13681E 08	0.14847E 10	0.16764E 01	0.31500E 04	0.18603E 02	0.18603E 02
47	0.491040E 04	0.105000E 04	0.162000E 02	0.11855E 08	0.13523E 10	0.12876E 01	0.26250E 04	0.28501E 02	0.28501E 02
48	0.501600E 04	0.105000E 04	0.162000E 02	0.10013E 08	0.10576E 10	0.10101E 01	0.16750E 04	0.17026E 02	0.17026E 02
49	0.512160E 04	0.105000E 04	0.162000E 02	0.97903E 08	0.10344E 10	0.94420E 01	0.15900E 04	0.15920E 02	0.15920E 02
50	0.522720E 04	0.105000E 04	0.162000E 02	0.12839E 08	0.13130E 10	0.10059E 01	0.26025E 04	0.21045E 02	0.21045E 02
51	0.533280E 04	0.105000E 04	0.162000E 02	0.12839E 08	0.13130E 10	0.10059E 01	0.26025E 04	0.21045E 02	0.21045E 02
52	0.543840E 04	0.105000E 04	0.162000E 02	0.15307E 08	0.16168E 10	0.11849E 01	0.32400E 04	0.49271E 02	0.49271E 02
53	0.554400E 04	0.105000E 04	0.162000E 02	0.15307E 08	0.16168E 10	0.11849E 01	0.32400E 04	0.49271E 02	0.49271E 02
54	0.564960E 04	0.105000E 04	0.162000E 02	0.15307E 08	0.16168E 10	0.11849E 01	0.32400E 04	0.49271E 02	0.49271E 02

55	0.575320E 04	0.105600E 05	0.677175E 02	0.154468E 06	0.164247E 10	0.229631E 04	0.360000E 04	0.431863E 02
56	0.586080E 04	0.105600E 05	0.680000E 02	0.164332E 06	0.175857E 10	0.242052E 04	0.517500E 04	0.742180E 02
57	0.596840E 04	0.105600E 05	0.603375E 02	0.203172E 06	0.215758E 10	0.338623E 04	0.982500E 04	0.162838E 03
58	0.607200E 04	0.105600E 05	0.328750E 02	0.241819E 06	0.244360E 10	0.735370E 04	0.137500E 05	0.479088E 01
59	0.617600E 04	0.105600E 05	0.373500E 02	0.214608E 06	0.228718E 10	0.579860E 04	0.156000E 05	0.417671E 01
60	0.628320E 04	0.105600E 05	0.392500E 02	0.198120E 06	0.208215E 10	0.507482E 04	0.121125E 05	0.108599E 01
61	0.638800E 04	0.105600E 05	0.386500E 02	0.217253E 06	0.239419E 10	0.562102E 04	0.118125E 05	0.105627E 01
62	0.649400E 04	0.105600E 05	0.400500E 02	0.204223E 06	0.217771E 10	0.418918E 04	0.123000E 05	0.107116E 01
63	0.660000E 04	0.105600E 05	0.419750E 02	0.213483E 06	0.225410E 10	0.508566E 04	0.127500E 05	0.103752E 01
64	0.670560E 04	0.105600E 05	0.474250E 02	0.196699E 06	0.207718E 10	0.418757E 04	0.102000E 05	0.215076E 01
65	0.681120E 04	0.105600E 05	0.499375E 02	0.185992E 06	0.195228E 10	0.298352E 04	0.570000E 04	0.118183E 01
66	0.691680E 04	0.105600E 05	0.455250E 02	0.137642E 06	0.145048E 10	0.301711E 04	0.483750E 04	0.104260E 01
67	0.702240E 04	0.105600E 05	0.461000E 02	0.151038E 06	0.159496E 10	0.327631E 04	0.528750E 04	0.114698E 01
68	0.712800E 04	0.105600E 05	0.486625E 02	0.144808E 06	0.153968E 10	0.298622E 04	0.495000E 04	0.101721E 01
69	0.723360E 04	0.105600E 05	0.557500E 02	0.133454E 06	0.140927E 10	0.238179E 04	0.402500E 04	0.808482E 02
70	0.733920E 04	0.105600E 05	0.575000E 02	0.136808E 06	0.148291E 10	0.205378E 04	0.405500E 04	0.617182E 02
71	0.744480E 04	0.105600E 05	0.643500E 02	0.128888E 06	0.136737E 10	0.197877E 04	0.379500E 04	0.479941E 02
72	0.755040E 04	0.105600E 05	0.654375E 02	0.121209E 06	0.127992E 10	0.218528E 04	0.401500E 04	0.719469E 02
73	0.765600E 04	0.105600E 05	0.510625E 02	0.124819E 06	0.118048E 10	0.248863E 04	0.417500E 04	0.846308E 02
74	0.776160E 04	0.105600E 05	0.426000E 02	0.132508E 06	0.119654E 10	0.251426E 04	0.400000E 04	0.774665E 02
75	0.786720E 04	0.105600E 05	0.511250E 02	0.166600E 06	0.178041E 10	0.329779E 04	0.497500E 04	0.975150E 02
76	0.797280E 04	0.105600E 05	0.506750E 02	0.204034E 06	0.219459E 10	0.402632E 04	0.515000E 04	0.114842E 03

*** DAYS AFTER START OF SPawning YEAR, IDAYOY = 71 *** JULIAN DAY, JULDAY = 161 *** DATE : 24.00 HOUR 10 JUNE 1971

SAMPLE OF IPII

***** TIDAL AVERAGED PHYSICAL CONDITIONS IN THE ELEMENTS *****

ELEMENT IN	LOCATION (FT) X (IN)	FRESH WATER FLOW RATE (CFS) GPR (IN)	MAXIMUM TIDAL SPEED (FPS) VLT (IN)	TEMPERATURE (DEG F) TMP (IN)	SALINITY () SLM (IN)
1	0.528000E 04	0.125980E 05	0.473180E 00	0.535080E 02	0.0
2	0.158700E 04	0.125980E 05	0.473180E 00	0.535080E 02	0.0
3	0.258000E 05	0.127240E 05	0.473180E 00	0.535080E 02	0.0
4	0.369600E 05	0.127240E 05	0.108933E 01	0.535080E 02	0.0
5	0.475200E 05	0.127240E 05	0.127240E 00	0.535080E 02	0.0
6	0.580800E 05	0.128500E 05	0.991535E 00	0.535080E 02	0.0
7	0.696400E 05	0.128500E 05	0.108679E 01	0.535080E 02	0.0
8	0.792000E 05	0.128500E 05	0.111451E 01	0.535080E 02	0.0
9	0.897600E 05	0.129763E 05	0.112883E 01	0.535080E 02	0.0
10	0.100320E 06	0.129763E 05	0.143276E 01	0.535080E 02	0.0
11	0.110880E 06	0.129763E 05	0.111071E 01	0.540540E 02	0.0
12	0.121440E 06	0.131023E 05	0.101997E 01	0.540540E 02	0.0
13	0.132000E 06	0.131023E 05	0.151851E 01	0.540540E 02	0.0
14	0.142560E 06	0.131023E 05	0.181207E 01	0.540540E 02	0.0
15	0.153120E 06	0.132283E 05	0.174120E 01	0.540540E 02	0.0
16	0.163680E 06	0.132283E 05	0.168508E 01	0.540540E 02	0.0
17	0.174240E 06	0.132283E 05	0.174487E 01	0.540540E 02	0.0
18	0.184800E 06	0.133543E 05	0.191109E 01	0.540540E 02	0.0
19	0.195360E 06	0.133543E 05	0.207124E 01	0.540540E 02	0.0
20	0.205920E 06	0.133543E 05	0.225318E 01	0.540540E 02	0.0
21	0.216480E 06	0.134803E 05	0.211893E 01	0.540540E 02	0.0
22	0.227040E 06	0.134803E 05	0.193536E 01	0.540540E 02	0.0
23	0.237600E 06	0.134803E 05	0.197844E 01	0.540540E 02	0.0
24	0.248160E 06	0.136063E 05	0.208620E 01	0.540540E 02	0.0
25	0.258720E 06	0.136063E 05	0.194063E 01	0.540540E 02	0.0
26	0.269280E 06	0.136063E 05	0.185081E 01	0.540540E 02	0.0
27	0.279840E 06	0.137322E 05	0.185661E 01	0.540540E 02	0.0
28	0.290400E 06	0.137322E 05	0.174469E 01	0.540540E 02	0.0
29	0.300960E 06	0.137322E 05	0.164117E 01	0.540540E 02	0.0
30	0.311520E 06	0.138582E 05	0.149900E 01	0.546000E 02	0.0
31	0.322080E 06	0.138582E 05	0.130181E 01	0.546000E 02	0.0
32	0.332640E 06	0.138582E 05	0.134786E 01	0.546000E 02	0.0
33	0.343200E 06	0.139842E 05	0.145080E 01	0.546000E 02	0.0
34	0.353760E 06	0.139842E 05	0.153659E 01	0.546000E 02	0.0
35	0.364320E 06	0.139842E 05	0.161668E 01	0.546000E 02	0.0
36	0.374880E 06	0.141102E 05	0.152754E 01	0.546000E 02	0.0
37	0.385440E 06	0.141102E 05	0.137899E 01	0.546000E 02	0.0
38	0.396000E 06	0.141102E 05	0.150888E 01	0.546000E 02	0.0
39	0.406560E 06	0.142362E 05	0.166765E 01	0.546000E 02	0.0
40	0.417120E 06	0.142362E 05	0.165088E 01	0.546000E 02	0.0
41	0.427680E 06	0.142362E 05	0.163499E 01	0.546000E 02	0.0
42	0.438240E 06	0.143622E 05	0.157734E 01	0.546000E 02	0.0
43	0.448800E 06	0.143622E 05	0.153804E 01	0.546000E 02	0.0
44	0.459360E 06	0.143622E 05	0.149741E 01	0.546000E 02	0.0
45	0.469920E 06	0.144881E 05	0.141074E 01	0.546000E 02	0.0
46	0.480480E 06	0.144881E 05	0.142556E 01	0.546000E 02	0.0
47	0.491040E 06	0.144881E 05	0.143046E 01	0.546000E 02	0.0
48	0.501600E 06	0.146141E 05	0.148683E 01	0.546000E 02	0.0
49	0.512160E 06	0.146141E 05	0.162512E 01	0.551460E 02	0.0
50	0.522720E 06	0.146141E 05	0.173651E 01	0.551460E 02	0.0
51	0.533280E 06	0.147401E 05	0.167125E 01	0.551460E 02	0.154175E-03
52	0.543840E 06	0.147401E 05	0.165591E 01	0.551460E 02	0.253126E-03
53	0.554400E 06	0.147401E 05	0.169920E 01	0.551460E 02	0.366159E-03
54	0.564960E 06	0.148661E 05	0.160529E 01	0.551460E 02	0.495277E-03

***** TOTAL NUMBER OF SPARSED EGGS AND POPULATION DENSITY OF AGE GROUPS IN THE ELEMENTS *****									
ELEMENT IX	LOCATION(MP) X(IX)	SPARSED EGGS EGG(IX)	POD(1,IX)	TOTAL SAC POD(2,IX)	LANVA POD(3,IX)	JUVENILE I POD(4,IX)	JUVENILE II POD(5,IX)		
55	0.575520E 06	0.100661E 05	0.100661E 01	0.100661E 01	0.551060E 02	0.602762E-03	0.602762E-03		
56	0.586000E 06	0.100661E 05	0.100661E 01	0.100661E 01	0.551060E 02	0.61218E-01	0.61218E-01		
57	0.596600E 06	0.100921E 05	0.100921E 01	0.100921E 01	0.551060E 02	0.100369E-02	0.100369E-02		
58	0.607200E 06	0.100921E 05	0.100921E 01	0.100921E 01	0.551060E 02	0.122352E-02	0.122352E-02		
59	0.617760E 06	0.100921E 05	0.100921E 01	0.100921E 01	0.551060E 02	0.147463E-02	0.147463E-02		
60	0.628320E 06	0.151181E 05	0.151181E 01	0.151181E 01	0.551060E 02	0.176168E-02	0.176168E-02		
61	0.638880E 06	0.151181E 05	0.151181E 01	0.151181E 01	0.551060E 02	0.208914E-02	0.208914E-02		
62	0.649440E 06	0.152400E 05	0.152400E 01	0.152400E 01	0.551060E 02	0.24632E-02	0.24632E-02		
63	0.660000E 06	0.152400E 05	0.152400E 01	0.152400E 01	0.551060E 02	0.28097E-02	0.28097E-02		
64	0.670560E 06	0.152400E 05	0.152400E 01	0.152400E 01	0.551060E 02	0.33795E-02	0.33795E-02		
65	0.681120E 06	0.152400E 05	0.152400E 01	0.152400E 01	0.551060E 02	0.39723E-02	0.39723E-02		
66	0.691680E 06	0.153700E 05	0.153700E 01	0.153700E 01	0.551060E 02	0.45749E-02	0.45749E-02		
67	0.702240E 06	0.153700E 05	0.153700E 01	0.153700E 01	0.551060E 02	0.53024E-02	0.53024E-02		
68	0.712800E 06	0.153700E 05	0.153700E 01	0.153700E 01	0.556920E 02	0.61319E-02	0.61319E-02		
69	0.723360E 06	0.154960E 05	0.154960E 01	0.154960E 01	0.556920E 02	0.70837E-02	0.70837E-02		
70	0.733920E 06	0.154960E 05	0.154960E 01	0.154960E 01	0.556920E 02	0.81687E-02	0.81687E-02		
71	0.744480E 06	0.154960E 05	0.154960E 01	0.154960E 01	0.556920E 02	0.94081E-02	0.94081E-02		
72	0.755040E 06	0.156220E 05	0.156220E 01	0.156220E 01	0.556920E 02	0.108239E-01	0.108239E-01		
73	0.765600E 06	0.156220E 05	0.156220E 01	0.156220E 01	0.556920E 02	0.12841E-01	0.12841E-01		
74	0.776160E 06	0.156220E 05	0.156220E 01	0.156220E 01	0.556920E 02	0.14288E-01	0.14288E-01		
75	0.786720E 06	0.157480E 05	0.157480E 01	0.157480E 01	0.556920E 02	0.16398E-01	0.16398E-01		
76	0.797280E 06	0.157480E 05	0.157480E 01	0.157480E 01	0.556920E 02	0.18609E-01	0.18609E-01		

0.5	-0.152000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
1	-0.151000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
2	-0.149000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
3	-0.147000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
4	-0.145000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
5	-0.143000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
6	-0.141000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
7	-0.139000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
8	-0.137000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
9	-0.135000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
10	-0.133000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
11	-0.131000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
12	-0.129000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
13	-0.127000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
14	-0.125000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
15	-0.123000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
16	-0.121000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
17	-0.119000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
18	-0.117000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
19	-0.115000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
20	-0.113000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
21	-0.111000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
22	-0.109000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
23	-0.107000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
24	-0.105000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
25	-0.103000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
26	-0.101000E 03	0.0	0.0	0.0	0.0	0.0	0.0		
27	-0.990000E 02	0.0	0.0	0.0	0.0	0.0	0.0		
28	-0.970000E 02	0.0	0.0	0.0	0.0	0.0	0.0		
29	-0.950000E 02	0.0	0.0	0.0	0.0	0.0	0.0		
30	-0.930000E 02	0.0	0.0	0.0	0.0	0.0	0.0		
31	-0.910000E 02	0.0	0.0	0.0	0.0	0.0	0.0		

9	-0.135000E 03	0.0	0.0
10	-0.133000E 03	0.0	0.0
11	-0.131000E 03	0.0	0.0
12	-0.129000E 03	0.0	0.0
13	-0.127000E 03	0.0	0.0
14	-0.125000E 03	0.0	0.0
15	-0.123000E 03	0.113974E-18	0.0
16	-0.121000E 03	0.146991E-17	0.0
17	-0.119000E 03	0.657871E-17	0.0
18	-0.117000E 03	0.298722E-16	0.0
19	-0.115000E 03	0.101171E-15	0.0
20	-0.113000E 03	0.249012E-15	0.0
21	-0.111000E 03	0.243635E-14	0.0
22	-0.109000E 03	0.290682E-13	0.0
23	-0.107000E 03	0.614743E-13	0.0
24	-0.105000E 03	0.107298E-12	0.0
25	-0.103000E 03	0.362863E-12	0.0
26	-0.101000E 03	0.101574E-11	0.0
27	-0.990000E 02	0.338966E-11	0.0
28	-0.970000E 02	0.403827E-11	0.0
29	-0.950000E 02	0.140365E-10	0.124072E-05
30	-0.930000E 02	0.171924E-09	0.200748E-05
31	-0.910000E 02	0.299899E-09	0.188447E-05
32	-0.890000E 02	0.305075E-09	0.324544E-05
33	-0.870000E 02	0.437866E-09	0.625238E-05
34	-0.850000E 02	0.576027E-09	0.618868E-05
35	-0.830000E 02	0.157851E-08	0.474687E-05
36	-0.810000E 02	0.145944E-08	0.359158E-05
37	-0.790000E 02	0.905585E-09	0.224875E-05
38	-0.770000E 02	0.188273E-08	0.101448E-05
39	-0.750000E 02	0.242503E-08	0.526277E-06
40	-0.730000E 02	0.280039E-08	0.577212E-06
41	-0.710000E 02	0.319127E-08	0.114701E-05
42	-0.690000E 02	0.672448E-08	0.845190E-06
43	-0.670000E 02	0.844702E-08	0.119009E-05
44	-0.650000E 02	0.164716E-07	0.119615E-05
45	-0.630000E 02	0.526504E-07	0.161844E-05
46	-0.610000E 02	0.101667E-06	0.322606E-05
47	-0.590000E 02	0.184892E-06	0.573648E-05
48	-0.570000E 02	0.179092E-06	0.936001E-05
49	-0.550000E 02	0.490435E-07	0.109640E-05
50	-0.530000E 02	0.733226E-07	0.126486E-04
51	-0.510000E 02	0.432043E-07	0.128133E-04
52	-0.490000E 02	0.355246E-07	0.765615E-05
53	-0.470000E 02	0.358255E-07	0.0
54	-0.450000E 02	0.344579E-07	0.0
55	-0.430000E 02	0.408817E-07	0.0
56	-0.410000E 02	0.324444E-07	0.0
57	-0.390000E 02	0.624070E-07	0.0
58	-0.370000E 02	0.204884E-06	0.0
59	-0.350000E 02	0.251643E-06	0.0
60	-0.330000E 02	0.238331E-06	0.0
61	-0.310000E 02	0.294739E-06	0.0
62	-0.290000E 02	0.395407E-06	0.0
63	-0.270000E 02	0.421188E-06	0.0
64	-0.250000E 02	0.663507E-06	0.0
65	-0.230000E 02	0.337234E-06	0.0
66	-0.210000E 02	0.362134E-06	0.0
67	-0.190000E 02	0.506268E-06	0.0
68	-0.170000E 02	0.508075E-06	0.0

69	-0.150000E 02	0.446788E-06	0.0
70	-0.130000E 02	0.316678E-06	0.0
71	-0.110000E 02	0.247153E-06	0.0
72	-0.900000E 01	0.307675E-06	0.0
73	-0.700007E 01	0.357519E-06	0.0
74	-0.500000E 01	0.273915E-06	0.0
75	-0.300000E 01	0.356626E-06	0.0
76	-0.100000E 01	0.429594E-06	0.0
76.5	0.0	0.466079E-06	0.0

***** TOTAL NUMBER OF EGGS SPAWNED IN ALL ELEMENTS IN THE ESTUARY, TOTEGG = 0.459274E 10

***** TOTAL NUMBER OF EGG IN ALL ELEMENTS IN THE ESTUARY, TOTPDN(1) = 0.436879E 07

***** TOTAL NUMBER OF YOLK SAC IN ALL ELEMENTS IN THE ESTUARY, TOTPDN(2) = 0.296192E 06

***** TOTAL NUMBER OF LARVA IN ALL ELEMENTS IN THE ESTUARY, TOTPDN(3) = 0.143124E 08

***** TOTAL NUMBER OF JUVENILE I IN ALL ELEMENTS IN THE ESTUARY TOTPDN(4) = 0.445584E 07

***** TOTAL NUMBER OF JUVENILE II IN ALL ELEMENTS IN THE ESTUARY TOTPDN(5) = 0.223482E 06

***** TOTAL NUMBER OF JUVENILE III IN ALL ELEMENTS IN THE ESTUARY TOTPDN(6) = 0.144185E 05

***** TOTAL NUMBER OF DUNNY SPAWNING IN ALL ELEMENTS IN THE ESTUARY, TOTPDN(7) = 0.132000E 06

***** SUM OF ERROR OVER ALL ELEMENTS FOR EACH AGE GROUP *****

0.464338E-12 0 0 0.462965E-33 -0.250463E-28 0.739557E-30 0.206997E-26

0.0

*** DAYS AFTER START OF SPAWNING YEAR, IDAYOT = 71 *** JULIAN DAY, JULDAY = 161 *** DATE : 20.00 HOUR 10 JUNE 1971

0000 DAYS AFTER START OF SPANNING YEAR, IDATOV = 155 0000 JULIAN DAY, JULDAY = 245 0000 DATE : 24.00 HOUR 2 SEPTEMBER 1973

00000000 TIDAL AVERAGED PHYSICAL CONDITIONS IN THE ELEMENTS 00000000

ELEMENT IX	LOCATION(PT) X(IX)	FRESH WATER FLOW RATE(CPS) GPR(IX)	MAXIMUM TIDAL SPEED(PPS) VEL(IX)	TEMPERATURE(DEG F) TMP(IX)	SALINITY() SLW(IX)
1	0.5280002 04	0.3542322 04	0.8731002 01	0.7868422 02	0.0
2	0.1504002 05	0.3542322 04	0.9975942 00	0.7868422 02	0.0
3	0.2640002 05	0.3577742 04	0.1187742 01	0.7868422 02	0.0
4	0.3696002 05	0.3577742 04	0.1089312 01	0.7868422 02	0.0
5	0.8752002 05	0.3577742 04	0.9223612 00	0.7868422 02	0.0
6	0.5808002 05	0.3613162 04	0.9915352 00	0.7868422 02	0.0
7	0.6840002 05	0.3613162 04	0.1066792 01	0.7868422 02	0.0
8	0.7920002 05	0.3613162 04	0.1148912 01	0.7868422 02	0.0
9	0.8976002 05	0.3648592 04	0.1328612 01	0.7868422 02	0.0
10	0.1003202 06	0.3648592 04	0.1612762 01	0.7868422 02	0.0
11	0.1104002 06	0.3648592 04	0.1110712 01	0.7948712 02	0.0
12	0.1214002 06	0.3648592 04	0.1019372 01	0.7948712 02	0.0
13	0.1320002 06	0.3648592 04	0.1518512 01	0.7548712 02	0.0
14	0.1425602 06	0.3648592 04	0.1832072 01	0.7948712 02	0.0
15	0.1531202 06	0.3719432 04	0.1751202 01	0.7948712 02	0.0
16	0.1636802 06	0.3719432 04	0.1685002 01	0.7948712 02	0.0
17	0.1742402 06	0.3719432 04	0.1744602 01	0.7948712 02	0.0
18	0.1848002 06	0.3754862 04	0.1811042 01	0.7948712 02	0.0
19	0.1953602 06	0.3754862 04	0.2071242 01	0.7948712 02	0.0
20	0.2059202 06	0.3754862 04	0.2251512 01	0.7948712 02	0.0
21	0.2164802 06	0.3790202 04	0.2118912 01	0.7948712 02	0.0
22	0.2270402 06	0.3790202 04	0.1935342 01	0.7948712 02	0.0
23	0.2376002 06	0.3790202 04	0.1978402 01	0.7948712 02	0.0
24	0.2481602 06	0.3825702 04	0.2044702 01	0.7948712 02	0.0
25	0.2587202 06	0.3825702 04	0.1940432 01	0.7948712 02	0.0
26	0.2692802 06	0.3825702 04	0.1856612 01	0.7948712 02	0.0
27	0.2798402 06	0.3841132 04	0.1856612 01	0.7948712 02	0.0
28	0.2904002 06	0.3841132 04	0.1744602 01	0.7948712 02	0.0
29	0.3009602 06	0.3861132 04	0.1641172 01	0.7948712 02	0.0
30	0.3115202 06	0.3896552 04	0.1499902 01	0.8029002 02	0.0
31	0.3220802 06	0.3896552 04	0.1301852 01	0.8029002 02	0.0
32	0.3326402 06	0.3896552 04	0.1347042 01	0.8029002 02	0.0
33	0.3432002 06	0.3931972 04	0.1616612 01	0.8029002 02	0.0
34	0.3537602 06	0.3931972 04	0.1527542 01	0.8029002 02	0.2569372-03
35	0.3643202 06	0.3947402 04	0.1378492 01	0.8029002 02	0.802272-03
36	0.3748802 06	0.3947402 04	0.1308802 01	0.8029002 02	0.7120302-03
37	0.3854402 06	0.4002812 04	0.1667652 01	0.8029002 02	0.9526602-03
38	0.3960002 06	0.4002812 04	0.1650402 01	0.8029002 02	0.1202402-02
39	0.4065602 06	0.4002812 04	0.1634992 01	0.8029002 02	0.1861812-02
40	0.4171202 06	0.4002812 04	0.1577342 01	0.8029002 02	0.1731032-02
41	0.4276802 06	0.4038242 04	0.1518042 01	0.8029002 02	0.2010512-02
42	0.4382402 06	0.4038242 04	0.1474112 01	0.8029002 02	0.230438-02
43	0.4488002 06	0.4073672 04	0.1410742 01	0.8029002 02	0.2601822-02
44	0.4593602 06	0.4073672 04	0.1255612 01	0.8029002 02	0.2914492-02
45	0.4699202 06	0.4073672 04	0.1430602 01	0.8029002 02	0.3231072-02
46	0.4804802 06	0.4109092 04	0.1486812 01	0.8029002 02	0.3574032-02
47	0.4910402 06	0.4109092 04	0.1425122 01	0.8149282 02	0.3925822-02
48	0.5016002 06	0.4109092 04	0.1736512 01	0.8109282 02	0.4284962-02
49	0.5121602 06	0.4144512 04	0.1655912 01	0.8109282 02	0.4665932-02
50	0.5227202 06	0.4144512 04	0.1655912 01	0.8109282 02	0.5057202-02
51	0.5332802 06	0.4144512 04	0.1689202 01	0.8109282 02	0.5461532-02
52	0.5438402 06	0.4144512 04	0.1689202 01	0.8109282 02	
53	0.5544002 06	0.4144512 04	0.1689202 01	0.8109282 02	

***** TOTAL NUMBER OF SPANED EGGS AND POPULATION DENSITY OF AGE GROUPS IN THE ELEMENTS *****									
ELEMENT IX	LOCATION(MP) X(IX)	SPANED EGGS EGG(IX)	EGG PDM(1,IX)	YOLK SAC PDM(2,IX)	LARVA PDM(1,IX)	JUVENILE I PDM(4,IX)	JUVENILE II PDM(5,IX)		
54	0.56940E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.58812E-02	
55	0.57152E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.63230E-02	
56	0.48608E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.77760E-02	
57	0.59664E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.72494E-02	
58	0.60720E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.77392E-02	
59	0.61776E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.82472E-02	
60	0.62832E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.87754E-02	
61	0.63888E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.93235E-02	
62	0.64944E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.98524E-02	
63	0.66000E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	1.04830E-01	
64	0.67056E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.11096E-01	
65	0.68112E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.11732E-01	
66	0.69168E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.12393E-01	
67	0.70224E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.13090E-01	
68	0.71280E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.13790E-01	
69	0.72336E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.14530E-01	
70	0.73392E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.15295E-01	
71	0.74448E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.16094E-01	
72	0.75504E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.16921E-01	
73	0.76560E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.17795E-01	
74	0.77616E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.18670E-01	
75	0.78672E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.19595E-01	
76	0.79728E 06	0.41799E 04	0.0	0.0	0.0	0.0	0.0	0.20556E-01	
0.5	-0.15200E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
1	-0.15100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
2	-0.14900E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
3	-0.14700E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
4	-0.14500E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5	-0.14300E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
6	-0.14100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	-0.13900E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	-0.13700E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
9	-0.13500E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
10	-0.13300E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
11	-0.13100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
12	-0.12900E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
13	-0.12700E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
14	-0.12500E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
15	-0.12300E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
16	-0.12100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
17	-0.11900E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
18	-0.11700E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
19	-0.11500E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
20	-0.11300E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
21	-0.11100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
22	-0.10900E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
23	-0.10700E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
24	-0.10500E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
25	-0.10300E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
26	-0.10100E 03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	-0.99000E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	-0.97000E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	-0.95000E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	-0.93000E 02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

ELEMENT	LOCATION(MP)	JUVENILE III	DUNY SPawning	PDM(7,IX)	PDM(8,IX)	PDM(9,IX)	PDM(10,IX)	PDM(11,IX)
31	-0.410000E 02	0.923169E 08	0.0	0.0	0.0	0.795168E-09	0.319909E-07	0.200219E-06
32	-0.490000E 02	0.13811E 09	0.0	0.0	0.0	0.360559E-09	0.481042E-07	0.137768E-06
33	-0.470000E 02	0.230850E 09	0.0	0.0	0.0	0.164451E-09	0.920939E-07	0.161137E-06
34	-0.450000E 02	0.230448E 09	0.0	0.0	0.0	0.938566E-09	0.160156E-06	0.176170E-06
35	-0.430000E 02	0.184677E 09	0.0	0.0	0.0	0.494476E-08	0.517248E-06	0.833285E-06
36	-0.410000E 02	0.33507E 09	0.0	0.0	0.0	0.241077E-08	0.742920E-06	0.293422E-06
37	-0.390000E 02	0.923367E 08	0.0	0.0	0.0	0.873868E-07	0.823473E-06	0.156206E-06
38	-0.370000E 02	0.461673E 08	0.0	0.0	0.0	0.241020E-06	0.167953E-05	0.376958E-06
39	-0.350000E 02	0.230438E 08	0.0	0.0	0.0	0.251117E-05	0.513292E-06	0.513292E-06
40	-0.330000E 02	0.230437E 08	0.0	0.0	0.0	0.823758E-04	0.315276E-05	0.649028E-06
41	-0.310000E 02	0.461673E 08	0.0	0.0	0.0	0.137865E-05	0.415193E-05	0.869648E-06
42	-0.290000E 02	0.461680E 08	0.0	0.0	0.0	0.237438E-05	0.734321E-05	0.219171E-05
43	-0.270000E 02	0.692521E 08	0.0	0.0	0.0	0.365581E-05	0.947992E-04	0.320922E-05
44	-0.250000E 02	0.692521E 08	0.0	0.0	0.0	0.518308E-05	0.123399E-04	0.691342E-05
45	-0.230000E 02	0.923369E 08	0.0	0.0	0.0	0.841208E-05	0.188518E-04	0.232447E-04
46	-0.210000E 02	0.184673E 09	0.0	0.0	0.0	0.109282E-04	0.255824E-04	0.470013E-04
47	-0.190000E 02	0.349337E 09	0.0	0.0	0.0	0.129258E-04	0.418566E-04	0.880636E-04
48	-0.170000E 02	0.554004E 09	0.0	0.0	0.0	0.14342E-04	0.510420E-04	0.780814E-04
49	-0.150000E 02	0.574154E 09	0.0	0.0	0.0	0.154341E-04	0.374282E-04	0.210056E-04
50	-0.130000E 02	0.478475E 09	0.0	0.0	0.0	0.177217E-04	0.449788E-04	0.227766E-04
51	-0.110000E 02	0.287087E 09	0.0	0.0	0.0	0.190311E-04	0.350527E-04	0.110842E-04
52	-0.090000E 02	0.0	0.0	0.0	0.0	0.199144E-04	0.327812E-04	0.872979E-05
53	-0.070000E 02	0.0	0.0	0.0	0.0	0.211152E-04	0.359067E-04	0.874251E-05
54	-0.050000E 02	0.0	0.0	0.0	0.0	0.220098E-04	0.349168E-04	0.803859E-05
55	-0.030000E 02	0.0	0.0	0.0	0.0	0.231742E-04	0.469335E-04	0.115282E-04
56	-0.010000E 02	0.0	0.0	0.0	0.0	0.24827E-04	0.312624E-04	0.355130E-05
57	-0.390000E 02	0.0	0.0	0.0	0.0	0.242010E-04	0.524015E-04	0.426954E-04
58	-0.370000E 02	0.0	0.0	0.0	0.0	0.315177E-04	0.134423E-03	0.296747E-03
59	-0.350000E 02	0.0	0.0	0.0	0.0	0.339683E-04	0.146735E-03	0.317152E-03
60	-0.330000E 02	0.0	0.0	0.0	0.0	0.360143E-04	0.111060E-03	0.256708E-03
61	-0.310000E 02	0.0	0.0	0.0	0.0	0.376563E-04	0.151492E-03	0.342325E-03
62	-0.290000E 02	0.0	0.0	0.0	0.0	0.398687E-04	0.149319E-03	0.460158E-03
63	-0.270000E 02	0.0	0.0	0.0	0.0	0.383189E-04	0.266206E-03	0.613592E-03
64	-0.250000E 02	0.0	0.0	0.0	0.0	0.356524E-04	0.261207E-03	0.465251E-03
65	-0.230000E 02	0.0	0.0	0.0	0.0	0.332707E-04	0.155218E-03	0.162674E-03
66	-0.210000E 02	0.0	0.0	0.0	0.0	0.305082E-04	0.158165E-03	0.178557E-03
67	-0.190000E 02	0.0	0.0	0.0	0.0	0.267634E-04	0.200660E-03	0.246847E-03
68	-0.170000E 02	0.0	0.0	0.0	0.0	0.239626E-04	0.207273E-03	0.234791E-03
69	-0.150000E 02	0.0	0.0	0.0	0.0	0.205459E-04	0.197424E-03	0.184420E-03
70	-0.130000E 02	0.0	0.0	0.0	0.0	0.173768E-04	0.157621E-03	0.124205E-03
71	-0.110000E 02	0.0	0.0	0.0	0.0	0.152440E-04	0.114648E-03	0.102134E-03
72	-0.090000E 02	0.0	0.0	0.0	0.0	0.130745E-04	0.150448E-03	0.133358E-03
73	-0.070000E 02	0.0	0.0	0.0	0.0	0.106401E-04	0.147722E-03	0.163318E-03
74	-0.050000E 02	0.0	0.0	0.0	0.0	0.852575E-05	0.134217E-03	0.127087E-03
75	-0.030000E 02	0.0	0.0	0.0	0.0	0.620417E-05	0.143107E-03	0.188009E-03
76	-0.010000E 02	0.0	0.0	0.0	0.0	0.404546E-05	0.172832E-03	0.237305E-03
76.5	0.0	0.0	0.0	0.0	0.0	0.296611E-05	0.182198E-03	0.261953E-03

8	-0.137000E 03	0.449759E-16	0.0
9	-0.135000E 03	0.189240E-15	0.0
10	-0.133000E 03	0.538674E-15	0.0
11	-0.131000E 03	0.172036E-14	0.0
12	-0.129000E 03	0.235906E-13	0.0
13	-0.127000E 03	0.935166E-13	0.0
14	-0.125000E 03	0.184786E-12	0.0
15	-0.123000E 03	0.789266E-12	0.0
16	-0.121000E 03	0.478741E-11	0.0
17	-0.119000E 03	0.983334E-11	0.0
18	-0.117000E 03	0.178225E-10	0.0
19	-0.115000E 03	0.284758E-10	0.0
20	-0.113000E 03	0.313648E-10	0.0
21	-0.111000E 03	0.160758E-09	0.0
22	-0.109000E 03	0.112469E-08	0.0
23	-0.107000E 03	0.130131E-08	0.0
24	-0.105000E 03	0.105665E-08	0.0
25	-0.103000E 03	0.221868E-08	0.0
26	-0.101000E 03	0.346074E-08	0.0
27	-0.990000E 02	0.736915E-08	0.0
28	-0.970000E 02	0.922441E-08	0.0
29	-0.950000E 02	0.906059E-08	0.128072E-05
30	-0.930000E 02	0.813617E-07	0.200768E-05
31	-0.910000E 02	0.909852E-07	0.188447E-05
32	-0.890000E 02	0.491234E-07	0.324544E-05
33	-0.870000E 02	0.477325E-07	0.625238E-05
34	-0.850000E 02	0.425912E-07	0.639868E-05
35	-0.830000E 02	0.941782E-07	0.474687E-05
36	-0.810000E 02	0.521637E-07	0.358358E-05
37	-0.790000E 02	0.218676E-07	0.224875E-05
38	-0.770000E 02	0.533162E-07	0.101488E-05
39	-0.750000E 02	0.727595E-07	0.526277E-06
40	-0.730000E 02	0.103033E-06	0.577212E-06
41	-0.710000E 02	0.179771E-06	0.114701E-05
42	-0.690000E 02	0.633179E-06	0.899190E-06
43	-0.670000E 02	0.106880E-05	0.119009E-05
44	-0.650000E 02	0.275582E-05	0.119615E-05
45	-0.630000E 02	0.981952E-05	0.161444E-05
46	-0.610000E 02	0.179550E-04	0.322606E-05
47	-0.590000E 02	0.291966E-04	0.573648E-05
48	-0.570000E 02	0.211586E-04	0.936001E-05
49	-0.550000E 02	0.325794E-05	0.109640E-04
50	-0.530000E 02	0.317026E-05	0.126486E-04
51	-0.510000E 02	0.126306E-05	0.124833E-04
52	-0.490000E 02	0.910353E-06	0.765615E-05
53	-0.470000E 02	0.844124E-06	0.0
54	-0.450000E 02	0.713609E-06	0.0
55	-0.430000E 02	0.849347E-06	0.0
56	-0.410000E 02	0.0	0.0
57	-0.390000E 02	0.154971E-04	0.0
58	-0.370000E 02	0.118964E-03	0.0
59	-0.350000E 02	0.113993E-03	0.0
60	-0.330000E 02	0.890530E-04	0.0
61	-0.310000E 02	0.113865E-03	0.0
62	-0.290000E 02	0.145375E-03	0.0
63	-0.270000E 02	0.181154E-03	0.0
64	-0.250000E 02	0.126486E-03	0.0
65	-0.230000E 02	0.371754E-04	0.0
66	-0.210000E 02	0.393979E-04	0.0
67	-0.190000E 02	0.530248E-04	0.0


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68 -0.170000E 02 0.402562E-04 0.0
69 -0.150000E 02 0.36021E-04 0.0
70 -0.130000E 02 0.22937E-04 0.0
71 -0.110000E 02 0.18465E-04 0.0
72 -0.900000E 01 0.25730E-04 0.0
73 -0.700000E 01 0.32496E-04 0.0
74 -0.500000E 01 0.25720E-04 0.0
75 -0.300000E 01 0.40732E-04 0.0
76 -0.100000E 01 0.52547E-04 0.0
76.5 0.0 0.50455E-04 0.0

***** TOTAL NUMBER OF EGGS SPAWNED IN ALL ELEMENTS IN THE ESTUARY, TOTEGG = 0.46833E 10
***** TOTAL NUMBER OF EGG IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 1) = 0.0
***** TOTAL NUMBER OF YOLK SAC IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 2) = 0.0
***** TOTAL NUMBER OF LARVA IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 3) = 0.12745E 07
***** TOTAL NUMBER OF JUVENILE I IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 4) = 0.67409E 07
***** TOTAL NUMBER OF JUVENILE II IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 5) = 0.10073E 08
***** TOTAL NUMBER OF JUVENILE III IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 6) = 0.28863E 07
***** TOTAL NUMBER OF PUPPY SPAWNING IN ALL ELEMENTS IN THE ESTUARY, TOTPDH( 7) = 0.13200E 06
***** SUM OF ERROR OVER ALL ELEMENTS FOR EACH AGE GROUP *****

0.0 0.0 -0.75231E-36 0.49303E-31 0.15772E-29 0.43108E-29
0.0

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***** DAYS AFTER START OF SPAWNING YEAR. IDAYOT = 153 **** JULIAN DAY, JULDAY = 245 **** DATE : 24.00 HOUR 2 SEPTEMBER 1973

NUMBER PER CUBIC FEET * 1.0E 03

B/L

AGE GROUP : EGG AT TIME = 0.672E 03 HRS

0000 DAYS AFTER START OF SPAWNING YEAR, 154VU = 57 0000 JULIAN DAY, JULIAN = 197 0000 DATE : 24.00 HOUR 27 MAY 1973

NUMBER PER CUBIC F.F. @ 1.0W U.S

AGE GROUP : YOLK SAC AT TIME : 0.6728 03 HRS

0000 DAYS AFTER START OF SPawning YEAR. DAYBY " 57 0000 JULIAN DAY. JULDAY " 107 0000 DATE : 26.00 MONTH 27 MAY 1971

NUMBER PER CUBIC FEET * 1.0E 04

AGE GROUP : LARVA AT TIME = 0.132E 04 HRS

0000 DAYS AFTER START OF SPawning YEAR. IDAYDY = 04 0000 JULIAN DAY. JIMDAY = 176 0000 DATE = 26.00 JULY 71 0000 1971

NUMBER PER CUBIC FOOT * 1.0E 04

AGE GROUP : JUVENILE 1 AT TIME = 0.204E 04 HRS

0000 DAYS AFTER START OF SPawning YEAR. TCAYDY = 114 0000 JULIAN DAY. JUDAY = 256 0000 DATE : 26.00 HOUR 23 JULY 1971

ITAVG	IXSNG	PMAVG(1)	PMAVG(2)	PMAVG(3)	PMAVG(4)	PMAVG(5)	PMAVG(6)	PMAJUV
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	5	0.190567E-00	0.862650E-00	0.212082E-00	0.897110E-02	0.170803E-02	0.0	0.106791E-01
6	6	0.804207E-07	0.991830E-06	0.252486E-06	0.435486E-08	0.719511E-02	0.0	0.882830E-04
7	7	0.205163E-08	0.781601E-07	0.272757E-07	0.711294E-04	0.130032E-04	0.0	0.727291E-05
8	8	0.567122E-07	0.101061E-08	0.607781E-07	0.276807E-06	0.711817E-03	0.0	0.283574E-04
9	9	0.100006E-08	0.684789E-07	0.493892E-07	0.593843E-06	0.280878E-05	0.0	0.622280E-06
10	10	0.518767E-08	0.223831E-08	0.697562E-07	0.714308E-06	0.411995E-05	0.0	0.770556E-06
11	11	0.194896E-08	0.272781E-08	0.106117E-08	0.892978E-06	0.512327E-04	0.0	0.745076E-04
12	12	0.817164E-06	0.540892E-07	0.618630E-07	0.161088E-07	0.142170E-04	0.0	0.175596E-07
13	13	0.741498E-08	0.105177E-06	0.246943E-06	0.108384E-07	0.184502E-04	0.0	0.119648E-07
14	14	0.998503E-01	0.107308E-04	0.355828E-04	0.544519E-06	0.426306E-05	0.0	0.480044E-06
15	15	0.192235E-01	0.100395E-02	0.807965E-02	0.172891E-06	0.719231E-05	0.0	0.889375E-06
		0.116030E-09	0.807181E-08	0.380705E-08	0.612595E-07	0.159549E-06	0.0	0.674065E-07

ITAVG	IXSNG	PMAVG(1)	PMAVG(2)	PMAVG(3)	PMAVG(4)	PMAVG(5)	PMAVG(6)	PMAJUV
1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	5	0.505877E-10	0.122814E-09	0.563006E-10	0.238184E-11	0.453812E-12	0.0	0.283487E-11
6	6	0.773839E-03	0.187465E-03	0.877222E-04	0.821298E-06	0.135995E-07	0.0	0.814992E-06
7	7	0.371343E-02	0.181839E-02	0.493718E-03	0.129113E-04	0.251661E-04	0.0	0.131646E-04
8	8	0.160573E-02	0.167793E-02	0.100508E-02	0.458242E-04	0.118118E-05	0.0	0.470824E-04
9	9	0.128199E-02	0.825322E-02	0.619365E-03	0.737352E-04	0.388705E-05	0.0	0.772548E-04
10	10	0.711850E-02	0.306591E-02	0.957191E-03	0.981442E-04	0.783710E-04	0.0	0.105715E-03
11	11	0.264078E-02	0.370317E-02	0.188081E-02	0.121245E-03	0.695617E-04	0.0	0.128318E-03
12	12	0.168176E-04	0.875097E-03	0.443378E-03	0.181558E-03	0.122052E-04	0.0	0.154236E-03
13	13	0.188759E-06	0.110576E-04	0.259614E-04	0.109740E-03	0.156173E-04	0.0	0.125605E-03
14	14	0.672810E-09	0.185918E-06	0.883298E-06	0.780419E-04	0.125956E-06	0.0	0.870321E-04
15	15	0.242427E-11	0.126608E-08	0.518888E-08	0.870252E-04	0.932242E-05	0.0	0.566701E-04
		0.711850E-02	0.370317E-02	0.188081E-02	0.181558E-03	0.156173E-04	0.0	0.887471E-04
		10	11	12	13	13	13	

ITAVE	IXS80	PMHAYG(1)	PMHAYG(2)	PMHAYG(3)	PMHAYG(4)	PMHAYG(5)	PMHAYG(6)	PMHAYG(7)
24	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24		0.0	0.0	0.0	0.0	0.0	0.0	0.0

ITAVE	IXS83	PMHAYG(1)	PMHAYG(2)	PMHAYG(3)	PMHAYG(4)	PMHAYG(5)	PMHAYG(6)	PMHAYG(7)
24	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24		0.0	0.0	0.0	0.0	0.0	0.0	0.0

9 ELEMENTARY AVERAGE NUMBERS 9 1.00-07

The graph displays the percentage of the population with access to electricity for several countries over a 20-year period. The data is as follows:

Country	1960	1970	1980
Algeria	0	0	0
Angola	0	0	0
Argentina	0	0	0
Australia	0	0	0
Austria	0	0	0
Bahamas	0	0	0
Bahrain	0	0	0
Bangladesh	0	0	0
Barbados	0	0	0
Belarus	0	0	0
Belgium	0	0	0
Belize	0	0	0
Benin	0	0	0
Bhutan	0	0	0
Bolivia	0	0	0
Bosnia and Herzegovina	0	0	0
Brazil	0	0	0
Bulgaria	0	0	0
Burkina Faso	0	0	0
Burundi	0	0	0
Cambodia	0	0	0
Cameroon	0	0	0
Canada	0	0	0
Cape Verde	0	0	0
Casakhstan	0	0	0
Cayman Islands	0	0	0
Czechia	0	0	0
Dominica	0	0	0
Dominican Republic	0	0	0
DRC	0	0	0
Ecuador	0	0	0
Egypt	0	0	0
El Salvador	0	0	0
Equatorial Guinea	0	0	0
Eritrea	0	0	0
Estonia	0	0	0
Ethiopia	0	0	0
Fiji	0	0	0
Finland	0	0	0
France	0	0	0
Gabon	0	0	0
Gambia	0	0	0
Germany	0	0	0
Ghana	0	0	0
Greece	0	0	0
Guatemala	0	0	0
Guinea	0	0	0
Guinea-Bissau	0	0	0
Haiti	0	0	0
Honduras	0	0	0
Hungary	0	0	0
Iceland	0	0	0
India	0	0	0
Indonesia	0	0	0
Iran	0	0	0
Ireland	0	0	0
Israel	0	0	0
Italy	0	0	0
Jamaica	0	0	0
Japan	0	0	0
Jordan	0	0	0
Kazakhstan	0	0	0
Kenya	0	0	0
Korea	0	0	0
Kuwait	0	0	0
Kyrgyzstan	0	0	0
Laos	0	0	0
Latvia	0	0	0
Lebanon	0	0	0
Lesotho	0	0	0
Liberia	0	0	0
Lithuania	0	0	0
Luxembourg	0	0	0
Macao	0	0	0
Madagascar	0	0	0
Mali	0	0	0
Malta	0	0	0
Mauritania	0	0	0
Mauritius	0	0	0
Mexico	0	0	0
Moldova	0	0	0
Mongolia	0	0	0
Montenegro	0	0	0
Morocco	0	0	0
Mozambique	0	0	0
Myanmar	0	0	0
Nicaragua	0	0	0
Niger	0	0	0
Nigeria	0	0	0
North Macedonia	0	0	0
North Korea	0	0	0
Oman	0	0	0
Pakistan	0	0	0
Panama	0	0	0
Papua New Guinea	0	0	0
Paraguay	0	0	0
Peru	0	0	0
Philippines	0	0	0
Poland	0	0	0
Portugal	0	0	0
Romania	0	0	0
Russia	0	0	0
Rwanda	0	0	0
Saudi Arabia	0	0	0
Senegal	0	0	0
Sierra Leone	0	0	0
Singapore	0	0	0
Slovakia	0	0	0
S			

AGE GROUP :	ALL	PCA WITH :
0-10	100	100
11-20	100	100
21-30	100	100
31-40	100	100
41-50	100	100
51-60	100	100
61-70	100	100
71-80	100	100
81-90	100	100
91-100	100	100

0000 DAYS AFTER START OF SPANNING YEAR, IDAYCV = 50 000 JULIAN DAY, JULCAY = 100 000 DATE ! 20.00 MONTH 24 MAY 1971

8 ELEMENT AVERAGE NUMBER 4 1.0E-07

104

AGE GROUP 1 VOLK SAC PEN WEEK 4

0000 DAYS AFTER START OF SPANNING YEAR, ICAYIV = 96 0000 JULIAN DAY, JULDAY = 166 0000 DATE 1 24.00 MOIN 26 MAY 1973

ELEMENT AVERAGE NUMBER 0 1.00-07

AGE GROUP : LARVA PER DEER 0
 0000 DAYS AFTER START OF SPANNING YEAR. (DAYCV = 0) 0000 JULIAN DAY, JULCAY = 181 0000 DATE : 24.00 HOUR 30 JUNE 1973

2 ELEMENT AVERAGE NUMBER * 1.00-07

AGE GROUP : JUVENILE 1 PER DECK 10

0000 DAYS AFTER START OF SPawning YEAR. (DAYBY = 00 0000 JULIAN DAY. JULDAY = 100 0000 DATA : 24.00 MGLN 7 JULY 1971

AVERAGE NUMBER = 1.05-07

ACF GROUP : 005 -55.00 MILPS FROM GALLERY

AVGAGE NUMBER = 1.05-07

AGE GROUP : VOLK SAC -55.00 MILES FROM BATTERY

AVERAGE NUMBER = 1.07-07

ACP GROUP : 1.07-07 -15.00 MILLS FROM MATTER

AVERAGE NUMBER = 1.00-07

ADDITIONAL DATA FROM BATTERY - 35.00 HILTS FROM BATTERY

AVERAGE MINIMUM = 1.06-07

AGE GROUP : JUVENILE 11 -25.00 MILES FROM BATTERY

***** MAXIMUM 5-ELEMENT AVERAGES PER CUBIC FOOT OVER THE TIME CYCLE *****

MAXIMUM PDMAVG (1) = 0.754943E-02 FOR SEGMENT 10 DURING WEEK 3
 MAXIMUM PDMAVG (2) = 0.370317E-02 FOR SEGMENT 11 DURING WEEK 4
 MAXIMUM PDMAVG (3) = 0.203398E-02 FOR SEGMENT 11 DURING WEEK 6
 MAXIMUM PDMAVG (4) = 0.650430E-03 FOR SEGMENT 13 DURING WEEK 9
 MAXIMUM PDMAVG (5) = 0.440930E-03 FOR SEGMENT 13 DURING WEEK 16
 MAXIMUM PDMAVG (6) = 0.132302E-03 FOR SEGMENT 13 DURING WEEK 24

ITAVE	PNTOT(1)	PNTOT(2)	PNTOT(3)	PNTOT(4)	PNTOT(5)	PNTOT(6)	PNTOT	PNTOT
1	0.142808E 07	0.192718E 05	0.348110E 08	0.549807E 02	0.595132E 00	0.0	0.575258E 02	0.149501E 07
2	0.616376E 08	0.104381E 08	0.169957E 07	0.913751E 04	0.292335E 04	0.272824E 02	0.943548E 05	0.738648E 08
3	0.115088E 09	0.339342E 08	0.154712E 08	0.162247E 07	0.103639E 06	0.178929E 04	0.172790E 07	0.386226E 09
4	0.106030E 09	0.807143E 08	0.380705E 08	0.512595E 07	0.599569E 06	0.151541E 05	0.674047E 07	0.241556E 09
5	0.104863E 09	0.821316E 08	0.591722E 08	0.122034E 08	0.153395E 07	0.509554E 05	0.137803E 08	0.261556E 09
6	0.159443E 08	0.443077E 08	0.694870E 08	0.191723E 08	0.310720E 07	0.114549E 06	0.224160E 08	0.152205E 09
7	0.988337E 07	0.219509E 08	0.650276E 08	0.250309E 08	0.519208E 07	0.245331E 06	0.305183E 08	0.127380E 09
8	0.190227E 02	0.803722E 07	0.548140E 08	0.287977E 08	0.747304E 07	0.330748E 06	0.148015E 08	0.992527E 08
9	0.0	0.883758E 06	0.421373E 08	0.300974E 08	0.965539E 07	0.521385E 06	0.405343E 08	0.835532E 08
10	0.0	0.854636E 03	0.305808E 08	0.259901E 08	0.967134E 07	0.960242E 06	0.364217E 08	0.672113E 08
11	0.0	0.200021E 02	0.216319E 08	0.214422E 08	0.923621E 07	0.103801E 07	0.319172E 08	0.535491E 08
12	0.0	0.382007E 00	0.152052E 02	0.192371E 08	0.982440E 07	0.123445E 07	0.302979E 08	0.455031E 08
13	0.0	0.0	0.102012E 08	0.171941E 08	0.105116E 08	0.147428E 07	0.291830E 08	0.390781E 08
14	0.0	0.0	0.571742E 07	0.155781E 08	0.105562E 08	0.170722E 07	0.282819E 08	0.319501E 08
15	0.0	0.0	0.172470E 07	0.140891E 08	0.112742E 08	0.193778E 07	0.273011E 08	0.290244E 08
16	0.0	0.0	0.211058E 06	0.114510E 08	0.112192E 08	0.216808E 07	0.250417E 08	0.252528E 08
17	0.0	0.0	0.178417E 05	0.861495E 07	0.112302E 08	0.237909E 07	0.222421E 08	0.222421E 08
18	0.0	0.0	0.119058E 04	0.480768E 07	0.108252E 08	0.257801E 07	0.194284E 08	0.198254E 08
19	0.0	0.0	0.325528E 03	0.480635E 07	0.103661E 08	0.277239E 07	0.179444E 08	0.179444E 08
20	0.0	0.0	0.776893E 02	0.355776E 07	0.970198E 07	0.293571E 07	0.161945E 08	0.161945E 08
21	0.0	0.0	0.254042E 02	0.240903E 07	0.896630E 07	0.107554E 07	0.146509E 08	0.146509E 08
22	0.0	0.0	0.772608E 01	0.180464E 07	0.803844E 07	0.113401E 07	0.129754E 08	0.129754E 08
23	0.0	0.0	0.277960E 01	0.126639E 07	0.724787E 07	0.319172E 07	0.117054E 08	0.117054E 08
24	0.0	0.0	0.923314E 00	0.878561E 06	0.649049E 07	0.322441E 07	0.105940E 08	0.105940E 08

TOTAL MINERS FOR AGF GROUP = 1.0F-06

AGE GROUP : 66

TOTAL NUMBER FOR AGE GROUP = 1.00-06

AGE GROUP : YOUNG SAC

TOTAL NUMBER FOR AGE GROUP = 1.06-04

AGE GROUP : 1.06-04

TOTAL NUMBER FOR AGE GROUP = 1.0P-04

AGE GROUP : JUVENILE 1

TOTAL NUMBER FOR AGE GROUP = 1.0E-06

AGE GROUP : JUVENILE 11

TOTAL NUMBER FOR AGE GROUP = 1.0E-06

AGE GROUP 1: JUVENILE 100