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**VALIDATION AND SOFTWARE DOCUMENTATION
OF THE ANL FISH-IMPINGEMENT MODEL**

by

**Ishwar P. Murarka, Deborah J. Bodeau,
and W. Kenneth Derickson**

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Prepared by

Division of Environmental Impact Studies

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ABSTRACT

This report contains the results of a validation test of the ANL Fish Impingement Model. By the use of 1974 fish-impingement and environmental data from the Zion Nuclear Power Station, it is shown that the modified and expanded mathematical model yields reasonably good results in calculations of daily fish-impingement losses at the cooling water intakes. Comparisons confirmed that the fish-impingement process depends primarily on the abundance of fish in the vicinity of a cooling water intake, whereas the probability function gives the susceptibility to impingement provided that fish are present in the "intensity region." In view of the limited amount of information available with regard to the various environmental and fish-abundance factors, it appears that the present form of the model is adequate and that efforts to refine the model further are not warranted.

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Fish impingement occurs at almost all once-through cooling systems that draw water from rivers, lakes, and impoundments where fish reside. Often the numbers of fish killed by impingement at these cooling systems are obtained by sampling the intake screens for impingement losses. A mathematical model has been developed by Murarka¹ to obtain fish impingement values by the use of environmental and plant-related factors which define the fish-kill process at the intakes. The conceptual development included the formulation of mathematical functions that relate environmental factors, plant operational factors, and fish abundance in the vicinity of a cooling-water intake to fish impingement occurring at the intake. In this report we present the validation-test results to establish the reasonableness of the mathematical model.

Because data on many aspects of fish behavior are unavailable, our validation of the model is restricted to the mathematical form that can be used with available data. In this effort, we have used data from the Zion Nuclear Power Station located on Lake Michigan in Illinois. The 1974 fish-impingement data, together with the established information on fish behavior, plant water intake data, and fish distribution data, were used in validating the model. We modified parts of the formulation to increase the predictive capacity of the mathematical model and to incorporate the improved knowledge of the cause and effect relationships between the various environmental characteristics and the impingement process.

Efforts were made to acquire data from other electric power plants so that examples from several aquatic systems could be presented in support of the validated tests. Unfortunately we were not able to add more cases as examples, because the necessary data simply were not available.

1. BIOLOGICAL AND PLANT OPERATIONAL DATA USED IN MODEL VALIDATION

An analysis of the 1974 impingement data from the Zion Nuclear Power Station indicated that alewives (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) accounted for over 90% of the total numbers of impinged fish.^{2,3} In order to determine why these species were so vulnerable to impingement, a literature search was made to assess the importance of their spatial distributions, seasonal abundances, size and growth rates, seasonal movements, swimming speeds and rheotactic behavior (attraction or adversion to currents) to the calculation of impingement rates. Ongoing studies⁴ have determined that abundance is plays an important factor; however, behavioral, morphological and physiological characteristics of these species may also contribute significantly to impingement rates. Certainly onshore migration and schooling would increase the chance of encountering cooling water intake currents. Once a group of these fish is exposed to an intake current their small body size, a positive rheotactic response, coupled with slow swimming speed, will interact to enhance the chance of entrapment and impingement of many individuals.

These biological data were incorporated into the model along with plant-related data on ambient water temperatures, intake pumping rates, and approach velocities. Calculated impingement rates were compared with observed rates; then data were modified or deleted if they did not add to the accuracy of the model. The final model contains only those biological factors that contribute significantly to its predictive ability.

1.1 MORPHOLOGICAL, BEHAVIORAL AND PHYSIOLOGICAL DATA ON ALEWIVES AND RAINBOW SMELT IN LAKE MICHIGAN

Size and swimming speeds, calculated from data in the literature, were incorporated into the expanded probability function discussed in Section 2. Data on schooling, seasonal movement, and rheotactic response were not really quantifiable, but were assumed to be implicit within the density function.

1.1.1 Alewives

Alewives are the most abundant species in Lake Michigan, comprising about 80% of the total fish biomass.⁵ In the Zion area, individuals average about 167 mm long with a maximum length of 215 mm.⁶ Alewife larvae are about 3.5 mm at hatching and reach a maximum length of 119 mm by the end of their first year. Growth rates are highest during the first year (ca. 115 mm), declining considerably in succeeding years (45, 22, 17 and 14 mm in the second, third, fourth and fifth years, respectively).⁶ These growth rates were used to generate the formula (Eq. 1),

$$L = 118.6 \times X^{0.383} , \quad (1)$$

where L is the total body length in mm and X is the age in years or fractions thereof. This formula was used to calculate monthly mean lengths for a maturing population of fish. These sizes were then incorporated into the expanded probability function, with the maximum length set at 162 mm since most of the impinged alewives were less than two years of age.⁷

Data on swimming speeds are from studies made by Colby⁸ and Kothas.⁹ These studies provided sustained swimming speeds (cm/sec) at different temperatures for fish 61-104 mm long, and such data were used to generate the formula (Eq. 2),

$$S = 1.608T + 0.116L , \quad (2)$$

where S is sustained swimming speed in cm/sec, T is the temperature in °C, and L is the total body length in mm. This formula was used to calculate mean monthly sustained swimming speeds for different sized fish at different temperatures for the expanded probability function. The maximum swimming speed for this function was based on the monthly mean maximum temperature for fish 162 mm long.

Information on seasonal movements by alewives indicates that adults (age-class II and older) remain in the deeper offshore waters,¹⁰ except during

spring and summer months when they move into the shallower inshore waters to spawn.^{2,6} Young-of-the-year and yearlings remain in the shallow waters until October, then migrate to deeper offshore waters.^{2,6,11}

Schooling and a positive rheotactic response have been observed in this species. Romberg et al.¹² and Emery¹³ have observed large schools of alewives congregating at outfalls. In their study of thermal effluents, Romberg et al.,¹² concluded that the alewives were attracted to the discharge's strong current rather than its temperature. Richkus^{14,15} also observed and experimentally demonstrated that alewives exhibit a positive rheotactic response.

From the above information on the morphological, behavioral and physiological characteristics of the fish, it is easy to see why alewives are so vulnerable to impingement. A large portion of the population--those fish less than two years old (162 mm in length)--spend most of the spring and summer months schooling in shallow waters where the power plant intakes are located, thereby increasing the likelihood of being exposed to intake currents.

1.1.2 Rainbow Smelt

Rainbow smelt are slightly smaller than alewives in this portion of Lake Michigan. The adults average 157 mm and reach a maximum length of 221 mm.⁶ The larvae are about 5 mm long at birth⁷ and reach a length of 106 mm by the end of their first year. Their growth rates are highest during the first year (ca. 100 mm) and remain fairly constant, though somewhat lower, during succeeding years (35, 30 and 40 mm in the second, third and fourth years, respectively).⁶ These growth rates were used to generate the relationship (Eq. 3)

$$L = 117.7 \times X^{0.345}, \quad (3)$$

where L is the total body length in mm and X is the years or fractions thereof. Lengths were generated and incorporated as described in Section 1.1.1. The maximum size for the probability function was 141 mm since most of the impinged smelt were less than two years old.⁷

The data on swimming speed were less comprehensive than those for alewives. Industrial Bio-Test Laboratories, Inc.¹⁶ tested fish averaging 134 mm in length at 5° and 15°C to ascertain their maximum sustained swimming speeds. These data, after some modification were used to calculate the relationship (Eq. 4)

$$S = 25.85 \times T^{0.169} , \quad (4)$$

where S is the maximum sustained swimming speed in cm/sec and T is the temperature in °C. In order to compensate for the lack of data on swimming speed as a function of body size, the maximum observed swimming speed (41 cm/sec) was used as the maximum value in the expanded probability function for all months.

Data on seasonal movements of rainbow smelt indicated that adults tend to remain in offshore waters most of the year, only coming inshore to spawn during spring. The young-of-the-year and yearlings are found in the shallower inshore waters during most of the year, moving offshore to cooler waters from June to August only.^{5,10,17}

Schooling and a negative rheotactic response have been observed in this species. Romberg et al.⁸ and Emery⁹ saw large schools of rainbow smelt during their studies. Romberg et al.⁸ also noted that this species congregated outside the thermal plume area and tended to avoid higher water velocities.

From these data, it is not readily apparent why young-of-the-year and yearlings are so vulnerable to impingement. While their schooling habits and tendency to remain inshore increases their chances of encountering intake currents, the negative rheotactic response should help counteract the danger. However, once entrapped, impingement is inevitable because of this species' small size and, hence, slow swimming speeds.

1.2 FISH DENSITY NEAR ZION IN 1974

Mean densities of alewife and rainbow smelt were computed for each of the days when trawl-catch data were available. Abundance was computed for the

two species from trawl collections taken in 1974 at the 5.5-m depth contour near the Zion intake structure.^{2,3} After consultation with several fishery biologists, the trawl was assumed to be only 20% efficient and all densities were adjusted accordingly.

1.3 PLANT OPERATIONAL DATA FOR 1974

Average daily pumping rates (cfs) and ambient water temperatures were taken from 1974 Zion Station Operational Monitoring Reports.^{2,3} Yearly maximum and minimum temperatures were used as inputs to the model. We calculated the approach velocities on the basis of the intake pipeline velocities. The intake structure is a crypt with a velocity cap about 254 cm below the water surface. The velocity past this cap is generally less than 25 cm/sec; however, fish can easily enter the crypt and once inside they are exposed to the higher velocities of the intake pipes. At maximum pumping rates (3990 cfs) intake velocities in the pipelines are 265 cm/sec and fish that come too close to the openings of the intake pipes will become entrapped and eventually impinged after entering the intake forebay area. We established Equation 5 below to relate approach velocities to water pumping rates by using data from the NALCO Environmental Sciences' studies:⁷

$$A = 0.066P , \quad (5)$$

where A is the approach velocity in cm/sec and P is the pumping rate in cfs.

2. THE MATHEMATICAL MODEL

The basic form of the model as formulated by Murarka¹ is given in Equation 6,

$$\dot{I}(t) = \sum_{i=1}^k P_i(t) \times Q(t) \times D_i(t) , \quad (6)$$

where $\dot{I}(t)$ = the total fish impingement rate at time t for all species of fish (usually a daily rate),

$P_i(t)$ = the probability that an individual fish of species i is impinged on the screen at time t , given that the fish is present in a defined "zone of influence" or "intensity region",

$Q(t)$ = the volume of the water entering the intake per unit of time at time t , and

$D_i(t)$ = the number of fish of species i in a unit volume of water in the zone of influence at time t .

In Equation 6, $Q(t)$ and $D_i(t)$ are measured quantities at known points in time. $Q(t)$ is normally calculated on the basis of the design capacity of the water pumps and the hours of use of the pumps during a given day. $D_i(t)$ is calculated from catch obtained by means of fishing gear suitable for sampling fish abundance. We used data obtained by trawling at a depth of 5.5 meters in the water column. The catch data were converted to number of fish per thousand cubic feet per day and were also adjusted for the gear efficiency.

The $P_i(t)$ function was formulated as given in Equation 7.¹ Then we made changes to expand and modify the form of Equation 7 as discussed in Section 2.1.

$$P_i(t) = \left(\frac{T(t) - T_{\min}}{T_{\max} - T_{\min}} \right) \left(\frac{A(t) - A_{\min}}{A_{\max} - A_{\min}} \right) \left(\frac{S_i(t) - S_{\min_i}}{S_{\max_i} - S_{\min_i}} \right) \left(1 - \frac{L_i(t)}{L_{\max_i}} \right) \quad (7)$$

where $T(t)$ is water temperature at time t ,

$A(t)$ is water approach velocity at time t ,

$S_i(t)$ is swimming speed of the fish of i^{th} species at time t , and

$L_i(t)$ is length of the fish of i^{th} species at time t .

The ranges of the variables are:

$$T_{\min} \leq T(t) \leq T_{\max},$$

$$A_{\min} \leq A(t) \leq A_{\max}$$

$$S_{\min_i} \leq S_i(t) \leq S_{\max_i},$$

$$L_{\min_i} \leq L_i(t) \leq L_{\max_i}.$$

2.1 MODIFICATIONS AND EXTENSIONS OF THE PROBABILITY-FUNCTION COMPONENT

As we progressed with the model validation work we found that there were some aspects of the formulation in Equation 2 that needed change. Since temperature, length, and swimming speed are heavily correlated, we felt that the length and temperature variables were the most important in the model consideration, therefore we eliminated S from the Equation 7. Pumping rate is strongly correlated with approach velocity and was considered to be more important to the model, thus A was also eliminated from Equation 7. Another reason for eliminating these two variables was that values for A and S were derived from very few data points and as a result introduced large errors into the model, thereby reducing its predictive ability. By assuming that the remaining two factors in Equation 7 are independent in affecting the probability of impingement for the i^{th} species at time t , we obtained the modified version shown as Equation 8. For Equation 8, we expanded the mathematical formulation using the length, L , variable. We divided the fish lengths into a maximum of six classes. From the trawl-catch data, we would know the shortest (beginning) and longest (ending) lengths of the fish in each of the

six classes. The relative frequency, $f_{i,j}(t)$, for each length class for each species of fish were also available from the catch data. This bivariate approach utilizing the length-class distribution and the conditional probability of impingement given the length class provides a better representation of the time-dependent fish-impingement process as it relates to fish lengths. The fish-length classes could be further increased to provide a higher degree of resolution in calculating the $P_i(t)$ values. However, the success of such changes would depend entirely on the availability of the relative frequency distribution data for the additional class intervals.

Thus the modified form of the probability function is the following:

$$P_i(t) = \left(\frac{T(t) - T_{\min}}{T_{\max} - T_{\min}} \right) + \left[\sum_{j=1}^{N_i} f_{i,j}(t) \left(\frac{L_{e,i,j} - L_{b,i,j}}{L_{\max_i} - L_{\min_i}} \right) \right] - \left(\frac{T(t) - T_{\min}}{T_{\max} - T_{\min}} \right) \left[\sum_{j=1}^{N_i} f_{i,j}(t) \left(\frac{L_{e,i,j} - L_{b,i,j}}{L_{\max_i} - L_{\min_i}} \right) \right] \quad (8)$$

where $L_{e,i,j}$ is the fish length for end of the j^{th} length class of the i^{th} species,

$L_{b,i,j}$ is the fish length for beginning of the j^{th} length class of the i^{th} species,

$f_{i,j}$ is the relative frequency of fish of species i belonging to the j^{th} class as estimated by the abundance data on the abundance in the vicinity of the cooling water intakes, and

N_i is the number of length classes (not to exceed 6) for the i^{th} species.

2.2 MODIFICATION OF THE FISH-DENSITY FUNCTION

In the basic form of the model (Eq. 6) we presented the function $D_i(t)$ as the time-dependent, species-specific fish density function near the water intakes. For the case when $D_i(t)$ was not actually observed for each of the time elements during the year, the function was expanded to include interpolated values for the daily fish densities. In validating our model on days when trawls were not made, we used a linear interpolation between successive observations to generate the fish-density values.

We provide the two alternative forms of the function $D_i(t)$. The linear formulation is Equation 9,

$$D_i(t) = d_i(t) , \quad (9)$$

where $d_i(t)$ is the fish density of i^{th} species given in terms of numbers per thousand cubic feet of water per 24-hour period. It is calculated from trawl-catch data by means of Equation 11.

The exponential formulation for $D_i(t)$ is given in Equation 10.

$$D_i(t) = \exp [\lambda_i \times d_i(t)] \quad (10)$$

where $d_i(t)$ is the fish density per thousand cubic feet per day observed or interpolated for the i^{th} species, and λ_i is the species-specific transfer coefficient.

The $d_i(t)$ value includes the correction for gear efficiency. Since trawl data were used to represent fish density for the Zion case, we have used 20% as the catch efficiency of the gear and, therefore, obtained the $d_i(t)$ from Equation 11,

$$d_i(t) = \frac{C_i \times 86.4}{W_g \times D_g \times V_g \times t_g \times e_g} , \quad (11)$$

where C_i = number of fish of i^{th} species in the trawl catch,
 W_g = width (in feet) of the trawling gear,
 D_g = diameter of the trawling gear opening,
 V_g = velocity with which the gear was towed,
 t_g = time duration (in seconds) of the trawl, and
 e_g = efficiency of the trawl gear.

In Equation 11 the value 86.4 is the conversion coefficient for obtaining fish density per thousand cubic feet of water per day.

2.3 SITE- AND SPECIES-SPECIFIC SEASONAL CORRECTION FACTORS

On further examination of the model, we found that the mathematical representation needed to be expanded to allow for site-specific and species-specific seasonal correction factors. Therefore, we included a term $M_i(t)$ in the model as a site- and species-specific seasonal correction factor, i.e., simply a constant multiplier for a given season for the i^{th} species.

Combining all these modifications and rewriting the complete mathematical form of the fish-impingement model we get Equation 12 as expansion of Equation 6 and of Equation 10,

$$\begin{aligned} \dot{I}(t) = & Q(t) \times \left[\sum_{i=1}^K \exp \left\{ \lambda_i \times d_i(t) \right\} \times M_i(t) \right] \\ & \times \left[\left(\frac{T(t) - T_{\min}}{T_{\max} - T_{\min}} \right) + \left\{ \sum_{j=1}^{N_i} f_{i,j}(t) \left(\frac{L_{e,i,j} - L_{b,i,j}}{L_{\max_i} - L_{\min_i}} \right) \right\} \right. \\ & \left. - \left(\frac{T(t) - T_{\min}}{T_{\max} - T_{\min}} \right) \left\{ \sum_{j=1}^{N_i} f_{i,j}(t) \left(\frac{L_{e,i,j} - L_{b,i,j}}{L_{\max_i} - L_{\min_i}} \right) \right\} \right] . \end{aligned} \quad (12)$$

The form of Equation 12 represents the exact mathematical formulation used in the model validation test with Zion Station data. Linear form of the density function may be chosen for cases where smaller aquatic systems are involved.

3. COMPUTED RESULTS AND SENSITIVITY ANALYSES

Predicted values for the daily impingement of alewives and smelt at the Zion Station during 1974 were calculated by means of the model in the form shown by Equation 12. A sensitivity analysis was incorporated into the calculations by manipulating two factors (fish-length distribution and water temperature) in the probability function within the model. Specifically, three cases were chosen:

Case I - fish length distribution used, water temperatures omitted.

Case II - water temperature used, fish length distribution omitted.

Case III - both water temperature and fish-length distribution used.

All predicted values were compared with the results of actual observations for the same period, and the apparent variation in sensitivity was attributed to the changes in the probability-function factors.

Those input parameters that are common to the calculations for all three cases are shown in Table 1. Data on the fish density and length-frequency distribution are given in Table 2. From these data, fish-density values in terms of number of fish per thousand cubic feet per day were computed. Table 3 shows the observed and interpolated values for the volume (in cfs) of water pumped and water temperature (in °C).

Figure 1 shows a plot of the daily water temperature, $T(t)$, as a function of the day of the year. Although the data shows many fluctuations in the daily temperatures, there is an underlying smooth behavior of the temperature curve, namely a warming trend through midautumn, and a cooling trend throughout the winter. The fluctuations in temperature are due to the many upwellings that are experienced in Lake Michigan during the summer and early fall months and which are an important factor in the fish behavior. Figure 2 presents a plot of the volume of water pumped per second--the $Q(t)$ factor. As expected

Table 1. Specification of Input Parameters to Define the
Model Form for Computing Daily Fish Impingements
at Zion Power Station in 1974

# OF SPECIES	# OF LENGTH CLASSES			BEGINNING DAY	ENDING DAY			
2	5	6	0	1	365			
TRANSFER COEFFICIENT								
ALEWIFE	0.5982E+00							
SMELT	0.1080E+02							
SEASON END DAYS				SEASONAL CORRECTION FACTORS				
ALEWIFE	120	148	218	365	0.50E+00	0.40E+00	0.65E+01	0.20E+01
SMELT	80	126	250	365	0.15E+01	0.12E+01	0.10E+01	0.30E+00
TEMPERATURE AVE. LENGTH								
ALEWIFE	MINIMUM		0.0		30.000			
	MAXIMUM		21.00		275.00			
LENGTH CLASS BOUNDARIES								
	1	2	3	4	5			
BEGINNING	0.0	76.00	127.00	152.00	178.00	178.00		
ENDING	76.00	127.00	152.00	178.00	178.00	260.00		
TEMPERATURE AVE. LENGTH								
SMEIT	MINIMUM		0.0		30.000			
	MAXIMUM		21.00		300.00			
LENGTH CLASS BOUNDARIES								
	1	2	3	4	5	6		
BEGINNING	0.0	102.00	127.00	152.00	178.00	230.00	230.00	
ENDING	102.00	127.00	152.00	178.00	230.00	300.00	300.00	

Table 2. Input Data on Fish Catch and Length-Relative
Frequency Distribution for Trawl Days in 1974

SPECIES	DATA	CATCH	LENGTH-RELATIVE FREQUENCY DISTRIBUTION					
ALEWIFE	1/15/74	0.0	0.0	0.0	0.0	0.0	0.0	
SMELT	1/15/74	1.50	0.56	0.04	0.03	0.04	0.35	0.0
ALEWIFE	1/22/74	0.0	0.0	0.0	0.0	0.0	0.0	
SMELT	1/22/74	0.0	0.56	0.04	0.03	0.04	0.35	0.0
ALEWIFE	2/12/74	0.0	0.0	0.0	0.0	0.0	0.0	
SMELT	2/12/74	2.50	0.48	0.03	0.02	0.12	0.26	0.03
ALEWIFE	3/ 6/74	0.0	0.06	0.01	0.51	0.42	0.01	
SMELT	3/ 6/74	10.00	0.19	0.11	0.30	0.28	0.09	0.02
ALEWIFE	3/27/74	0.0	0.06	0.01	0.51	0.42	0.01	
SMELT	3/27/74	63.00	0.19	0.11	0.30	0.28	0.09	0.02
ALEWIFE	4/ 6/74	35.00	0.04	0.01	0.67	0.32	0.0	
SMELT	4/ 6/74	150.00	0.11	0.12	0.36	0.28	0.09	0.02
ALEWIFE	4/16/74	430.00	0.04	0.01	0.67	0.32	0.0	
SMELT	4/16/74	60.00	0.11	0.12	0.36	0.28	0.09	0.02
ALEWIFE	5/ 3/74	3210.00	0.01	0.0	0.02	0.68	0.28	
SMELT	5/ 3/74	60.00	0.11	0.18	0.35	0.27	0.06	0.02
ALEWIFE	5/15/74	3233.00	0.01	0.0	0.02	0.68	0.28	
SMELT	5/15/74	4.00	0.11	0.18	0.35	0.27	0.06	0.02
ALEWIFE	6/ 5/74	366.00	0.06	0.04	0.66	0.22	0.01	
SMELT	6/ 5/74	0.0	0.26	0.22	0.27	0.17	0.06	0.02
ALEWIFE	6/18/74	481.00	0.06	0.04	0.66	0.22	0.01	
SMELT	6/18/74	0.0	0.26	0.22	0.27	0.17	0.06	0.02
ALEWIFE	7/ 2/74	310.00	0.12	0.04	0.72	0.11	0.0	
SMELT	7/ 2/74	0.50	0.13	0.22	0.37	0.21	0.06	0.0
ALEWIFE	7/16/74	1012.00	0.12	0.04	0.72	0.11	0.0	
SMELT	7/16/74	0.0	0.13	0.22	0.37	0.21	0.06	0.0
ALEWIFE	8/ 7/74	499.00	0.07	0.08	0.74	0.12	0.0	
SMELT	8/ 7/74	0.0	0.30	0.29	0.22	0.05	0.01	0.0
ALEWIFE	8/20/74	470.00	0.07	0.08	0.74	0.12	0.0	
SMELT	8/20/74	0.0	0.30	0.29	0.22	0.05	0.01	0.0
ALEWIFE	9/ 4/74	0.0	0.10	0.08	0.67	0.13	0.0	
SMELT	9/ 4/74	0.0	0.40	0.34	0.15	0.07	0.02	0.01
ALEWIFE	9/17/74	2.50	0.10	0.08	0.67	0.13	0.0	
SMELT	9/17/74	0.0	0.40	0.34	0.15	0.07	0.02	0.01
ALEWIFE	10/ 1/74	10.00	0.11	0.10	0.63	0.15	0.01	
SMELT	10/ 1/74	45.00	0.19	0.28	0.23	0.20	0.08	0.02
ALEWIFE	10/14/74	74.00	0.11	0.10	0.63	0.15	0.01	
SMELT	10/14/74	4.00	0.19	0.28	0.23	0.20	0.08	0.02
ALEWIFE	11/ 6/74	27.00	0.13	0.11	0.55	0.21	0.01	
SMELT	11/ 6/74	0.0	0.03	0.15	0.27	0.31	0.17	0.07
ALEWIFE	11/19/74	0.0	0.13	0.11	0.55	0.21	0.01	
SMELT	11/19/74	0.0	0.03	0.15	0.27	0.31	0.17	0.07
ALEWIFE	12/ 5/74	0.0	0.11	0.38	0.44	0.08	0.0	
SMELT	12/ 5/74	0.50	0.04	0.03	0.20	0.39	0.06	0.01
ALEWIFE	12/16/74	0.0	0.11	0.38	0.44	0.08	0.0	
SMELT	12/16/74	1.00	0.04	0.03	0.20	0.39	0.06	0.01

Table 3. Observed and Interpolated Values of Daily Water-Volume Pumped and Water Temperature in the Vicinity of the Zion Intakes in 1974

DAY	VOLUME (CFS)	TEMPERATURE (C)	DAY	VOLUME (CFS)	TEMPERATURE (C)
1	632.80	1.00	2	632.80	1.00
3	632.80	1.00	4	632.80	1.00
5	632.80	1.00	6	632.80	1.00
7	632.80	1.00	8	632.80	1.00
9	632.80	1.00	10	632.80	1.00
11	632.80	1.00	12	632.80	1.00
13	632.80	1.00	14	632.80	1.00
15	632.80	1.00	16	632.80	1.00
17	632.80	1.00	18	632.80	1.00
19	632.80	1.00	20	632.80	1.00
21	632.80	1.00	22	632.80	1.00
23	632.80	1.00	24	632.80	1.00
25	664.44	1.00	26	696.08	1.01
27	727.72	1.01	28	759.36	1.02
29	791.00	1.02	30	822.64	1.03
31	854.28	1.03	32	885.92	1.04
33	917.56	1.05	34	949.20	1.05
35	980.84	1.05	36	1012.48	1.06
37	1044.12	1.06	38	1075.76	1.07
39	1107.40	1.07	40	1139.04	1.08
41	1170.68	1.09	42	1202.32	1.09
43	1233.96	1.09	44	1265.60	1.10
45	1265.60	1.18	46	1265.60	1.27
47	1265.60	1.35	48	1265.60	1.44
49	1265.60	1.52	50	1265.60	1.61
51	1265.60	1.69	52	1265.60	1.78
53	1265.60	1.86	54	1265.60	1.95
55	1265.60	2.03	56	1265.60	2.12
57	1265.60	2.20	58	1265.60	2.29
59	1265.60	2.37	60	1265.60	2.46
61	1265.60	2.54	62	1265.60	2.63
63	1265.60	2.71	64	1265.60	2.80
65	1898.40	2.80	66	1898.40	3.30
67	1808.00	3.46	68	1717.60	3.61
69	1627.20	3.77	70	1536.80	3.93
71	1446.40	4.09	72	1356.00	4.24
73	1265.60	4.40	74	1476.53	4.22
75	1687.46	4.03	76	1898.40	3.85
77	2109.33	3.67	78	2320.26	3.48
79	2531.19	3.30	80	2531.19	3.90
81	2404.63	3.46	82	2278.07	3.02
83	2151.51	2.58	84	2024.96	2.14
85	1898.40	1.70	86	2531.19	3.30
87	2531.19	3.30	88	2452.09	3.44

Table 3. Continued

DAY	VOLUME (CFS)	TEMPERATURE (C)	DAY	VOLUME (CFS)	TEMPERATURE (C)
89	2372.99	3.57	90	2293.89	3.71
91	2214.79	3.85	92	2135.69	3.99
93	2056.59	4.12	94	1977.50	4.26
95	1898.40	4.40	96	1265.60	2.80
97	1107.40	3.50	98	949.20	4.20
99	791.00	4.90	100	632.80	5.60
101	885.92	5.70	102	1139.04	5.80
103	1392.16	5.90	104	1645.28	6.00
105	1898.40	6.10	106	2531.19	6.10
107	3163.99	6.10	108	3005.79	6.31
109	2847.59	6.52	110	2689.39	6.74
111	2531.19	6.95	112	2372.99	7.16
113	2214.79	7.37	114	2056.59	7.59
115	1898.40	7.80	116	1898.40	7.65
117	1898.40	7.50	118	1898.40	7.35
119	1898.40	7.20	120	1898.40	6.70
121	1898.40	7.50	122	1898.40	8.30
123	1898.40	7.20	124	2531.19	7.20
125	2460.88	7.39	126	2390.57	7.58
127	2320.26	7.77	128	2249.95	7.96
129	2179.64	8.14	130	2109.33	8.33
131	2039.02	8.52	132	1968.71	8.71
133	1898.40	8.90	134	1898.40	8.90
135	1898.40	8.90	136	1898.40	9.40
137	1898.40	9.40	138	1898.40	9.40
139	1898.40	9.40	140	1898.40	9.40
141	1898.40	9.40	142	1898.40	9.40
143	1548.13	9.30	144	1197.86	9.20
145	847.59	9.10	146	497.33	9.00
147	147.06	8.90	148	147.06	8.90
149	445.08	8.96	150	743.09	9.02
151	1041.11	9.09	152	1339.13	9.15
153	1637.14	9.21	154	1935.16	9.27
155	2233.18	9.34	156	2531.19	9.40
157	2531.19	8.90	158	2531.19	8.30
159	2467.91	8.36	160	2404.63	8.42
161	2341.35	8.48	162	2278.07	8.54
163	2214.79	8.60	164	2151.51	8.66
165	2088.23	8.72	166	2024.96	8.78
167	1961.68	8.84	168	1898.40	8.90
169	1898.40	9.40	170	1898.40	10.00
171	1898.40	10.35	172	1898.40	10.70
173	1898.40	11.05	174	1898.40	11.40
175	1898.40	11.75	176	1898.40	12.10

Table 3. Continued

DAY	VOLUME (CFS)	TEMPERATURE (C)	DAY	VOLUME (CFS)	TEMPERATURE (C)
177	1898.40	12.45	178	1898.40	12.80
179	1898.40	12.20	180	1898.40	12.10
181	1898.40	12.00	182	1898.40	11.90
183	1898.40	11.80	184	1898.40	11.70
185	1898.40	11.60	186	1898.40	11.50
187	1898.40	11.40	188	1898.40	11.30
189	1898.40	11.20	190	1898.40	11.10
191	1898.40	12.03	192	1898.40	12.97
193	1898.40	13.90	194	1898.40	14.83
195	1898.40	15.77	196	1898.40	16.70
197	1898.40	19.40	198	1898.40	15.00
199	1898.40	15.35	200	1898.40	15.70
201	1898.40	16.05	202	1898.40	16.40
203	1898.40	16.75	204	1898.40	17.10
205	1898.40	17.45	206	1898.40	17.80
207	1898.40	15.60	208	1898.40	14.87
209	1898.40	14.14	210	1898.40	13.41
211	1898.40	12.68	212	1898.40	11.95
213	1898.40	11.22	214	1898.40	10.49
215	1898.40	9.76	216	1898.40	9.03
217	1898.40	8.30	218	2214.79	8.60
219	2531.19	8.90	220	1898.40	12.80
221	2531.19	16.70	222	2657.75	16.31
223	2784.31	15.92	224	2910.87	15.53
225	3037.43	15.14	226	3163.99	14.75
227	3290.55	14.36	228	3417.11	13.97
229	3543.67	13.58	230	3670.23	13.19
231	3796.79	12.80	232	2531.19	11.10
233	2531.19	9.40	234	2531.19	7.80
235	3163.99	15.00	236	2847.59	15.73
237	2531.19	16.47	238	2214.79	17.20
239	1898.40	17.93	240	1582.00	18.67
241	1265.60	19.40	242	1476.53	19.13
243	1687.46	18.87	244	1898.40	18.60
245	2109.33	18.33	246	2320.26	18.07
247	2531.19	17.80	248	3163.99	17.80
249	2531.19	18.90	250	2636.66	17.23
251	2742.13	15.57	252	2847.59	13.90
253	2953.06	12.23	254	3058.53	10.57
255	3163.99	8.90	256	3322.19	10.42
257	3480.39	11.95	258	3638.59	13.47
259	3796.79	15.00	260	3796.79	13.30
261	3796.79	12.80	262	3796.79	13.90
263	3796.79	13.70	264	3796.79	13.50

Table 3. Continued

DAY	VOLUME (CFS)	TEMPERATURE (C)	DAY	VOLUME (CFS)	TEMPERATURE (C)
265	3796.79	13.30	266	3796.79	13.10
267	3796.79	12.90	268	3796.79	12.70
269	3796.79	12.50	270	3796.79	12.30
271	3796.79	12.10	272	3796.79	11.90
273	3796.79	11.70	274	3796.79	11.50
275	3796.79	11.30	276	3796.79	11.10
277	3624.21	11.15	278	3451.63	11.21
279	3279.05	11.26	280	3106.47	11.32
281	2933.88	11.37	282	2761.30	11.43
283	2588.72	11.48	284	2416.14	11.54
285	2243.56	11.59	286	2070.98	11.65
287	1898.40	11.70	288	1898.40	11.40
289	1898.40	11.10	290	2056.59	11.01
291	2214.79	10.92	292	2372.99	10.82
293	2531.19	10.73	294	2689.39	10.64
295	2847.59	10.55	296	3005.79	10.46
297	3163.99	10.37	298	3322.19	10.27
299	3480.39	10.18	300	3638.59	10.09
301	3796.79	10.00	302	3796.79	10.60
303	3796.79	11.70	304	3796.79	11.46
305	3796.79	11.21	306	3796.79	10.97
307	3796.79	10.73	308	3796.79	10.49
309	3796.79	10.24	310	3796.79	10.00
311	3163.99	9.40	312	1898.40	8.90
313	2278.07	9.00	314	2657.75	9.10
315	3037.43	9.20	316	3417.11	9.30
317	3796.79	9.40	318	3796.79	9.17
319	3796.79	8.94	320	3796.79	8.71
321	3796.79	8.49	322	3796.79	8.26
323	3796.79	8.03	324	3796.79	7.80
325	3670.23	7.50	326	3543.67	7.20
327	3417.11	6.90	328	3290.55	6.60
329	3163.99	6.30	330	3037.43	6.00
331	2910.87	5.70	332	2784.31	5.40
333	2657.75	5.10	334	2531.19	4.80
335	2404.63	4.50	336	2278.07	4.20
337	2151.51	3.90	338	2024.96	3.60
339	1898.40	3.30	340	1898.40	4.40
341	1898.40	4.00	342	1898.40	3.60
343	1898.40	3.20	344	1898.40	2.80
345	2531.19	2.80	346	3163.99	3.30
347	3322.19	3.02	348	3480.39	2.75
349	3638.59	2.47	350	3796.79	2.20
351	3796.79	5.00	352	3796.79	3.90

Table 3. Continued

DAY	VOLUME (CFS)	TEMPERATURE (C)	DAY	VOLUME (CFS)	TEMPERATURE (C)
353	3796.79	3.94	354	3796.79	3.98
355	3796.79	4.02	356	3796.79	4.07
357	3796.79	4.11	358	3796.79	4.15
359	3796.79	4.19	360	3796.79	4.23
361	3796.79	4.27	362	3796.79	4.32
363	3796.79	4.36	364	3796.79	4.40
365	3796.79	4.40

Fig. 1. Water Temperature (°C) at the Intakes of the Zion Station during 1974.

Fig. 2. Volume of Water (cfs) Pumped through the Intakes of the Zion Station during 1974.

there are a number of discrete changes in the volume of water being pumped. These sudden changes may be producing drastic changes in the fish-impingement process.

The daily fish-density values for alewives and rainbow smelt, $d_i(t)$, used in computing the impingement predictions, are plotted in Figures 3 and 4 as functions of the day of the year. These figures show periods with a fish-abundance value of zero for both species; however, impingement observations during these periods indicate that fish are present (particularly alewives) in the intake area and subject to high impingement probabilities. These zero values indicate that the determination of fish abundance in the vicinity of the cooling-water intake is inadequate. Thus we find that the data on fish density--the most important factor affecting fish impingement--are unreliable for predicting impingement rates during such periods.

By use of the model with the exponential form of the density function, $d_i(t)$, and by experimenting with the two factors--temperature and length class--in the probability function, the results for the three cases were obtained. In the following sections we present the results and discuss the effects of the water-temperature and fish-length distribution factors on the predictability of daily fish impingement at the Zion Station for the year 1974. Where appropriate, the inadequacy of the fish-density measurements is emphasized in discussions of the model's performance in predicting daily fish impingement.

3.1 CASE I FOR THE EXPONENTIAL MODEL

The predicted values for Case I (in which only the length-frequency factor is included) are given in Table 4. In Figures 5 through 7, the predicted values are shown as a solid line against the scatter of observed data. It is apparent that the behavior of predicted values resembles that of the observed data, but the numerical values of the predictions are much smaller.

The fish-impingement probability function for alewives is shown in Figure 8, and for rainbow smelt in Figure 9; the numerical results are given in Table 5. It should be noted that due to gross resolution of the length-

Fig. 3. Alewife Fish Density (number/1000 ft³/day) in the Vicinity of the Intakes of the Zion Station during 1974.

Fig. 4. Smelt Fish Density (number/1000 ft³/day) in the Vicinity of the Intakes of the Zion Station during 1974..

frequency classes, the probability function behavior is relatively smooth and varies only slightly between successive days. The numerical values of the impingement probabilities (Table 5) are fairly small, giving rise to predicted fish impingement values that are smaller than the observed values (Figs. 5-7).

3.2 CASE II FOR THE EXPONENTIAL MODEL

Table 6 shows the computed fish impingements for Case II (in which only the water-temperature distribution factor is included). Figures 10 through 12 show that the predicted values (solid line) mimic the observed fish impingements for both the species. However, again the numerical values are noticeably small compared to the observed values.

The fish-impingement probability function is shown in Figures 13 and 14 and the numerical results in Table 7. The probability function shows a higher degree of variation because of the much more rapid changes in the temperature as a function of day of the year. Therefore, the numerical values of the probabilities produce predicted values that are higher than those given in Case I. These results show that perhaps the calculation of fish-impingement probabilities and daily fish-impingement values is more sensitive to the temperature behavior in time (and hence to upwelling and lack of upwelling) than to the length-frequency classes, which have very small resolution.

3.3 CASE III FOR THE EXPONENTIAL MODEL

Table 8 shows the computed fish-impingement predictions for Case III (both factors included). Figures 15 through 17 show the predicted values with the scatter of observed fish impingement for both of the species and the total impingement. In this case it is noted that the numerical values of the predictions are much closer to the observed fish-impingement values. The probability function and the fish-impingement prediction values show that the combination of length class and temperature provides a fish-impingement probability function that is perhaps much closer to that determining behavior of the process and therefore yields a better prediction. The fish-impingement probability function is shown in Figures 18 and 19, and the numeric results in Table 9.

Table 4. Daily Fish-Impingement Predictions Calculated
According to Case-I Specifications

DATE	ALEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
1/ 1/74	0	220	220	220
1/ 2/74	0	220	220	440
1/ 3/74	0	220	220	660
1/ 4/74	0	220	220	880
1/ 5/74	0	220	220	1100
1/ 6/74	0	220	220	1320
1/ 7/74	0	220	220	1540
1/ 8/74	0	220	220	1760
1/ 9/74	0	220	220	1980
1/10/74	0	220	220	2200
1/11/74	0	220	220	2420
1/12/74	0	220	220	2640
1/13/74	0	220	220	2860
1/14/74	0	220	220	3080
1/15/74	0	220	220	3300
1/16/74	0	219	219	3519
1/17/74	0	219	219	3738
1/18/74	0	218	218	3956
1/19/74	0	217	217	4173
1/20/74	0	217	217	4390
1/21/74	0	216	216	4606
1/22/74	0	0	0	4606
1/23/74	0	215	215	4821
1/24/74	0	214	214	5035
1/25/74	0	224	224	5259
1/26/74	0	234	234	5493
1/27/74	0	243	243	5736
1/28/74	0	253	253	5989
1/29/74	0	262	262	6251
1/30/74	0	272	272	6523
1/31/74	0	281	281	6804
2/ 1/74	0	290	290	7094
2/ 2/74	0	300	300	7394
2/ 3/74	0	309	309	7703
2/ 4/74	0	318	318	8021
2/ 5/74	0	327	327	8348
2/ 6/74	0	335	335	8683
2/ 7/74	0	344	344	9027
2/ 8/74	0	353	353	9380
2/ 9/74	0	361	361	9741
2/10/74	0	370	370	10111
2/11/74	0	378	378	10489

Table 4. Continued

DATE	AIEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
2/12/74	0	387	387	10876
2/13/74	0	392	392	11268
2/14/74	0	389	389	11657
2/15/74	0	384	384	12041
2/16/74	0	380	380	12421
2/17/74	0	376	376	12797
2/18/74	0	372	372	13169
2/19/74	0	368	368	13537
2/20/74	0	364	364	13901
2/21/74	0	359	359	14260
2/22/74	0	355	355	14615
2/23/74	0	351	351	14966
2/24/74	0	346	346	15312
2/25/74	0	342	342	15654
2/26/74	0	337	337	15991
2/27/74	0	333	333	16324
2/28/74	0	328	328	16652
3/ 1/74	0	323	323	16975
3/ 2/74	0	319	319	17294
3/ 3/74	0	314	314	17608
3/ 4/74	0	309	309	17917
3/ 5/74	0	304	304	18221
3/ 6/74	0	449	449	18670
3/ 7/74	0	464	464	19134
3/ 8/74	0	457	457	19591
3/ 9/74	0	449	449	20040
3/10/74	0	440	440	20480
3/11/74	0	429	429	20909
3/12/74	0	418	418	21327
3/13/74	0	405	405	21732
3/14/74	0	391	391	22123
3/15/74	0	471	471	22594
3/16/74	0	557	557	23151
3/17/74	0	648	648	23799
3/18/74	0	744	744	24543
3/19/74	0	847	847	25390
3/20/74	0	955	955	26345
3/21/74	0	987	987	27332
3/22/74	0	776	776	28108
3/23/74	0	760	760	28868
3/24/74	0	742	742	29610
3/25/74	0	722	722	30332

Table 4. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
3/26/74	0	700	700	31032
3/27/74	0	965	965	31997
3/28/74	144	1071	1215	33212
3/29/74	139	1151	1290	34502
3/30/74	135	1236	1371	35873
3/31/74	131	1326	1457	37330
4/ 1/74	126	1420	1546	38876
4/ 2/74	122	1518	1640	40516
4/ 3/74	118	1622	1740	42256
4/ 4/74	113	1729	1842	44098
4/ 5/74	109	1840	1949	46047
4/ 6/74	73	1360	1433	47480
4/ 7/74	65	1056	1121	48601
4/ 8/74	58	804	862	49463
4/ 9/74	50	595	645	50108
4/10/74	41	422	463	50571
4/11/74	59	525	584	51155
4/12/74	78	599	677	51832
4/13/74	98	650	748	52580
4/14/74	119	682	801	53381
4/15/74	141	699	840	54221
4/16/74	194	828	1022	55243
4/17/74	324	1083	1407	56650
4/18/74	410	1077	1487	58137
4/19/74	517	1068	1585	59722
4/20/74	649	1055	1704	61426
4/21/74	813	1040	1853	63279
4/22/74	1012	1020	2032	65311
4/23/74	1254	997	2251	67562
4/24/74	1545	969	2514	70076
4/25/74	1892	936	2828	72904
4/26/74	2507	980	3487	76391
4/27/74	3321	1025	4346	80737
4/28/74	4397	1073	5470	86207
4/29/74	5818	1124	6942	93149
4/30/74	7696	1176	8872	102021
5/ 1/74	8139	1231	9370	111391
5/ 2/74	10756	1288	12044	123435
5/ 3/74	14208	1349	15557	138992
5/ 4/74	18997	1589	20586	159578
5/ 5/74	18521	1366	19887	179465
5/ 6/74	18042	1173	19215	198680

Table 4. Continued

DATE	ALEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
5/ 7/74	17561	838	18399	217079
5/ 8/74	17077	719	17796	234875
5/ 9/74	16589	615	17204	252079
5/10/74	16099	526	16625	268704
5/11/74	15607	450	16057	284761
5/12/74	15111	384	15495	300256
5/13/74	14612	327	14939	315195
5/14/74	14653	289	14942	330137
5/15/74	14694	256	14950	345087
5/16/74	11691	257	11948	357035
5/17/74	9299	258	9557	366592
5/18/74	7395	260	7655	374247
5/19/74	5879	261	6140	380387
5/20/74	4672	262	4934	385321
5/21/74	3712	264	3976	389297
5/22/74	2949	265	3214	392511
5/23/74	1909	217	2126	394637
5/24/74	1173	169	1342	395979
5/25/74	658	120	778	396757
5/26/74	306	71	377	397134
5/27/74	72	21	93	397227
5/28/74	57	21	78	397305
5/29/74	2220	64	2284	399589
5/30/74	2935	107	3042	402631
5/31/74	3256	151	3407	406038
6/ 1/74	3314	195	3509	409547
6/ 2/74	3204	239	3443	412990
6/ 3/74	2995	284	3279	416269
6/ 4/74	2731	329	3060	419329
6/ 5/74	2444	0	2444	421773
6/ 6/74	2460	0	2460	424233
6/ 7/74	2476	0	2476	426709
6/ 8/74	2430	0	2430	429139
6/ 9/74	2383	0	2383	431522
6/10/74	2335	0	2335	433857
6/11/74	2287	0	2287	436144
6/12/74	2238	0	2238	438382
6/13/74	2188	0	2188	440570
6/14/74	2138	0	2138	442708
6/15/74	2086	0	2086	444794
6/16/74	2034	0	2034	446828
6/17/74	1981	0	1981	448809

Table 4. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
6/18/74	1994	0	1994	450803
6/19/74	1980	277	2257	453060
6/20/74	1965	274	2239	455299
6/21/74	1950	270	2220	457519
6/22/74	1936	267	2203	459722
6/23/74	1921	263	2184	461906
6/24/74	1907	260	2167	464073
6/25/74	1893	256	2149	466222
6/26/74	1879	253	2132	468354
6/27/74	1865	249	2114	470468
6/28/74	1851	246	2097	472565
6/29/74	1837	242	2079	474644
6/30/74	1823	238	2061	476705
7/ 1/74	1810	235	2045	478750
7/ 2/74	1796	231	2027	480777
7/ 3/74	1863	231	2094	482871
7/ 4/74	1933	231	2164	485035
7/ 5/74	2005	231	2236	487271
7/ 6/74	2080	231	2311	489582
7/ 7/74	2158	231	2389	491971
7/ 8/74	2239	231	2470	494441
7/ 9/74	2323	231	2554	496995
7/10/74	2410	230	2640	499635
7/11/74	2500	230	2730	502365
7/12/74	2593	230	2823	505188
7/13/74	2690	230	2920	508108
7/14/74	2791	230	3021	511129
7/15/74	2895	230	3125	514254
7/16/74	3004	0	3004	517258
7/17/74	2955	0	2955	520213
7/18/74	2908	0	2908	523121
7/19/74	2861	0	2861	525982
7/20/74	2814	0	2814	528796
7/21/74	2769	0	2769	531565
7/22/74	2724	0	2724	534289
7/23/74	2680	0	2680	536969
7/24/74	2637	0	2637	539606
7/25/74	2594	0	2594	542200
7/26/74	2552	0	2552	544752
7/27/74	2511	0	2511	547263
7/28/74	2471	0	2471	549734
7/29/74	2431	0	2431	552165

Table 4. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
7/30/74	2391	0	2391	554556
7/31/74	2353	0	2353	556909
8/ 1/74	2315	0	2315	559224
8/ 2/74	2277	0	2277	561501
8/ 3/74	2241	0	2241	563742
8/ 4/74	2204	0	2204	565946
8/ 5/74	2169	0	2169	568115
8/ 6/74	2489	0	2489	570604
8/ 7/74	861	0	861	571465
8/ 8/74	645	0	645	572110
8/ 9/74	858	0	858	572968
8/10/74	900	0	900	573868
8/11/74	941	0	941	574809
8/12/74	982	0	982	575791
8/13/74	1023	0	1023	576814
8/14/74	1064	0	1064	577878
8/15/74	1105	0	1105	578983
8/16/74	1146	0	1146	580129
8/17/74	1186	0	1186	581315
8/18/74	1227	0	1227	582542
8/19/74	1267	0	1267	583809
8/20/74	843	0	843	584652
8/21/74	824	0	824	585476
8/22/74	805	0	805	586281
8/23/74	983	0	983	587264
8/24/74	864	0	864	588128
8/25/74	751	0	751	588879
8/26/74	642	0	642	589521
8/27/74	538	0	538	590059
8/28/74	438	0	438	590497
8/29/74	342	0	342	590839
8/30/74	390	0	390	591229
8/31/74	435	0	435	591664
9/ 1/74	479	0	479	592143
9/ 2/74	520	0	520	592663
9/ 3/74	558	0	558	593221
9/ 4/74	0	0	0	593221
9/ 5/74	744	0	744	593965
9/ 6/74	595	0	595	594560
9/ 7/74	620	0	620	595180
9/ 8/74	645	0	645	595825
9/ 9/74	670	0	670	596495

Table 4. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
9/10/74	695	0	695	597190
9/11/74	720	0	720	597910
9/12/74	745	0	745	598655
9/13/74	782	0	782	599437
9/14/74	820	0	820	600257
9/15/74	857	0	857	601114
9/16/74	894	0	894	602008
9/17/74	895	0	895	602903
9/18/74	899	194	1093	603996
9/19/74	903	200	1103	605099
9/20/74	908	206	1114	606213
9/21/74	912	212	1124	607337
9/22/74	917	219	1136	608473
9/23/74	921	226	1147	609620
9/24/74	925	232	1157	610777
9/25/74	930	239	1169	611946
9/26/74	934	246	1180	613126
9/27/74	939	254	1193	614319
9/28/74	943	261	1204	615523
9/29/74	947	269	1216	616739
9/30/74	952	276	1228	617967
10/ 1/74	956	284	1240	619207
10/ 2/74	960	273	1233	620440
10/ 3/74	963	262	1225	621665
10/ 4/74	923	240	1163	622828
10/ 5/74	882	219	1101	623929
10/ 6/74	841	199	1040	624969
10/ 7/74	800	181	981	625950
10/ 8/74	758	164	922	626872
10/ 9/74	716	148	864	627736
10/10/74	674	133	807	628543
10/11/74	631	119	750	629293
10/12/74	588	106	694	629987
10/13/74	545	94	639	630626
10/14/74	501	83	584	631210
10/15/74	501	82	583	631793
10/16/74	501	82	583	632376
10/17/74	543	88	631	633007
10/18/74	584	94	678	633685
10/19/74	626	101	727	634412
10/20/74	668	107	775	635187
10/21/74	709	113	822	636009

Table 4. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
10/22/74	751	119	870	636879
10/23/74	793	125	918	637797
10/24/74	834	130	964	638761
10/25/74	876	136	1012	639773
10/26/74	918	142	1060	640833
10/27/74	959	147	1106	641939
10/28/74	1001	153	1154	643093
10/29/74	1001	152	1153	644246
10/30/74	1001	151	1152	645398
10/31/74	1000	150	1150	646548
11/ 1/74	1000	150	1150	647698
11/ 2/74	1000	149	1149	648847
11/ 3/74	1000	148	1148	649995
11/ 4/74	1000	147	1147	651142
11/ 5/74	1000	146	1146	652288
11/ 6/74	1000	0	1000	653288
11/ 7/74	832	0	832	654120
11/ 8/74	498	0	498	654618
11/ 9/74	597	0	597	655215
11/10/74	695	0	695	655910
11/11/74	794	0	794	656704
11/12/74	891	0	891	657595
11/13/74	989	0	989	658584
11/14/74	988	0	988	659572
11/15/74	986	0	986	660558
11/16/74	985	0	985	661543
11/17/74	983	0	983	662526
11/18/74	982	0	982	663508
11/19/74	0	0	0	663508
11/20/74	0	142	142	663650
11/21/74	0	135	135	663785
11/22/74	0	127	127	663912
11/23/74	0	120	120	664032
11/24/74	0	113	113	664145
11/25/74	0	106	106	664251
11/26/74	0	99	99	664350
11/27/74	0	93	93	664443
11/28/74	0	86	86	664529
11/29/74	0	80	80	664609
11/30/74	0	74	74	664683
12/ 1/74	0	69	69	664752
12/ 2/74	0	63	63	664815

Table 4. Continued

DATE	ALEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
12/ 3/74	0	58	58	664873
12/ 4/74	0	53	53	664926
12/ 5/74	0	48	48	664974
12/ 6/74	0	48	48	665022
12/ 7/74	0	48	48	665070
12/ 8/74	0	48	48	665118
12/ 9/74	0	48	48	665166
12/10/74	0	48	48	665214
12/11/74	0	64	64	665278
12/12/74	0	80	80	665358
12/13/74	0	84	84	665442
12/14/74	0	88	88	665530
12/15/74	0	92	92	665622
12/16/74	0	97	97	665719
12/17/74	0	97	97	665816
12/18/74	0	97	97	665913
12/19/74	0	97	97	666010
12/20/74	0	97	97	666107
12/21/74	0	97	97	666204
12/22/74	0	97	97	666301
12/23/74	0	97	97	666398
12/24/74	0	97	97	666495
12/25/74	0	97	97	666592
12/26/74	0	97	97	666689
12/27/74	0	97	97	666786
12/28/74	0	97	97	666883
12/29/74	0	97	97	666980
12/30/74	0	97	97	667077
12/31/74	0	97	97	667174

Fig. 5. Predicted Impingement (solid line) for Case I and Observed Impingement (circles) of Alewives of the Zich Station during 1974 (No. of fish/day).

Fig. 6. Predicted Impingement (solid line) for Case I and Observed Impingement (circles) of Smelt at the Zion Station during 1974 (No. of fish/day).

Fig. 7. Predicted Impingement (solid line) for Case I and Observed Impingement (circles) of Both Species at the Zion Station during 1974 (No. of fish/day).

ESTIMATED PROBABILITY ALEWIFE

Fig. 8. The Risk of Impingement of Alewives According to the Probability Function under the Conditions of Case I.

Fig. 9. The Risk of Impingement of Smelt According to the Probability Function under the Conditions of Case I.

Table 5. Numerical Values for Fish Density and Probability of Impingement for Case I

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
1	0.0	0.0	0.00	0.23	2	0.0	0.0	0.00	0.23	3	0.0	0.0	0.00	0.23
4	0.0	0.0	0.00	0.23	5	0.0	0.0	0.00	0.23	6	0.0	0.0	0.00	0.23
7	0.0	0.0	0.00	0.23	8	0.0	0.0	0.00	0.23	9	0.0	0.0	0.00	0.23
10	0.0	0.0	0.00	0.23	11	0.0	0.0	0.00	0.23	12	0.0	0.0	0.00	0.23
13	0.0	0.0	0.00	0.23	14	0.0	0.0	0.00	0.23	15	0.0	0.0	0.00	0.23
16	0.0	0.0	0.00	0.23	17	0.0	0.0	0.00	0.23	18	0.0	0.0	0.00	0.23
19	0.0	0.0	0.00	0.23	20	0.0	0.0	0.00	0.23	21	0.0	0.0	0.00	0.23
22	0.0	0.0	0.0	0.23	23	0.0	0.0	0.00	0.23	24	0.0	0.0	0.00	0.22
25	0.0	0.0	0.00	0.22	26	0.0	0.0	0.00	0.22	27	0.0	0.0	0.00	0.22
28	0.0	0.0	0.00	0.22	29	0.0	0.0	0.00	0.22	30	0.0	0.0	0.00	0.22
31	0.0	0.0	0.00	0.22	32	0.0	0.0	0.00	0.22	33	0.0	0.0	0.00	0.21
34	0.0	0.0	0.00	0.21	35	0.0	0.0	0.00	0.21	36	0.0	0.0	0.00	0.21
37	0.0	0.0	0.00	0.21	38	0.0	0.0	0.00	0.21	39	0.0	0.0	0.00	0.21
40	0.0	0.0	0.00	0.21	41	0.0	0.0	0.00	0.20	42	0.0	0.0	0.00	0.20
43	0.0	0.0	0.00	0.20	44	0.0	0.01	0.00	0.20	45	0.0	0.01	0.00	0.20
46	0.0	0.02	0.00	0.19	47	0.0	0.02	0.00	0.19	48	0.0	0.03	0.01	0.19
49	0.0	0.03	0.01	0.18	50	0.0	0.04	0.01	0.18	51	0.0	0.04	0.01	0.18
52	0.0	0.05	0.01	0.18	53	0.0	0.05	0.01	0.17	54	0.0	0.06	0.01	0.17
55	0.0	0.06	0.01	0.17	56	0.0	0.07	0.01	0.16	57	0.0	0.07	0.01	0.16
58	0.0	0.08	0.01	0.16	59	0.0	0.08	0.01	0.16	60	0.0	0.09	0.01	0.15
61	0.0	0.09	0.01	0.15	62	0.0	0.10	0.01	0.15	63	0.0	0.10	0.01	0.14
64	0.0	0.11	0.01	0.14	65	0.0	0.11	0.01	0.14	66	0.0	0.11	0.02	0.14
67	0.0	0.11	0.02	0.14	68	0.0	0.11	0.02	0.14	69	0.0	0.11	0.02	0.14
70	0.0	0.11	0.03	0.14	71	0.0	0.11	0.03	0.14	72	0.0	0.11	0.03	0.14
73	0.0	0.11	0.04	0.14	74	0.0	0.11	0.04	0.14	75	0.0	0.11	0.04	0.14
76	0.0	0.11	0.05	0.14	77	0.0	0.11	0.05	0.14	78	0.0	0.11	0.05	0.14
79	0.0	0.11	0.06	0.14	80	0.0	0.11	0.06	0.14	81	0.0	0.11	0.06	0.14
82	0.0	0.11	0.06	0.14	83	0.0	0.11	0.07	0.14	84	0.0	0.11	0.07	0.14
85	0.0	0.11	0.07	0.14	86	0.0	0.11	0.08	0.14	87	0.00	0.11	0.09	0.14
88	0.01	0.11	0.10	0.14	89	0.01	0.11	0.11	0.13	90	0.02	0.11	0.12	0.13
91	0.02	0.11	0.13	0.13	92	0.03	0.11	0.14	0.13	93	0.03	0.11	0.15	0.13
94	0.03	0.11	0.16	0.13	95	0.04	0.11	0.17	0.12	96	0.04	0.11	0.18	0.12
97	0.09	0.11	0.17	0.12	98	0.14	0.11	0.16	0.12	99	0.19	0.11	0.15	0.12
100	0.24	0.11	0.14	0.12	101	0.28	0.11	0.13	0.12	102	0.33	0.11	0.12	0.12
103	0.38	0.11	0.11	0.12	104	0.43	0.11	0.10	0.12	105	0.48	0.11	0.08	0.12
106	0.53	0.11	0.07	0.12	107	0.96	0.12	0.08	0.12	108	1.39	0.12	0.08	0.12
109	1.82	0.12	0.09	0.12	110	2.25	0.13	0.09	0.12	111	2.68	0.13	0.10	0.12
112	3.12	0.13	0.10	0.12	113	3.55	0.14	0.10	0.12	114	3.98	0.14	0.11	0.12
115	4.41	0.14	0.11	0.12	116	4.84	0.15	0.12	0.12	117	5.27	0.15	0.12	0.12
118	5.70	0.15	0.13	0.12	119	6.14	0.16	0.13	0.12	120	6.57	0.16	0.13	0.12
121	7.00	0.16	0.14	0.12	122	7.43	0.17	0.14	0.12	123	7.86	0.17	0.15	0.12
124	7.87	0.17	0.14	0.12	125	7.87	0.17	0.12	0.12	126	7.88	0.17	0.11	0.12
127	7.88	0.17	0.10	0.12	128	7.88	0.17	0.09	0.12	129	7.89	0.17	0.08	0.12
130	7.89	0.17	0.07	0.12	131	7.90	0.17	0.06	0.12	132	7.90	0.17	0.04	0.12
133	7.91	0.17	0.03	0.12	134	7.91	0.17	0.02	0.12	135	7.92	0.17	0.01	0.12
136	7.56	0.17	0.01	0.12	137	7.21	0.16	0.01	0.12	138	6.85	0.16	0.01	0.12

Table 5. Continued

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
277	0.03	0.13	0.04	0.14	278	0.04	0.13	0.04	0.14	279	0.04	0.13	0.04	0.14
280	0.05	0.13	0.03	0.14	281	0.05	0.13	0.03	0.14	282	0.06	0.13	0.02	0.14
283	0.07	0.13	0.02	0.14	284	0.07	0.13	0.02	0.14	285	0.08	0.13	0.01	0.14
286	0.08	0.13	0.01	0.14	287	0.09	0.13	0.00	0.14	288	0.09	0.13	0.00	0.14
289	0.09	0.13	0.00	0.14	290	0.08	0.13	0.00	0.14	291	0.08	0.13	0.00	0.14
292	0.08	0.13	0.00	0.14	293	0.08	0.13	0.00	0.14	294	0.07	0.13	0.00	0.13
295	0.07	0.13	0.00	0.13	296	0.07	0.13	0.00	0.13	297	0.07	0.13	0.00	0.13
298	0.06	0.13	0.00	0.13	299	0.06	0.13	0.00	0.13	300	0.06	0.13	0.00	0.13
301	0.06	0.13	0.00	0.13	302	0.05	0.13	0.00	0.13	303	0.05	0.13	0.00	0.13
304	0.05	0.13	0.00	0.13	305	0.05	0.13	0.00	0.13	306	0.04	0.13	0.00	0.13
307	0.04	0.13	0.00	0.13	308	0.04	0.13	0.00	0.13	309	0.04	0.13	0.00	0.13
310	0.03	0.13	0.0	0.13	311	0.03	0.13	0.0	0.13	312	0.03	0.13	0.0	0.13
313	0.03	0.13	0.0	0.13	314	0.02	0.13	0.0	0.13	315	0.02	0.13	0.0	0.13
316	0.02	0.13	0.0	0.13	317	0.02	0.13	0.0	0.13	318	0.01	0.13	0.0	0.13
319	0.01	0.13	0.0	0.13	320	0.01	0.13	0.0	0.13	321	0.01	0.13	0.0	0.13
322	0.00	0.13	0.0	0.13	323	0.0	0.13	0.0	0.13	324	0.0	0.13	0.00	0.12
325	0.0	0.13	0.00	0.12	326	0.0	0.13	0.00	0.12	327	0.0	0.14	0.00	0.12
328	0.0	0.14	0.00	0.11	329	0.0	0.14	0.00	0.11	330	0.0	0.14	0.00	0.11
331	0.0	0.14	0.00	0.11	332	0.0	0.14	0.00	0.10	333	0.0	0.14	0.00	0.10
334	0.0	0.15	0.00	0.10	335	0.0	0.15	0.00	0.09	336	0.0	0.15	0.00	0.09
337	0.0	0.15	0.00	0.09	338	0.0	0.15	0.00	0.09	339	0.0	0.15	0.00	0.08
340	0.0	0.15	0.00	0.08	341	0.0	0.15	0.00	0.08	342	0.0	0.15	0.00	0.08
343	0.0	0.15	0.00	0.08	344	0.0	0.15	0.00	0.08	345	0.0	0.15	0.00	0.08
346	0.0	0.15	0.00	0.08	347	0.0	0.15	0.00	0.08	348	0.0	0.15	0.00	0.08
349	0.0	0.15	0.00	0.08	350	0.0	0.15	0.00	0.08	351	0.0	0.15	0.00	0.08
352	0.0	0.15	0.00	0.08	353	0.0	0.15	0.00	0.08	354	0.0	0.15	0.00	0.08
355	0.0	0.15	0.00	0.08	356	0.0	0.15	0.00	0.08	357	0.0	0.15	0.00	0.08
358	0.0	0.15	0.00	0.08	359	0.0	0.15	0.00	0.08	360	0.0	0.15	0.00	0.08
361	0.0	0.15	0.00	0.08	362	0.0	0.15	0.00	0.08	363	0.0	0.15	0.00	0.08
364	0.0	0.15	0.00	0.08	365	0.0	0.15	0.00	0.08					

Table 6. Daily Fish-Impingement Predictions Calculated
According to Case-II Specifications

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
1/ 1/74	0	46	46	46
1/ 2/74	0	46	46	92
1/ 3/74	0	46	46	138
1/ 4/74	0	46	46	184
1/ 5/74	0	46	46	230
1/ 6/74	0	46	46	276
1/ 7/74	0	46	46	322
1/ 8/74	0	46	46	368
1/ 9/74	0	46	46	414
1/10/74	0	46	46	460
1/11/74	0	46	46	506
1/12/74	0	46	46	552
1/13/74	0	46	46	598
1/14/74	0	46	46	644
1/15/74	0	46	46	690
1/16/74	0	46	46	736
1/17/74	0	46	46	782
1/18/74	0	46	46	828
1/19/74	0	46	46	874
1/20/74	0	45	45	919
1/21/74	0	45	45	964
1/22/74	0	0	0	964
1/23/74	0	45	45	1009
1/24/74	0	45	45	1054
1/25/74	0	48	48	1102
1/26/74	0	51	51	1153
1/27/74	0	53	53	1206
1/28/74	0	56	56	1262
1/29/74	0	59	59	1321
1/30/74	0	61	61	1382
1/31/74	0	64	64	1446
2/ 1/74	0	67	67	1513
2/ 2/74	0	70	70	1583
2/ 3/74	0	73	73	1656
2/ 4/74	0	75	75	1731
2/ 5/74	0	78	78	1809
2/ 6/74	0	81	81	1890
2/ 7/74	0	84	84	1974
2/ 8/74	0	87	87	2061
2/ 9/74	0	90	90	2151
2/10/74	0	93	93	2244
2/11/74	0	97	97	2341

Table 6. Continued

DATE	ALEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
2/12/74	0	100	100	2441
2/13/74	0	103	103	2544
2/14/74	0	112	112	2656
2/15/74	0	120	120	2776
2/16/74	0	129	129	2905
2/17/74	0	138	138	3043
2/18/74	0	146	146	3189
2/19/74	0	155	155	3344
2/20/74	0	164	164	3508
2/21/74	0	173	173	3681
2/22/74	0	182	182	3863
2/23/74	0	191	191	4054
2/24/74	0	201	201	4255
2/25/74	0	210	210	4465
2/26/74	0	219	219	4684
2/27/74	0	229	229	4913
2/28/74	0	239	239	5152
3/ 1/74	0	248	248	5400
3/ 2/74	0	258	258	5658
3/ 3/74	0	268	268	5926
3/ 4/74	0	278	278	6204
3/ 5/74	0	288	288	6492
3/ 6/74	0	433	433	6925
3/ 7/74	0	528	528	7453
3/ 8/74	0	545	545	7998
3/ 9/74	0	559	559	8557
3/10/74	0	572	572	9129
3/11/74	0	582	582	9711
3/12/74	0	589	589	10300
3/13/74	0	592	592	10892
3/14/74	0	593	593	11485
3/15/74	0	685	685	12170
3/16/74	0	775	775	12945
3/17/74	0	860	860	13805
3/18/74	0	941	941	14746
3/19/74	0	1017	1017	15763
3/20/74	0	1086	1086	16849
3/21/74	0	1327	1327	18176
3/22/74	0	925	925	19101
3/23/74	0	791	791	19892
3/24/74	0	660	660	20552
3/25/74	0	533	533	21085

Table 6. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
3/26/74	0	410	410	21495
3/27/74	0	1098	1098	22593
3/28/74	199	1232	1431	24024
3/29/74	202	1394	1596	25620
3/30/74	204	1574	1778	27398
3/31/74	205	1773	1978	29376
4/ 1/74	206	1992	2198	31574
4/ 2/74	206	2232	2438	34012
4/ 3/74	206	2494	2700	36712
4/ 4/74	205	2780	2985	39697
4/ 5/74	204	3091	3295	42992
4/ 6/74	87	1471	1558	44550
4/ 7/74	97	1428	1525	46075
4/ 8/74	103	1304	1407	47482
4/ 9/74	103	1126	1229	48711
4/10/74	97	914	1011	49722
4/11/74	143	1156	1299	51021
4/12/74	192	1343	1535	52556
4/13/74	246	1483	1729	54285
4/14/74	304	1582	1886	56171
4/15/74	367	1648	2015	58186
4/16/74	504	1950	2454	60640
4/17/74	815	2554	3369	64009
4/18/74	1037	2631	3668	67677
4/19/74	1315	2700	4015	71692
4/20/74	1660	2758	4418	76110
4/21/74	2086	2806	4892	81002
4/22/74	2608	2840	5440	86450
4/23/74	3245	2860	6105	92555
4/24/74	4013	2863	6876	99431
4/25/74	4929	2846	7775	107206
4/26/74	6257	2925	9182	116388
4/27/74	7941	3005	10946	127334
4/28/74	10073	3085	13158	140492
4/29/74	12773	3167	15940	156432
4/30/74	15386	3087	18473	174905
5/ 1/74	17835	3621	21456	196361
5/ 2/74	25549	4199	29748	226109
5/ 3/74	28688	3816	32504	258613
5/ 4/74	38359	4498	42657	301470
5/ 5/74	38379	3967	42346	343816
5/ 6/74	38343	3493	41836	385652

Table 6. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
5/ 7/74	38250	2560	40810	426462
5/ 8/74	38100	2247	40347	466809
5/ 9/74	37892	1970	39862	506671
5/10/74	37626	1724	39350	546021
5/11/74	37300	1507	38807	584828
5/12/74	36916	1314	38230	623058
5/13/74	36472	1145	37617	660675
5/14/74	36574	1012	37586	698261
5/15/74	36677	894	37571	735832
5/16/74	31314	940	32254	768086
5/17/74	25313	935	26248	794334
5/18/74	20462	930	21392	815726
5/19/74	16540	926	17466	833192
5/20/74	13370	921	14291	847483
5/21/74	10808	916	11724	859207
5/22/74	8737	912	9649	868856
5/23/74	5698	732	6430	875286
5/24/74	3526	557	4083	879369
5/25/74	1995	388	2383	881752
5/26/74	936	224	1160	882912
5/27/74	221	65	286	883198
5/28/74	179	65	244	883442
5/29/74	7158	197	7355	890797
5/30/74	9727	329	10056	900853
5/31/74	11093	462	11555	912408
6/ 1/74	11613	595	12208	924616
6/ 2/74	11555	729	12284	936900
6/ 3/74	11116	863	11979	948879
6/ 4/74	10439	998	11437	960316
6/ 5/74	9629	0	9629	969945
6/ 6/74	9176	0	9176	979121
6/ 7/74	8613	0	8613	987734
6/ 8/74	8513	0	8513	996247
6/ 9/74	8409	0	8409	1004656
6/10/74	8299	0	8299	1012955
6/11/74	8185	0	8185	1021140
6/12/74	8066	0	8066	1029206
6/13/74	7941	0	7941	1037147
6/14/74	7812	0	7812	1044959
6/15/74	7677	0	7677	1052636
6/16/74	7536	0	7536	1060172
6/17/74	7390	0	7390	1067562

Table 6. Continued

DATE	FISH SPECIES ALEWIFE SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
6/18/74	7856 0	7856	1075418
6/19/74	8283 904	9187	1084605
6/20/74	8497 937	9434	1094039
6/21/74	8706 969	9675	1103714
6/22/74	8911 1001	9912	1113626
6/23/74	9111 1033	10144	1123770
6/24/74	9307 1065	10372	1134142
6/25/74	9499 1097	10596	1144738
6/26/74	9687 1130	10817	1155555
6/27/74	9870 1162	11032	1166587
6/28/74	9324 1108	10432	1177019
6/29/74	9165 1100	10265	1187284
6/30/74	9008 1091	10099	1197383
7/ 1/74	8854 1082	9936	1207319
7/ 2/74	8701 1074	9775	1217094
7/ 3/74	8950 1064	10014	1227108
7/ 4/74	9205 1055	10260	1237368
7/ 5/74	9468 1045	10513	1247881
7/ 6/74	9736 1035	10771	1258652
7/ 7/74	10012 1026	11038	1269690
7/ 8/74	10295 1016	11311	1281001
7/ 9/74	10584 1007	11591	1292592
7/10/74	11904 1091	12995	1305587
7/11/74	13307 1175	14482	1320069
7/12/74	14798 1259	16057	1336126
7/13/74	16382 1343	17725	1353851
7/14/74	18065 1427	19492	1373343
7/15/74	19850 1510	21360	1394703
7/16/74	23922 0	23922	1418625
7/17/74	18183 0	18183	1436808
7/18/74	18292 0	18292	1455100
7/19/74	18392 0	18392	1473492
7/20/74	18484 0	18484	1491976
7/21/74	18567 0	18567	1510543
7/22/74	18642 0	18642	1529185
7/23/74	18710 0	18710	1547895
7/24/74	18769 0	18769	1566664
7/25/74	18821 0	18821	1585485
7/26/74	16216 0	16216	1601701
7/27/74	15195 0	15195	1616896
7/28/74	14205 0	14205	1631101
7/29/74	13243 0	13243	1644344

Table 6. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
7/30/74	12310	0	12310	1656654
7/31/74	11405	0	11405	1668059
8/ 1/74	10527	0	10527	1678586
8/ 2/74	9675	0	9675	1688261
8/ 3/74	8850	0	8850	1697111
8/ 4/74	8049	0	8049	1705160
8/ 5/74	7273	0	7273	1712433
8/ 6/74	8643	0	8643	1721076
8/ 7/74	3092	0	3092	1724168
8/ 8/74	3330	0	3330	1727498
8/ 9/74	5783	0	5783	1733281
8/10/74	5921	0	5921	1739202
8/11/74	6045	0	6045	1745247
8/12/74	6154	0	6154	1751401
8/13/74	6250	0	6250	1757651
8/14/74	6333	0	6333	1763984
8/15/74	6402	0	6402	1770386
8/16/74	6457	0	6457	1776843
8/17/74	6498	0	6498	1783341
8/18/74	6526	0	6526	1789867
8/19/74	6541	0	6541	1796408
8/20/74	3775	0	3775	1800183
8/21/74	3125	0	3125	1803308
8/22/74	2534	0	2534	1805842
8/23/74	5953	0	5953	1811795
8/24/74	5492	0	5492	1817287
8/25/74	4994	0	4994	1822281
8/26/74	4460	0	4460	1826741
8/27/74	3896	0	3896	1830637
8/28/74	3303	0	3303	1833940
8/29/74	2684	0	2684	1836624
8/30/74	3018	0	3018	1839642
8/31/74	3324	0	3324	1842966
9/ 1/74	3603	0	3603	1846569
9/ 2/74	3856	0	3856	1850425
9/ 3/74	4085	0	4085	1854510
9/ 4/74	0	0	0	1854510
9/ 5/74	5364	0	5364	1859874
9/ 6/74	4557	0	4557	1864431
9/ 7/74	4329	0	4329	1868760
9/ 8/74	4068	0	4068	1872828
9/ 9/74	3772	0	3772	1876600

Table 6. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
9/10/74	3443	0	3443	1880043
9/11/74	3081	0	3081	1883124
9/12/74	2685	0	2685	1885809
9/13/74	3303	0	3303	1889112
9/14/74	3967	0	3967	1893079
9/15/74	4677	0	4677	1897756
9/16/74	5433	0	5433	1903189
9/17/74	4818	0	4818	1908007
9/18/74	4639	724	5363	1913370
9/19/74	5039	821	5860	1919230
9/20/74	4969	844	5813	1925043
9/21/74	4898	868	5766	1930809
9/22/74	4828	892	5720	1936529
9/23/74	4757	917	5674	1942203
9/24/74	4686	942	5628	1947831
9/25/74	4615	968	5583	1953414
9/26/74	4544	994	5538	1958952
9/27/74	4473	1020	5493	1964445
9/28/74	4402	1047	5449	1969894
9/29/74	4331	1075	5406	1975300
9/30/74	4260	1103	5363	1980663
10/ 1/74	4189	1131	5320	1985983
10/ 2/74	4131	1066	5197	1991180
10/ 3/74	4073	1004	5077	1996257
10/ 4/74	3921	924	4845	2001102
10/ 5/74	3766	848	4614	2005716
10/ 6/74	3608	777	4385	2010101
10/ 7/74	3447	709	4156	2014257
10/ 8/74	3283	645	3928	2018185
10/ 9/74	3116	585	3701	2021886
10/10/74	2946	529	3475	2025361
10/11/74	2772	476	3248	2028609
10/12/74	2596	426	3022	2031631
10/13/74	2416	379	2795	2034426
10/14/74	2233	335	2568	2036994
10/15/74	2173	325	2498	2039492
10/16/74	2112	316	2428	2041920
10/17/74	2266	339	2605	2044525
10/18/74	2416	361	2777	2047302
10/19/74	2563	382	2945	2050247
10/20/74	2707	404	3111	2053358
10/21/74	2847	424	3271	2056629

Table 6. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
10/22/74	2985	444	3429	2060058
10/23/74	3118	464	3582	2063640
10/24/74	3249	483	3732	2067372
10/25/74	3376	501	3877	2071249
10/26/74	3500	519	4019	2075268
10/27/74	3621	537	4158	2079426
10/28/74	3738	554	4292	2083718
10/29/74	3957	586	4543	2088261
10/30/74	4361	645	5006	2093267
10/31/74	4264	630	4894	2098161
11/ 1/74	4167	615	4782	2102943
11/ 2/74	4071	601	4672	2107615
11/ 3/74	3975	586	4561	2112176
11/ 4/74	3879	571	4450	2116626
11/ 5/74	3783	557	4340	2120966
11/ 6/74	3688	0	3688	2124654
11/ 7/74	2885	0	2885	2127539
11/ 8/74	1636	0	1636	2129175
11/ 9/74	1983	0	1983	2131158
11/10/74	2335	0	2335	2133493
11/11/74	2694	0	2694	2136187
11/12/74	3059	0	3059	2139246
11/13/74	3430	0	3430	2142676
11/14/74	3342	0	3342	2146018
11/15/74	3253	0	3253	2149271
11/16/74	3165	0	3165	2152436
11/17/74	3078	0	3078	2155514
11/18/74	2990	0	2990	2158504
11/19/74	0	0	0	2158504
11/20/74	0	423	423	2158927
11/21/74	0	394	394	2159321
11/22/74	0	365	365	2159686
11/23/74	0	337	337	2160023
11/24/74	0	311	311	2160334
11/25/74	0	285	285	2160619
11/26/74	0	261	261	2160880
11/27/74	0	238	238	2161118
11/28/74	0	216	216	2161334
11/29/74	0	194	194	2161528
11/30/74	0	174	174	2161702
12/ 1/74	0	155	155	2161857
12/ 2/74	0	137	137	2161994

Table 6. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
12/ 3/74	0	121	121	2162115
12/ 4/74	0	105	105	2162220
12/ 5/74	0	90	90	2162310
12/ 6/74	0	120	120	2162430
12/ 7/74	0	109	109	2162539
12/ 8/74	0	98	98	2162637
12/ 9/74	0	88	88	2162725
12/10/74	0	77	77	2162802
12/11/74	0	102	102	2162904
12/12/74	0	151	151	2163055
12/13/74	0	145	145	2163200
12/14/74	0	138	138	2163338
12/15/74	0	130	130	2163468
12/16/74	0	121	121	2163589
12/17/74	0	275	275	2163864
12/18/74	0	214	214	2164078
12/19/74	0	217	217	2164295
12/20/74	0	219	219	2164514
12/21/74	0	221	221	2164735
12/22/74	0	224	224	2164959
12/23/74	0	226	226	2165185
12/24/74	0	228	228	2165413
12/25/74	0	230	230	2165643
12/26/74	0	233	233	2165876
12/27/74	0	235	235	2166111
12/28/74	0	237	237	2166348
12/29/74	0	240	240	2166588
12/30/74	0	242	242	2166830
12/31/74	0	242	242	2167072

Fig. 10. Predicted Impingement (solid line) for Case II, and Observed Impingement (circle points) of Alewives at the Zion Station during 1974 (No. of fish/day).

Fig. 11. Predicted Impingement (solid line) for Case II and Observed Impingement (circles) of Smelt at the Zior Station during 1974 (No. of fish/day).

Fig. 12. Predicted Impingement (solid line) for Case II and Observed Impingement of Both Species at Zion Station during 1974 (No. of fish/day).

Fig. 13. The Risk of Impingement of Alewives According to the Probability Function under the Conditions of Case II.

Fig. 14. The Risk of Impingement of Smelt According to the Probability Function under the Conditions of Case II.

Table 7. Numerical Values for Fish Density and Probability of Impingement for Case II

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
1	0.0	0.05	0.00	0.05	2	0.0	0.05	0.00	0.05	3	0.0	0.05	0.00	0.05
4	0.0	0.05	0.00	0.05	5	0.0	0.05	0.00	0.05	6	0.0	0.05	0.00	0.05
7	0.0	0.05	0.00	0.05	8	0.0	0.05	0.00	0.05	9	0.0	0.05	0.00	0.05
10	0.0	0.05	0.00	0.05	11	0.0	0.05	0.00	0.05	12	0.0	0.05	0.00	0.05
13	0.0	0.05	0.00	0.05	14	0.0	0.05	0.00	0.05	15	0.0	0.05	0.00	0.05
16	0.0	0.05	0.00	0.05	17	0.0	0.05	0.00	0.05	18	0.0	0.05	0.00	0.05
19	0.0	0.05	0.00	0.05	20	0.0	0.05	0.00	0.05	21	0.0	0.05	0.00	0.05
22	0.0	0.05	0.0	0.05	23	0.0	0.05	0.00	0.05	24	0.0	0.05	0.00	0.05
25	0.0	0.05	0.00	0.05	26	0.0	0.05	0.00	0.05	27	0.0	0.05	0.00	0.05
28	0.0	0.05	0.00	0.05	29	0.0	0.05	0.00	0.05	30	0.0	0.05	0.00	0.05
31	0.0	0.05	0.00	0.05	32	0.0	0.05	0.00	0.05	33	0.0	0.05	0.00	0.05
34	0.0	0.05	0.00	0.05	35	0.0	0.05	0.00	0.05	36	0.0	0.05	0.00	0.05
37	0.0	0.05	0.00	0.05	38	0.0	0.05	0.00	0.05	39	0.0	0.05	0.00	0.05
40	0.0	0.05	0.00	0.05	41	0.0	0.05	0.00	0.05	42	0.0	0.05	0.00	0.05
43	0.0	0.05	0.00	0.05	44	0.0	0.05	0.00	0.05	45	0.0	0.06	0.00	0.06
46	0.0	0.06	0.00	0.06	47	0.0	0.06	0.00	0.06	48	0.0	0.07	0.01	0.07
49	0.0	0.07	0.01	0.07	50	0.0	0.08	0.01	0.08	51	0.0	0.08	0.01	0.08
52	0.0	0.08	0.01	0.08	53	0.0	0.09	0.01	0.09	54	0.0	0.09	0.01	0.09
55	0.0	0.10	0.01	0.10	56	0.0	0.10	0.01	0.10	57	0.0	0.10	0.01	0.10
58	0.0	0.11	0.01	0.11	59	0.0	0.11	0.01	0.11	60	0.0	0.12	0.01	0.12
61	0.0	0.12	0.01	0.12	62	0.0	0.13	0.01	0.13	63	0.0	0.13	0.01	0.13
64	0.0	0.13	0.01	0.13	65	0.0	0.13	0.01	0.13	66	0.0	0.16	0.02	0.16
67	0.0	0.16	0.02	0.16	68	0.0	0.17	0.02	0.17	69	0.0	0.18	0.02	0.18
70	0.0	0.19	0.03	0.19	71	0.0	0.19	0.03	0.19	72	0.0	0.20	0.03	0.20
73	0.0	0.21	0.04	0.21	74	0.0	0.20	0.04	0.20	75	0.0	0.19	0.04	0.19
76	0.0	0.18	0.05	0.18	77	0.0	0.17	0.05	0.17	78	0.0	0.17	0.05	0.17
79	0.0	0.16	0.06	0.16	80	0.0	0.19	0.06	0.19	81	0.0	0.16	0.06	0.16
82	0.0	0.14	0.06	0.14	83	0.0	0.12	0.07	0.12	84	0.0	0.10	0.07	0.10
85	0.0	0.08	0.07	0.08	86	0.0	0.16	0.08	0.16	87	0.00	0.16	0.09	0.16
88	0.01	0.16	0.10	0.16	89	0.01	0.17	0.11	0.17	90	0.02	0.18	0.12	0.18
91	0.02	0.18	0.13	0.18	92	0.03	0.19	0.14	0.19	93	0.03	0.20	0.15	0.20
94	0.03	0.20	0.16	0.20	95	0.04	0.21	0.17	0.21	96	0.04	0.13	0.18	0.13
97	0.09	0.17	0.17	0.17	98	0.14	0.20	0.16	0.20	99	0.19	0.23	0.15	0.23
100	0.24	0.27	0.14	0.27	101	0.28	0.27	0.13	0.27	102	0.33	0.28	0.12	0.28
103	0.38	0.28	0.11	0.28	104	0.43	0.29	0.10	0.29	105	0.48	0.29	0.08	0.29
106	0.53	0.29	0.07	0.29	107	0.96	0.29	0.08	0.29	108	1.39	0.30	0.08	0.30
109	1.82	0.31	0.09	0.31	110	2.25	0.32	0.09	0.32	111	2.68	0.33	0.10	0.33
112	3.12	0.34	0.10	0.34	113	3.55	0.35	0.10	0.35	114	3.98	0.36	0.11	0.36
115	4.41	0.37	0.11	0.37	116	4.84	0.36	0.12	0.36	117	5.27	0.36	0.12	0.36
118	5.70	0.35	0.13	0.35	119	6.14	0.34	0.13	0.34	120	6.57	0.32	0.13	0.32
121	7.00	0.36	0.14	0.36	122	7.43	0.40	0.14	0.40	123	7.86	0.34	0.15	0.34
124	7.87	0.34	0.14	0.34	125	7.87	0.35	0.12	0.35	126	7.88	0.36	0.11	0.36
127	7.88	0.37	0.10	0.37	128	7.88	0.38	0.09	0.38	129	7.89	0.39	0.08	0.39
130	7.89	0.40	0.07	0.40	131	7.90	0.41	0.06	0.41	132	7.90	0.41	0.04	0.41
133	7.91	0.42	0.03	0.42	134	7.91	0.42	0.02	0.42	135	7.92	0.42	0.01	0.42
136	7.56	0.45	0.01	0.45	137	7.21	0.45	0.01	0.45	138	6.95	0.45	0.01	0.45

Table 7. Continued

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
139	6.49	0.45	0.01	0.45	140	6.14	0.45	0.01	0.45	141	5.78	0.45	0.01	0.45
142	5.43	0.45	0.01	0.45	143	5.07	0.44	0.01	0.44	144	4.72	0.44	0.01	0.44
145	4.36	0.43	0.01	0.43	146	4.01	0.43	0.00	0.43	147	3.65	0.42	0.00	0.42
148	3.29	0.42	0.00	0.42	149	2.94	0.43	0.00	0.43	150	2.58	0.43	0.00	0.43
151	2.23	0.43	0.00	0.43	152	1.87	0.44	0.00	0.44	153	1.52	0.44	0.00	0.44
154	1.16	0.44	0.00	0.44	155	0.80	0.44	0.00	0.44	156	0.45	0.45	0.0	0.45
157	0.46	0.42	0.0	0.42	158	0.47	0.40	0.0	0.40	159	0.48	0.40	0.0	0.40
160	0.49	0.40	0.0	0.40	161	0.50	0.40	0.0	0.40	162	0.51	0.41	0.0	0.41
163	0.52	0.41	0.0	0.41	164	0.53	0.41	0.0	0.41	165	0.55	0.42	0.0	0.42
166	0.56	0.42	0.0	0.42	167	0.57	0.42	0.0	0.42	168	0.58	0.42	0.0	0.42
169	0.59	0.45	0.0	0.45	170	0.57	0.48	0.00	0.48	171	0.56	0.49	0.00	0.49
172	0.54	0.51	0.00	0.51	173	0.53	0.53	0.00	0.53	174	0.51	0.54	0.00	0.54
175	0.50	0.56	0.00	0.56	176	0.48	0.58	0.00	0.58	177	0.47	0.59	0.00	0.59
178	0.45	0.61	0.00	0.61	179	0.44	0.58	0.00	0.58	180	0.42	0.58	0.00	0.58
181	0.41	0.57	0.00	0.57	182	0.39	0.57	0.00	0.57	183	0.38	0.56	0.00	0.56
184	0.44	0.56	0.00	0.56	185	0.50	0.55	0.00	0.55	186	0.56	0.55	0.00	0.55
187	0.63	0.54	0.00	0.54	188	0.69	0.54	0.00	0.54	189	0.75	0.53	0.00	0.53
190	0.81	0.53	0.00	0.53	191	0.87	0.57	0.00	0.57	192	0.93	0.62	0.00	0.62
193	0.99	0.66	0.00	0.66	194	1.05	0.71	0.00	0.71	195	1.12	0.75	0.00	0.75
196	1.18	0.80	0.00	0.80	197	1.24	0.92	0.0	0.92	198	1.21	0.71	0.0	0.71
199	1.18	0.73	0.0	0.73	200	1.15	0.75	0.0	0.75	201	1.12	0.76	0.0	0.76
202	1.10	0.78	0.0	0.78	203	1.07	0.80	0.0	0.80	204	1.04	0.81	0.0	0.81
205	1.01	0.83	0.0	0.83	206	0.98	0.85	0.0	0.85	207	0.95	0.74	0.0	0.74
208	0.93	0.71	0.0	0.71	209	0.90	0.67	0.0	0.67	210	0.87	0.64	0.0	0.64
211	0.84	0.60	0.0	0.60	212	0.81	0.57	0.0	0.57	213	0.78	0.53	0.0	0.53
214	0.75	0.50	0.0	0.50	215	0.73	0.46	0.0	0.46	216	0.70	0.43	0.0	0.43
217	0.67	0.40	0.0	0.40	218	0.64	0.41	0.0	0.41	219	0.61	0.42	0.0	0.42
220	0.61	0.61	0.0	0.61	221	0.61	0.80	0.0	0.80	222	0.60	0.78	0.0	0.78
223	0.60	0.76	0.0	0.76	224	0.60	0.74	0.0	0.74	225	0.59	0.72	0.0	0.72
226	0.59	0.70	0.0	0.70	227	0.59	0.68	0.0	0.68	228	0.59	0.67	0.0	0.67
229	0.58	0.65	0.0	0.65	230	0.58	0.63	0.0	0.63	231	0.58	0.61	0.0	0.61
232	0.58	0.53	0.0	0.53	233	0.54	0.45	0.0	0.45	234	0.50	0.37	0.0	0.37
235	0.46	0.71	0.0	0.71	236	0.42	0.75	0.0	0.75	237	0.38	0.78	0.0	0.78
238	0.35	0.82	0.0	0.82	239	0.31	0.85	0.0	0.85	240	0.27	0.89	0.0	0.89
241	0.23	0.92	0.0	0.92	242	0.19	0.91	0.0	0.91	243	0.15	0.90	0.0	0.90
244	0.12	0.89	0.0	0.89	245	0.08	0.87	0.0	0.87	246	0.04	0.86	0.0	0.86
247	0.0	0.85	0.0	0.85	248	0.00	0.85	0.0	0.85	249	0.00	0.90	0.0	0.90
250	0.00	0.82	0.0	0.82	251	0.00	0.74	0.0	0.74	252	0.00	0.66	0.0	0.66
253	0.00	0.58	0.0	0.58	254	0.00	0.50	0.0	0.50	255	0.00	0.42	0.0	0.42
256	0.00	0.50	0.0	0.50	257	0.00	0.57	0.0	0.57	258	0.00	0.64	0.0	0.64
259	0.00	0.71	0.0	0.71	260	0.00	0.63	0.0	0.63	261	0.00	0.61	0.00	0.61
262	0.00	0.66	0.01	0.66	263	0.01	0.65	0.01	0.65	264	0.01	0.64	0.02	0.64
265	0.01	0.63	0.02	0.63	266	0.01	0.62	0.02	0.62	267	0.01	0.61	0.03	0.61
268	0.01	0.60	0.03	0.60	269	0.01	0.60	0.04	0.60	270	0.01	0.59	0.04	0.59
271	0.01	0.58	0.04	0.58	272	0.01	0.57	0.05	0.57	273	0.01	0.56	0.05	0.56
274	0.01	0.55	0.06	0.55	275	0.02	0.54	0.05	0.54	276	0.02	0.53	0.05	0.53

Table 7. Continued

ALEWIFE			SMELT		ALEWIFE			SMELT		ALEWIFE			SMELT	
OBS.	DENS.	PROB.	DENS.	PROB.	OBS.	DENS.	PROB.	DENS.	PROB.	OBS.	DENS.	PROB.	DENS.	PROB.
277	0.03	0.53	0.04	0.53	278	0.04	0.53	0.04	0.53	279	0.04	0.54	0.04	0.54
280	0.05	0.54	0.03	0.54	281	0.05	0.54	0.03	0.54	282	0.06	0.54	0.02	0.54
283	0.07	0.55	0.02	0.55	284	0.07	0.55	0.02	0.55	285	0.08	0.55	0.01	0.55
286	0.08	0.55	0.01	0.55	287	0.09	0.56	0.00	0.56	288	0.09	0.54	0.00	0.54
289	0.09	0.53	0.00	0.53	290	0.08	0.52	0.00	0.52	291	0.08	0.52	0.00	0.52
292	0.08	0.52	0.00	0.52	293	0.08	0.51	0.00	0.51	294	0.07	0.51	0.00	0.51
295	0.07	0.50	0.00	0.50	296	0.07	0.50	0.00	0.50	297	0.07	0.49	0.00	0.49
298	0.06	0.49	0.00	0.49	299	0.06	0.48	0.00	0.48	300	0.06	0.48	0.00	0.48
301	0.06	0.48	0.00	0.48	302	0.05	0.50	0.00	0.50	303	0.05	0.56	0.00	0.56
304	0.05	0.55	0.00	0.55	305	0.05	0.53	0.00	0.53	306	0.04	0.52	0.00	0.52
307	0.04	0.51	0.00	0.51	308	0.04	0.50	0.00	0.50	309	0.04	0.49	0.00	0.49
310	0.03	0.48	0.0	0.48	311	0.03	0.45	0.0	0.45	312	0.03	0.42	0.0	0.42
313	0.03	0.43	0.0	0.43	314	0.02	0.43	0.0	0.43	315	0.02	0.44	0.0	0.44
316	0.02	0.44	0.0	0.44	317	0.02	0.45	0.0	0.45	318	0.01	0.44	0.0	0.44
319	0.01	0.43	0.0	0.43	320	0.01	0.41	0.0	0.41	321	0.01	0.40	0.0	0.40
322	0.00	0.39	0.0	0.39	323	0.0	0.38	0.0	0.38	324	0.0	0.37	0.00	0.37
325	0.0	0.36	0.00	0.36	326	0.0	0.34	0.00	0.34	327	0.0	0.33	0.00	0.33
328	0.0	0.31	0.00	0.31	329	0.0	0.30	0.00	0.30	330	0.0	0.29	0.00	0.29
331	0.0	0.27	0.00	0.27	332	0.0	0.26	0.00	0.26	333	0.0	0.24	0.00	0.24
334	0.0	0.23	0.00	0.23	335	0.0	0.21	0.00	0.21	336	0.0	0.20	0.00	0.20
337	0.0	0.19	0.00	0.19	338	0.0	0.17	0.00	0.17	339	0.0	0.16	0.00	0.16
340	0.0	0.21	0.00	0.21	341	0.0	0.19	0.00	0.19	342	0.0	0.17	0.00	0.17
343	0.0	0.15	0.00	0.15	344	0.0	0.13	0.00	0.13	345	0.0	0.13	0.00	0.13
346	0.0	0.16	0.00	0.16	347	0.0	0.14	0.00	0.14	348	0.0	0.13	0.00	0.13
349	0.0	0.12	0.00	0.12	350	0.0	0.10	0.00	0.10	351	0.0	0.24	0.00	0.24
352	0.0	0.19	0.00	0.19	353	0.0	0.19	0.00	0.19	354	0.0	0.19	0.00	0.19
355	0.0	0.19	0.00	0.19	356	0.0	0.19	0.00	0.19	357	0.0	0.20	0.00	0.20
358	0.0	0.20	0.00	0.20	359	0.0	0.20	0.00	0.20	360	0.0	0.20	0.00	0.20
361	0.0	0.20	0.00	0.20	362	0.0	0.21	0.00	0.21	363	0.0	0.21	0.00	0.21
364	0.0	0.21	0.00	0.21	365	0.0	0.21	0.00	0.21					

Table 8. Daily Fish-Impingement Predictions Calculated
According to Case-III Specifications

DATE	ALEWIFE	FISH SPECIES		TOTAL	CUMULATIVE
		SMELT		IMPINGEMENT	TOTAL
1/ 1/74	0	255		255	255
1/ 2/74	0	255		255	510
1/ 3/74	0	255		255	765
1/ 4/74	0	255		255	1020
1/ 5/74	0	255		255	1275
1/ 6/74	0	255		255	1530
1/ 7/74	0	255		255	1785
1/ 8/74	0	255		255	2040
1/ 9/74	0	255		255	2295
1/10/74	0	255		255	2550
1/11/74	0	255		255	2805
1/12/74	0	255		255	3060
1/13/74	0	255		255	3315
1/14/74	0	255		255	3570
1/15/74	0	255		255	3825
1/16/74	0	255		255	4080
1/17/74	0	254		254	4334
1/18/74	0	253		253	4587
1/19/74	0	253		253	4840
1/20/74	0	252		252	5092
1/21/74	0	251		251	5343
1/22/74	0	0		0	5343
1/23/74	0	250		250	5593
1/24/74	0	249		249	5842
1/25/74	0	261		261	6103
1/26/74	0	273		273	6376
1/27/74	0	285		285	6661
1/28/74	0	296		296	6957
1/29/74	0	308		308	7265
1/30/74	0	320		320	7585
1/31/74	0	331		331	7916
2/ 1/74	0	343		343	8259
2/ 2/74	0	354		354	8613
2/ 3/74	0	366		366	8979
2/ 4/74	0	377		377	9356
2/ 5/74	0	389		389	9745
2/ 6/74	0	400		400	10145
2/ 7/74	0	411		411	10556
2/ 8/74	0	422		422	10978
2/ 9/74	0	433		433	11411
2/10/74	0	444		444	11855
2/11/74	0	455		455	12310

Table 8. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
2/12/74	0	466	466	12776
2/13/74	0	475	475	13251
2/14/74	0	478	478	13729
2/15/74	0	482	482	14211
2/16/74	0	485	485	14696
2/17/74	0	488	488	15184
2/18/74	0	492	492	15676
2/19/74	0	495	495	16171
2/20/74	0	499	499	16670
2/21/74	0	502	502	17172
2/22/74	0	506	506	17678
2/23/74	0	510	510	18188
2/24/74	0	513	513	18701
2/25/74	0	517	517	19218
2/26/74	0	521	521	19739
2/27/74	0	525	525	20264
2/28/74	0	529	529	20793
3/ 1/74	0	534	534	21327
3/ 2/74	0	538	538	21865
3/ 3/74	0	542	542	22407
3/ 4/74	0	547	547	22954
3/ 5/74	0	551	551	23505
3/ 6/74	0	822	822	24327
3/ 7/74	0	919	919	25246
3/ 8/74	0	926	926	26172
3/ 9/74	0	931	931	27103
3/10/74	0	932	932	28035
3/11/74	0	931	931	28966
3/12/74	0	925	925	29891
3/13/74	0	916	916	30807
3/14/74	0	902	902	31709
3/15/74	0	1062	1062	32771
3/16/74	0	1225	1225	33996
3/17/74	0	1389	1389	35385
3/18/74	0	1555	1555	36940
3/19/74	0	1723	1723	38663
3/20/74	0	1891	1891	40554
3/21/74	0	2131	2131	42685
3/22/74	0	1573	1573	44258
3/23/74	0	1442	1442	45700
3/24/74	0	1311	1311	47011
3/25/74	0	1181	1181	48192

Table 8. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
3/26/74	0	1053	1053	49245
3/27/74	0	1911	1911	51156
3/28/74	320	2134	2454	53610
3/29/74	318	2357	2675	56285
3/30/74	316	2600	2916	59201
3/31/74	312	2864	3176	62377
4/ 1/74	309	3151	3460	65837
4/ 2/74	305	3462	3767	69604
4/ 3/74	300	3797	4097	73701
4/ 4/74	295	4158	4453	78154
4/ 5/74	290	4545	4835	82989
4/ 6/74	150	2650	2800	85789
4/ 7/74	152	2309	2461	88250
4/ 8/74	149	1948	2097	90347
4/ 9/74	141	1582	1723	92070
4/10/74	127	1224	1351	93421
4/11/74	185	1539	1724	95145
4/12/74	248	1777	2025	97170
4/13/74	316	1950	2266	99436
4/14/74	389	2069	2458	101894
4/15/74	467	2144	2611	104505
4/16/74	641	2537	3178	107683
4/17/74	1045	3323	4368	112051
4/18/74	1324	3384	4708	116759
4/19/74	1671	3436	5107	121866
4/20/74	2101	3475	5576	127442
4/21/74	2629	3502	6131	133573
4/22/74	3275	3513	6788	140361
4/23/74	4059	3507	7566	147927
4/24/74	5000	3482	8482	156409
4/25/74	6118	3435	9553	165962
4/26/74	7851	3548	11399	177361
4/27/74	10076	3664	13740	191101
4/28/74	12931	3783	16714	207815
4/29/74	16596	3905	20501	228316
4/30/74	20626	3888	24514	252830
5/ 1/74	23067	4412	27479	280309
5/ 2/74	32053	4978	37031	317340
5/ 3/74	38025	4703	42728	360068
5/ 4/74	50842	5542	56384	416452
5/ 5/74	50383	4852	55235	471687
5/ 6/74	49875	4243	54118	525805

Table 8. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
5/ 7/74	49316	3088	52404	578209
5/ 8/74	48707	2694	51401	629610
5/ 9/74	48048	2347	50395	680005
5/10/74	47336	2042	49378	729383
5/11/74	46574	1774	48348	777731
5/12/74	45759	1539	47298	825029
5/13/74	44891	1333	46224	871253
5/14/74	45017	1178	46195	917448
5/15/74	45144	1042	46186	963634
5/16/74	37772	1082	38854	1002488
5/17/74	30449	1078	31527	1034015
5/18/74	24546	1074	25620	1059635
5/19/74	19788	1070	20858	1080493
5/20/74	15951	1066	17017	1097510
5/21/74	12859	1062	13921	1111431
5/22/74	10365	1058	11423	1122854
5/23/74	6762	853	7615	1130469
5/24/74	4185	652	4837	1135306
5/25/74	2368	456	2824	1138130
5/26/74	1111	265	1376	1139506
5/27/74	263	77	340	1139846
5/28/74	212	77	289	1140135
5/29/74	8430	233	8663	1148798
5/30/74	11401	390	11791	1160589
5/31/74	12940	548	13488	1174077
6/ 1/74	13483	705	14188	1188265
6/ 2/74	13354	863	14217	1202482
6/ 3/74	12788	1022	13810	1216292
6/ 4/74	11956	1181	13137	1229429
6/ 5/74	10979	0	10979	1240408
6/ 6/74	10593	0	10593	1251001
6/ 7/74	10110	0	10110	1261111
6/ 8/74	9976	0	9976	1271087
6/ 9/74	9836	0	9836	1280923
6/10/74	9692	0	9692	1290615
6/11/74	9542	0	9542	1300157
6/12/74	9387	0	9387	1309544
6/13/74	9227	0	9227	1318771
6/14/74	9062	0	9062	1327833
6/15/74	8891	0	8891	1336724
6/16/74	8714	0	8714	1345438
6/17/74	8532	0	8532	1353970

Table 8. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
6/18/74	8958	0	8958	1362928
6/19/74	9320	1050	10370	1373298
6/20/74	9493	1075	10568	1383866
6/21/74	9662	1101	10763	1394629
6/22/74	9828	1127	10955	1405584
6/23/74	9989	1153	11142	1416726
6/24/74	10147	1180	11327	1428053
6/25/74	10301	1206	11507	1439560
6/26/74	10451	1233	11684	1451244
6/27/74	10598	1259	11857	1463101
6/28/74	10099	1211	11310	1474411
6/29/74	9944	1202	11146	1485557
6/30/74	9790	1193	10983	1496540
7/ 1/74	9638	1184	10822	1507362
7/ 2/74	9488	1175	10663	1518025
7/ 3/74	9775	1167	10942	1528967
7/ 4/74	10071	1158	11229	1540196
7/ 5/74	10375	1150	11525	1551721
7/ 6/74	10687	1141	11828	1563549
7/ 7/74	11009	1132	12141	1575690
7/ 8/74	11339	1124	12463	1588153
7/ 9/74	11679	1115	12794	1600947
7/10/74	12932	1189	14121	1615068
7/11/74	14263	1263	15526	1630594
7/12/74	15675	1337	17012	1647606
7/13/74	17172	1410	18582	1666188
7/14/74	18760	1484	20244	1686432
7/15/74	20443	1557	22000	1708432
7/16/74	24150	0	24150	1732582
7/17/74	19027	0	19027	1751609
7/18/74	19074	0	19074	1770683
7/19/74	19114	0	19114	1789797
7/20/74	19147	0	19147	1808944
7/21/74	19174	0	19174	1828118
7/22/74	19194	0	19194	1847312
7/23/74	19207	0	19207	1866519
7/24/74	19215	0	19215	1885734
7/25/74	19217	0	19217	1904951
7/26/74	16872	0	16872	1921823
7/27/74	15928	0	15928	1937751
7/28/74	15012	0	15012	1952763
7/29/74	14122	0	14122	1966885

Table 8. Continued

DATE	FISH SPECIES		TOTAL	CUMULATIVE
	ALEWIFE	SMELT	IMPINGEMENT	TOTAL
7/30/74	13258	0	13258	1980143
7/31/74	12419	0	12419	1992562
8/ 1/74	11605	0	11605	2004167
8/ 2/74	10815	0	10815	2014982
8/ 3/74	10049	0	10049	2025031
8/ 4/74	9306	0	9306	2034337
8/ 5/74	8585	0	8585	2042922
8/ 6/74	10113	0	10113	2053035
8/ 7/74	3588	0	3588	2056623
8/ 8/74	3582	0	3582	2060205
8/ 9/74	5959	0	5959	2066164
8/10/74	6122	0	6122	2072286
8/11/74	6272	0	6272	2078558
8/12/74	6410	0	6410	2084968
8/13/74	6536	0	6536	2091504
8/14/74	6650	0	6650	2098154
8/15/74	6751	0	6751	2104905
8/16/74	6840	0	6840	2111745
8/17/74	6917	0	6917	2118662
8/18/74	6983	0	6983	2125645
8/19/74	7036	0	7036	2132681
8/20/74	4173	0	4173	2136854
8/21/74	3580	0	3580	2140434
8/22/74	3040	0	3040	2143474
8/23/74	6234	0	6234	2149708
8/24/74	5709	0	5709	2155417
8/25/74	5156	0	5156	2160573
8/26/74	4577	0	4577	2165150
8/27/74	3974	0	3974	2169124
8/28/74	3351	0	3351	2172475
8/29/74	2710	0	2710	2175185
8/30/74	3052	0	3052	2178237
8/31/74	3368	0	3368	2181605
9/ 1/74	3657	0	3657	2185262
9/ 2/74	3922	0	3922	2189184
9/ 3/74	4163	0	4163	2193347
9/ 4/74	0	0	0	2193347
9/ 5/74	5478	0	5478	2198825
9/ 6/74	4617	0	4617	2203442
9/ 7/74	4441	0	4441	2207883
9/ 8/74	4235	0	4235	2212118
9/ 9/74	3999	0	3999	2216117

Table 8. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
9/10/74	3734	0	3734	2219851
9/11/74	3439	0	3439	2223290
9/12/74	3114	0	3114	2226404
9/13/74	3697	0	3697	2230101
9/14/74	4320	0	4320	2234421
9/15/74	4984	0	4984	2239405
9/16/74	5689	0	5689	2245094
9/17/74	5146	0	5146	2250240
9/18/74	4990	800	5790	2256030
9/19/74	5345	888	6233	2262263
9/20/74	5284	916	6200	2268463
9/21/74	5224	944	6168	2274631
9/22/74	5164	972	6136	2280767
9/23/74	5103	1002	6105	2286872
9/24/74	5043	1032	6075	2292947
9/25/74	4983	1062	6045	2298992
9/26/74	4922	1094	6016	2305008
9/27/74	4862	1125	5987	2310995
9/28/74	4802	1158	5960	2316955
9/29/74	4742	1191	5933	2322888
9/30/74	4682	1225	5907	2328795
10/ 1/74	4622	1259	5881	2334676
10/ 2/74	4574	1192	5766	2340442
10/ 3/74	4527	1127	5654	2346096
10/ 4/74	4353	1036	5389	2351485
10/ 5/74	4177	950	5127	2356612
10/ 6/74	3998	869	4867	2361479
10/ 7/74	3816	793	4609	2366088
10/ 8/74	3630	721	4351	2370439
10/ 9/74	3442	653	4095	2374534
10/10/74	3251	589	3840	2378374
10/11/74	3057	530	3587	2381961
10/12/74	2859	473	3332	2385293
10/13/74	2659	421	3080	2388373
10/14/74	2455	371	2826	2391199
10/15/74	2402	363	2765	2393964
10/16/74	2349	354	2703	2396667
10/17/74	2524	381	2905	2399572
10/18/74	2697	406	3103	2402675
10/19/74	2867	431	3298	2405973
10/20/74	3034	456	3490	2409463
10/21/74	3197	480	3677	2413140

Table 8. Continued

DATE	FISH SPECIES		TOTAL IMPINGEMENT	CUMULATIVE TOTAL
	ALEWIFE	SMELT		
10/22/74	3358	503	3861	2417001
10/23/74	3516	526	4042	2421043
10/24/74	3671	549	4220	2425263
10/25/74	3823	571	4394	2429657
10/26/74	3973	592	4565	2434222
10/27/74	4119	613	4732	2438954
10/28/74	4262	634	4896	2443850
10/29/74	4452	661	5113	2448963
10/30/74	4804	712	5516	2454479
10/31/74	4718	698	5416	2459895
11/ 1/74	4633	685	5318	2465213
11/ 2/74	4548	672	5220	2470433
11/ 3/74	4464	658	5122	2475555
11/ 4/74	4380	645	5025	2480580
11/ 5/74	4296	632	4928	2485508
11/ 6/74	4212	0	4212	2489720
11/ 7/74	3344	0	3344	2493064
11/ 8/74	1923	0	1923	2494987
11/ 9/74	2324	0	2324	2497311
11/10/74	2729	0	2729	2500040
11/11/74	3140	0	3140	2503180
11/12/74	3556	0	3556	2506736
11/13/74	3977	0	3977	2510713
11/14/74	3898	0	3898	2514611
11/15/74	3820	0	3820	2518431
11/16/74	3741	0	3741	2522172
11/17/74	3664	0	3664	2525836
11/18/74	3586	0	3586	2529422
11/19/74	0	0	0	2529422
11/20/74	0	513	513	2529935
11/21/74	0	480	480	2530415
11/22/74	0	448	448	2530863
11/23/74	0	418	418	2531281
11/24/74	0	388	388	2531669
11/25/74	0	359	359	2532028
11/26/74	0	332	332	2532360
11/27/74	0	305	305	2532665
11/28/74	0	280	280	2532945
11/29/74	0	255	255	2533200
11/30/74	0	232	232	2533432
12/ 1/74	0	209	209	2533641
12/ 2/74	0	188	188	2533829

Table 8. Continued

DATE	ALEWIFE	FISH SPECIES SMELT	TOTAL IMPINGEMENT	CUMULATIVE TOTAL
12/ 3/74	0	168	168	2533997
12/ 4/74	0	149	149	2534146
12/ 5/74	0	131	131	2534277
12/ 6/74	0	158	158	2534435
12/ 7/74	0	148	148	2534583
12/ 8/74	0	138	138	2534721
12/ 9/74	0	128	128	2534849
12/10/74	0	118	118	2534967
12/11/74	0	158	158	2535125
12/12/74	0	218	218	2535343
12/13/74	0	217	217	2535560
12/14/74	0	215	215	2535775
12/15/74	0	212	212	2535987
12/16/74	0	207	207	2536194
12/17/74	0	348	348	2536542
12/18/74	0	293	293	2536835
12/19/74	0	295	295	2537130
12/20/74	0	297	297	2537427
12/21/74	0	299	299	2537726
12/22/74	0	301	301	2538027
12/23/74	0	303	303	2538330
12/24/74	0	306	306	2538636
12/25/74	0	308	308	2538944
12/26/74	0	310	310	2539254
12/27/74	0	312	312	2539566
12/28/74	0	314	314	2539880
12/29/74	0	316	316	2540196
12/30/74	0	318	318	2540514
12/31/74	0	318	318	2540832

Fig. 15. Predicted Impingement (solid line) for Case III and Observed Impingement (circles) of Alewives at the Zion Station during 1974 (No. of fish/day).

Fig. 16. Predicted Impingement (solid line) for Case III and Observed Impingement (circles) of Smelt at the Zion Station during 1974 (No. of fish/day).

Fig. 17. Predicted Impingement (solid line) for Case III and Observed Impingement (circles) of Both Species at the Zion Station during 1974 (No. of fish/day).

Fig. 18. The Risk of Impingement of Alewives According to the Probability Function under the Conditions of Case III.

Fig. 19. The Risk of Impingement of Smelt According to the Probability Function under the Conditions of Case III.

Table 9. Numerical Values for Fish Density and Probability of Impingement for Case III

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
1	0.0	0.05	0.00	0.26	2	0.0	0.05	0.00	0.26	3	0.0	0.05	0.00	0.26
4	0.0	0.05	0.00	0.26	5	0.0	0.05	0.00	0.26	6	0.0	0.05	0.00	0.26
7	0.0	0.05	0.00	0.26	8	0.0	0.05	0.00	0.26	9	0.0	0.05	0.00	0.26
10	0.0	0.05	0.00	0.26	11	0.0	0.05	0.00	0.26	12	0.0	0.05	0.00	0.26
13	0.0	0.05	0.00	0.26	14	0.0	0.05	0.00	0.26	15	0.0	0.05	0.00	0.26
16	0.0	0.05	0.00	0.26	17	0.0	0.05	0.00	0.26	18	0.0	0.05	0.00	0.26
19	0.0	0.05	0.00	0.26	20	0.0	0.05	0.00	0.26	21	0.0	0.05	0.00	0.26
22	0.0	0.05	0.0	0.26	23	0.0	0.05	0.00	0.26	24	0.0	0.05	0.00	0.26
25	0.0	0.05	0.00	0.26	26	0.0	0.05	0.00	0.26	27	0.0	0.05	0.00	0.26
28	0.0	0.05	0.00	0.26	29	0.0	0.05	0.00	0.26	30	0.0	0.05	0.00	0.26
31	0.0	0.05	0.00	0.25	32	0.0	0.05	0.00	0.25	33	0.0	0.05	0.00	0.25
34	0.0	0.05	0.00	0.25	35	0.0	0.05	0.00	0.25	36	0.0	0.05	0.00	0.25
37	0.0	0.05	0.00	0.25	38	0.0	0.05	0.00	0.25	39	0.0	0.05	0.00	0.25
40	0.0	0.05	0.00	0.25	41	0.0	0.05	0.00	0.25	42	0.0	0.05	0.00	0.24
43	0.0	0.05	0.00	0.24	44	0.0	0.06	0.00	0.24	45	0.0	0.07	0.00	0.24
46	0.0	0.07	0.00	0.24	47	0.0	0.08	0.00	0.24	48	0.0	0.09	0.01	0.24
49	0.0	0.10	0.01	0.24	50	0.0	0.11	0.01	0.24	51	0.0	0.12	0.01	0.25
52	0.0	0.13	0.01	0.25	53	0.0	0.14	0.01	0.25	54	0.0	0.14	0.01	0.25
55	0.0	0.15	0.01	0.25	56	0.0	0.16	0.01	0.25	57	0.0	0.17	0.01	0.25
58	0.0	0.18	0.01	0.25	59	0.0	0.19	0.01	0.25	60	0.0	0.19	0.01	0.25
61	0.0	0.20	0.01	0.25	62	0.0	0.21	0.01	0.25	63	0.0	0.22	0.01	0.25
64	0.0	0.23	0.01	0.26	65	0.0	0.23	0.01	0.25	66	0.0	0.25	0.02	0.27
67	0.0	0.26	0.02	0.28	68	0.0	0.27	0.02	0.29	69	0.0	0.27	0.02	0.29
70	0.0	0.28	0.03	0.30	71	0.0	0.29	0.03	0.31	72	0.0	0.29	0.03	0.31
73	0.0	0.30	0.04	0.32	74	0.0	0.29	0.04	0.31	75	0.0	0.28	0.04	0.30
76	0.0	0.28	0.05	0.30	77	0.0	0.27	0.05	0.29	78	0.0	0.26	0.05	0.28
79	0.0	0.25	0.06	0.27	80	0.0	0.28	0.06	0.30	81	0.0	0.26	0.06	0.28
82	0.0	0.24	0.06	0.26	83	0.0	0.22	0.07	0.24	84	0.0	0.20	0.07	0.23
85	0.0	0.19	0.07	0.21	86	0.0	0.25	0.08	0.27	87	0.00	0.25	0.09	0.27
88	0.01	0.26	0.10	0.28	89	0.01	0.26	0.11	0.28	90	0.02	0.27	0.12	0.29
91	0.02	0.28	0.13	0.29	92	0.03	0.28	0.14	0.29	93	0.03	0.29	0.15	0.30
94	0.03	0.29	0.16	0.30	95	0.04	0.30	0.17	0.31	96	0.04	0.23	0.18	0.24
97	0.09	0.26	0.17	0.27	98	0.14	0.29	0.16	0.30	99	0.19	0.32	0.15	0.33
100	0.24	0.35	0.14	0.36	101	0.28	0.35	0.13	0.36	102	0.33	0.36	0.12	0.37
103	0.38	0.36	0.11	0.37	104	0.43	0.37	0.10	0.37	105	0.48	0.37	0.08	0.38
106	0.53	0.37	0.07	0.38	107	0.96	0.37	0.08	0.38	108	1.39	0.38	0.08	0.39
109	1.82	0.39	0.09	0.40	110	2.25	0.41	0.09	0.40	111	2.68	0.42	0.10	0.41
112	3.12	0.43	0.10	0.42	113	3.55	0.44	0.10	0.43	114	3.98	0.45	0.11	0.44
115	4.41	0.46	0.11	0.45	116	4.84	0.46	0.12	0.44	117	5.27	0.45	0.12	0.44
118	5.70	0.45	0.13	0.43	119	6.14	0.45	0.13	0.42	120	6.57	0.43	0.13	0.40
121	7.00	0.46	0.14	0.44	122	7.43	0.50	0.14	0.47	123	7.86	0.45	0.15	0.42
124	7.87	0.45	0.14	0.42	125	7.87	0.46	0.12	0.43	126	7.88	0.47	0.11	0.44
127	7.88	0.48	0.10	0.45	128	7.88	0.48	0.09	0.45	129	7.89	0.49	0.08	0.46
130	7.89	0.50	0.07	0.47	131	7.90	0.51	0.06	0.48	132	7.90	0.51	0.04	0.49
133	7.91	0.52	0.03	0.49	134	7.91	0.52	0.02	0.49	135	7.92	0.52	0.01	0.49
136	7.56	0.54	0.01	0.52	137	7.21	0.54	0.01	0.52	138	6.85	0.54	0.01	0.52

Table 9. Continued

OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT		OBS.	ALEWIFE		SMELT	
	DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.		DENS.	PROB.	DENS.	PROB.
139	6.49	0.54	0.01	0.52	140	6.14	0.53	0.01	0.52	141	5.78	0.53	0.01	0.52
142	5.43	0.53	0.01	0.52	143	5.07	0.53	0.01	0.52	144	4.72	0.52	0.01	0.51
145	4.36	0.51	0.01	0.51	146	4.01	0.51	0.00	0.51	147	3.65	0.50	0.00	0.50
148	3.29	0.50	0.00	0.50	149	2.94	0.50	0.00	0.51	150	2.58	0.50	0.00	0.51
151	2.23	0.50	0.00	0.51	152	1.87	0.51	0.00	0.52	153	1.52	0.51	0.00	0.52
154	1.16	0.51	0.00	0.52	155	0.80	0.51	0.00	0.53	156	0.45	0.51	0.0	0.53
157	0.46	0.49	0.0	0.51	158	0.47	0.46	0.0	0.48	159	0.48	0.47	0.0	0.49
160	0.49	0.47	0.0	0.49	161	0.50	0.47	0.0	0.49	162	0.51	0.47	0.0	0.49
163	0.52	0.48	0.0	0.50	164	0.53	0.48	0.0	0.50	165	0.55	0.48	0.0	0.50
166	0.56	0.48	0.0	0.50	167	0.57	0.49	0.0	0.51	168	0.58	0.49	0.0	0.51
169	0.59	0.51	0.0	0.53	170	0.57	0.54	0.00	0.55	171	0.56	0.55	0.00	0.57
172	0.54	0.57	0.00	0.58	173	0.53	0.58	0.00	0.59	174	0.51	0.60	0.00	0.61
175	0.50	0.61	0.00	0.62	176	0.48	0.62	0.00	0.63	177	0.47	0.64	0.00	0.65
178	0.45	0.65	0.00	0.66	179	0.44	0.63	0.00	0.63	180	0.42	0.63	0.00	0.63
181	0.41	0.62	0.00	0.62	182	0.39	0.62	0.00	0.62	183	0.38	0.61	0.00	0.61
184	0.44	0.61	0.00	0.61	185	0.50	0.60	0.00	0.61	186	0.56	0.60	0.00	0.60
187	0.63	0.60	0.00	0.60	188	0.69	0.59	0.00	0.59	189	0.75	0.59	0.00	0.59
190	0.81	0.58	0.00	0.59	191	0.87	0.62	0.00	0.62	192	0.93	0.66	0.00	0.66
193	0.99	0.70	0.00	0.70	194	1.05	0.74	0.00	0.74	195	1.12	0.78	0.00	0.78
196	1.18	0.82	0.00	0.82	197	1.24	0.93	0.0	0.93	198	1.21	0.75	0.0	0.75
199	1.18	0.76	0.0	0.76	200	1.15	0.78	0.0	0.78	201	1.12	0.79	0.0	0.79
202	1.10	0.81	0.0	0.81	203	1.07	0.82	0.0	0.82	204	1.04	0.84	0.0	0.84
205	1.01	0.85	0.0	0.85	206	0.98	0.87	0.0	0.87	207	0.95	0.77	0.0	0.78
208	0.93	0.74	0.0	0.75	209	0.90	0.71	0.0	0.72	210	0.87	0.68	0.0	0.69
211	0.84	0.65	0.0	0.66	212	0.81	0.62	0.0	0.63	213	0.78	0.59	0.0	0.60
214	0.75	0.56	0.0	0.57	215	0.73	0.53	0.0	0.54	216	0.70	0.50	0.0	0.51
217	0.67	0.47	0.0	0.48	218	0.64	0.48	0.0	0.49	219	0.61	0.49	0.0	0.50
220	0.61	0.66	0.0	0.66	221	0.61	0.82	0.0	0.82	222	0.60	0.80	0.0	0.81
223	0.60	0.79	0.0	0.79	224	0.60	0.77	0.0	0.77	225	0.59	0.75	0.0	0.76
226	0.59	0.74	0.0	0.74	227	0.59	0.72	0.0	0.73	228	0.59	0.70	0.0	0.71
229	0.58	0.69	0.0	0.69	230	0.58	0.67	0.0	0.68	231	0.58	0.66	0.0	0.66
232	0.58	0.58	0.0	0.59	233	0.54	0.51	0.0	0.52	234	0.50	0.45	0.0	0.46
235	0.46	0.75	0.0	0.75	236	0.42	0.78	0.0	0.78	237	0.38	0.81	0.0	0.82
238	0.35	0.84	0.0	0.85	239	0.31	0.87	0.0	0.88	240	0.27	0.90	0.0	0.91
241	0.23	0.93	0.0	0.94	242	0.19	0.92	0.0	0.92	243	0.15	0.91	0.0	0.91
244	0.12	0.90	0.0	0.90	245	0.08	0.89	0.0	0.89	246	0.04	0.88	0.0	0.88
247	0.0	0.87	0.0	0.87	248	0.00	0.87	0.0	0.87	249	0.00	0.91	0.0	0.92
250	0.00	0.84	0.0	0.85	251	0.00	0.77	0.0	0.78	252	0.00	0.70	0.0	0.72
253	0.00	0.63	0.0	0.65	254	0.00	0.56	0.0	0.59	255	0.00	0.49	0.0	0.52
256	0.00	0.56	0.0	0.58	257	0.00	0.62	0.0	0.64	258	0.00	0.68	0.0	0.70
259	0.00	0.75	0.0	0.76	260	0.00	0.68	0.0	0.69	261	0.00	0.66	0.00	0.67
262	0.00	0.70	0.01	0.72	263	0.01	0.69	0.01	0.71	264	0.01	0.69	0.02	0.70
265	0.01	0.68	0.02	0.69	266	0.01	0.67	0.02	0.68	267	0.01	0.66	0.03	0.67
268	0.01	0.65	0.03	0.66	269	0.01	0.64	0.04	0.65	270	0.01	0.64	0.04	0.65
271	0.01	0.63	0.04	0.64	272	0.01	0.62	0.05	0.63	273	0.01	0.61	0.05	0.62
274	0.01	0.60	0.06	0.61	275	0.02	0.60	0.05	0.60	276	0.02	0.59	0.05	0.59

Table 9. Continued

ALEWIFE					SMELT					ALEWIFE					SMELT				
OBS.	DENS.	PROB.	DENS.	PROB.	OBS.	DENS.	PROB.	DENS.	PROB.	OBS.	DENS.	PROB.	DENS.	PROB.	OBS.	DENS.	PROB.	DENS.	PROB.
277	0.03	0.59	0.04	0.60	278	0.04	0.59	0.04	0.60	279	0.04	0.59	0.04	0.60	280	0.05	0.60	0.05	0.60
280	0.05	0.60	0.05	0.60	281	0.05	0.60	0.03	0.60	282	0.06	0.60	0.02	0.61	283	0.07	0.60	0.02	0.61
283	0.07	0.60	0.02	0.61	284	0.07	0.61	0.02	0.61	285	0.08	0.61	0.01	0.61	286	0.08	0.61	0.01	0.61
286	0.08	0.61	0.01	0.62	287	0.09	0.61	0.00	0.62	288	0.09	0.60	0.00	0.61	289	0.09	0.59	0.00	0.59
289	0.09	0.59	0.00	0.59	290	0.08	0.58	0.00	0.59	291	0.08	0.58	0.00	0.59	292	0.08	0.58	0.00	0.58
292	0.08	0.58	0.00	0.58	293	0.08	0.57	0.00	0.58	294	0.07	0.57	0.00	0.57	295	0.07	0.57	0.00	0.57
295	0.07	0.57	0.00	0.57	296	0.07	0.56	0.00	0.57	297	0.07	0.56	0.00	0.56	298	0.06	0.55	0.00	0.56
298	0.06	0.55	0.00	0.56	299	0.06	0.55	0.00	0.55	300	0.06	0.55	0.00	0.55	301	0.06	0.54	0.00	0.55
301	0.06	0.54	0.00	0.55	302	0.05	0.57	0.00	0.57	303	0.05	0.61	0.00	0.62	304	0.05	0.60	0.00	0.60
304	0.05	0.60	0.00	0.60	305	0.05	0.59	0.00	0.59	306	0.04	0.58	0.00	0.58	307	0.04	0.57	0.00	0.57
307	0.04	0.57	0.00	0.57	308	0.04	0.56	0.00	0.56	309	0.04	0.55	0.00	0.55	310	0.03	0.54	0.0	0.54
310	0.03	0.54	0.0	0.54	311	0.03	0.52	0.0	0.52	312	0.03	0.50	0.0	0.50	313	0.03	0.50	0.0	0.50
313	0.03	0.50	0.0	0.50	314	0.02	0.51	0.0	0.51	315	0.02	0.51	0.0	0.51	316	0.02	0.51	0.0	0.51
316	0.02	0.51	0.0	0.51	317	0.02	0.52	0.0	0.52	318	0.01	0.51	0.0	0.51	319	0.01	0.50	0.0	0.50
319	0.01	0.50	0.0	0.50	320	0.01	0.49	0.0	0.49	321	0.01	0.48	0.0	0.48	322	0.00	0.47	0.0	0.47
322	0.00	0.47	0.0	0.47	323	0.0	0.46	0.0	0.46	324	0.0	0.45	0.00	0.45	325	0.0	0.44	0.00	0.44
325	0.0	0.44	0.00	0.44	326	0.0	0.43	0.00	0.42	327	0.0	0.42	0.00	0.41	328	0.0	0.41	0.00	0.39
328	0.0	0.41	0.00	0.39	329	0.0	0.40	0.00	0.38	330	0.0	0.39	0.00	0.36	331	0.0	0.37	0.00	0.35
331	0.0	0.37	0.00	0.35	332	0.0	0.36	0.00	0.33	333	0.0	0.35	0.00	0.32	334	0.0	0.34	0.00	0.30
334	0.0	0.34	0.00	0.30	335	0.0	0.33	0.00	0.29	336	0.0	0.32	0.00	0.27	337	0.0	0.31	0.00	0.26
337	0.0	0.31	0.00	0.26	338	0.0	0.30	0.00	0.24	339	0.0	0.29	0.00	0.23	340	0.0	0.33	0.00	0.28
340	0.0	0.33	0.00	0.28	341	0.0	0.31	0.00	0.26	342	0.0	0.30	0.00	0.24	343	0.0	0.28	0.00	0.22
343	0.0	0.28	0.00	0.22	344	0.0	0.27	0.00	0.21	345	0.0	0.27	0.00	0.21	346	0.0	0.29	0.00	0.23
346	0.0	0.29	0.00	0.23	347	0.0	0.25	0.00	0.22	348	0.0	0.26	0.00	0.20	349	0.0	0.25	0.00	0.19
349	0.0	0.25	0.00	0.19	350	0.0	0.24	0.00	0.18	351	0.0	0.35	0.00	0.30	352	0.0	0.31	0.00	0.25
352	0.0	0.31	0.00	0.25	353	0.0	0.31	0.00	0.26	354	0.0	0.31	0.00	0.26	355	0.0	0.32	0.00	0.26
355	0.0	0.32	0.00	0.26	356	0.0	0.32	0.00	0.26	357	0.0	0.32	0.00	0.26	358	0.0	0.32	0.00	0.26
358	0.0	0.32	0.00	0.26	359	0.0	0.32	0.00	0.27	360	0.0	0.32	0.00	0.27	361	0.0	0.33	0.00	0.27
361	0.0	0.33	0.00	0.27	362	0.0	0.33	0.00	0.27	363	0.0	0.33	0.00	0.27	364	0.0	0.33	0.00	0.28
364	0.0	0.33	0.00	0.28	365	0.0	0.33	0.00	0.28										

3.4 COMPARISON AND DISCUSSION OF THE THREE CASES

By comparing the three cases we find that the exponential model seems to predict fish-impingement values that generally behave in the manner of observed fish impingements. The most important aspect in these calculations arises from the fish-density observations, followed by the water-temperature effects and then the length-frequency classes. On the whole we find that the model formulation and computations are in agreement with observed fish impingements.

The low correlation between computed fish-impingement values and those actually observed is due primarily to the separation in time between fish density measurements (trawls) and impingement data per se. Also, the frequency of trawls and the need to interpolate makes for further uncertainty and mismatch. It is expected that the model formulation will perform adequately for predicting fish impingement at cooling-water intakes if much more frequent fish-abundance observations are available; for instance, every week or every third day. It is our opinion that improvements in the means for measuring the fish abundance nondestructively and accurately are necessary if predictions are to be improved. Increased accuracy of the length-class distribution that will result in better defined probabilities is needed before we can advance the modeling formulation to improve its predictive capabilities.

4. DESCRIPTION AND DOCUMENTATION OF THE SOFTWARE SYSTEM

The Argonne Fish-Impingement Model Simulator (AFIMS) is a software package for implementing the mathematical models for predicting fish impingement at cooling water intakes. A user can select either the linear or the exponential form of the fish-density function in the models. User-supplied parameters, such as fish densities derived from trawl catches, fish-behavior characteristics, water temperatures, and water pumping rates, are necessary inputs and the choice of the model or a function sometimes depends on the data the user can provide. The modular construction of AFIMS, which provides both tabular and graphical outputs, consists of a main program, SIMULATE, and five subroutines--VOLUME, NUMBER, OUTPUT, IPLOT, and SCALE. A special purpose BLOCK DATA subroutine is also used to initialize variables and arrays. A listing of the FORTRAN source statements is given in Table 10.

The subroutine VOLUME reads in and interpolates the input data on the volume of water pumped and the water temperature recorded. The NUMBER subroutine reads in the fish-density and the length-frequency distribution data to generate probability values and daily fish-density values. Subroutine OUTPUT can then be used to print out tables of the daily fish-impingement values, and the graphical output may be generated by the subroutine IPLOT, which uses subroutine SCALE to prepare the axes for the plots.

The input card types A-J are used to fix the parameters of the model and the simulation instructions for the software system. Card types 1-3 are used to input the data on the site-specific, time-dependent, fisheries observations.

4.1 VARIABLES USED IN "COMMON" BLOCKS

There are a number of labeled COMMON blocks which are used in the software system, i.e.:

COMMON/REFER/

*ICODE(I,J): Jth species label

*LABEL(10): title of the output

*IBEG,IEND: beginning and ending days of fish-impingement simulation

@TEMP(I): temperature in °C for the Ith day.

COMMON/CALC/

FISH(I,J): fish density for the Ith day for the Jth species

FPROB(I,J): probability of impingement for the Ith day for the Jth species

VOLUM(I): volume of water used during the Ith day, given in millions of gallons
per minute and converted internally to cubic feet per second

INDX(I): Julian day of Ith observation

IDAYS(K): cumulative number of days in the year up to the Kth month

*NUM: number of species (integer values 1, 2, or 3 only)

*IYR: calendar year for which simulation is done (last two digits only)

NCL(J): number of length classes for species J (integer values 1, 2, 3,
4, 5, or 6 only)

*IFLAG(3): used to suppress selected factors in the model

If IFLAG(1) = 1, water temperature is not used to calculate probability

If IFLAG(3) = 1, fish length is not used to calculate probability

IFLAG(2) is an extra element that was used in the model validation
effort, but is no longer needed.

COMMON/LONG/

XLEN(I,J,K) = relative frequency of occurrence of length class K for species
J on day I

*YLENB(J,K): smallest length in class K for species J

*YLEND(J,K): largest length in class K for species J

COMMON/FOROUT/

IMPING(K,J): predicted impingement for the Ith day for the Jth species

FPLANT(J,L): site-specific correction factor for species J in season L

Variables flagged with an * are required input. For variables flagged
with an @, values must be provided for some observations throughout the year;

values for those days for which there are no data are then obtained by linear interpolation from values that are provided as inputs.

4.2 MAIN PROGRAM "SIMULATE"

The main program consists of 152 statements, given by card numbers 1 through 152 in Table 10. It reads the general simulation parameters. It uses VOLUME and then NUMBER to read the remaining data and to estimate the probabilities. Then it calculates the predicted impingement according to the desired model and calls OUTPUT to print the results. The main program may also use IPLOT to plot the predicted values and a scatter of the observed impingements.

4.2.1 Input to SIMULATE

- (a) ICODE (Card type A)
(10A4)

Species names (up to 8 characters long) for each of the NUM species.

- (b) LABEL (Card type B)
(10A4)

Up to 40 alphanumeric characters to be used as heading on the output tables.

- (c) NUM, ISWTCH, JFLAG, IBEG, IEND, NCL, (Card type C)
(3(I1,1X), 2(I3,1X), 3(I1,1X))

NUM specifies the number of species for which fish-impingement calculations are to be made.

ISWTCH determines the model to be used. If ISWTCH = 1, the exponential model is used; if ISWTCH = 2, the linear model is used.

JFLAG determines the plot option. If JFLAG = 2, no plotting is done. If JFLAG = 1, observed data for the entire year must be read in from logical unit 14 and are shown as a scatter of points in the plot of predicted impingement. If JFLAG = 0, no observed data are available and only a predicted impingement plot is prepared. There is a plot for each of the NUM species and one for total impingement.

- (d) (ISEAS(J,L), L=1,4), J=1,NUM) (Card type D)
(12(13,1X))

ISEAS describes the species-specific seasons. ISEAS(J,L) = the last day of season L for species J.

- (e) ((FPLANT(J,L), L = 1,4), J = 1, NUM) (Card type E)
(4(E8.2,1X))

Plant-specific seasonal correction factors for each species. One data card is required for each species.

- (f) FLEMDA (Card type F)
(6X, 3(E14.8,1X))

If the exponential model is used, FLEMDA(J) = transfer coefficient for species J.

- (g) If JFLAG = 1 then the main program reads in
(FORM(I), I = 1,10) (Card type G)
(10A4)

Format to specify the fields for observed impingement values that are read in from logical unit 14. Any of the FORTRAN-allowed REAL formats can be used.

4.2.2 Output Produced by SIMULATE

All the input data are echoed in output tables. One table is generated as outputs with extensive labels identifying the input data. Examples of this output table is Table 1 in Section 3.

4.3 SUBROUTINE "VOLUME"

VOLUME is listed as card numbers 153 through 205 in Table 10. The subroutine VOLUME is used to read in the water volume pumped and temperature data for the available observations at several time points in the year. Linear interpolation is used to generate the values for the days when observations are not available.

4.3.1 Input Required by VOLUME

MO, IDAY, VOL, TEMPER
(2I2,F8.0,F4.0)

(Card type 1)

MO = month of observation, IDAY = day of month, VOL = volume in millions of gallons per minute, TEMPER = temperature in °C.

VOLUME stops reading data when a value of 99 is read for MO. Therefore, the input stream of this data must end with a record with 99 in columns 1 and 2.

4.3.2 Output Produced by VOLUME

There is no output generated by this subroutine. The generated data on water volume pumped and water temperature are printed out by the subroutine OUTPUT.

4.4 SUBROUTINE "NUMBER"

NUMBER consists of 154 FORTRAN statements, listed as card numbers 206 through 359 in Table 10. In this subroutine, model specification parameters and data on fish abundance, fish length, and frequency distribution are read in from logical unit 5. Up to 50 data points can be provided as inputs. These data are used to generate linearly interpolated daily observations. Fish-impingement probability values are also calculated in card numbers 317-343 from the inputs to this subroutine and from values created in subroutine VOLUME.

4.4.1 Input Required by NUMBER

There is a sequence of formatted inputs that are needed data. These are described in the order of the input stream to the subroutine.

(a) TMIN(J), XLMIN(J), IMAX(J), XLMAX(J)
(4F4.0)

(Card type H)

TMIN(J) = minimum allowable temperature for species J

XLMIN(J) = minimum allowable length

TMAX(J) = maximum allowable temperature

XLMAX(J) = maximum allowable length

(b) (YLENB(J,L), L = 1, NCL(J)) (Card type I)

(6F4.0) This variable reads in the beginning length values for each of the NCL(J) classes for the Jth species.

(c) (YLEND(J,L), L = 1, NCL(J)) (Card type J)

(6F4.0) This variable reads in the ending length values for each of the NCL(J) classes of the Jth species.

For each observation:

(a) IMON, IDAY, IYR, NWIDTH, NDEPTH, NSPEED, NTIME (Card type 2)

(6I2,I3)

IMON, IDAY, IYR = date of observation, converted to IND

NWIDTH = diameter of the trawling gear in feet

NDEPTH = length of the trawling gear in feet

NSPEED = travel speed used in ft/sec.

NTIME = time duration of the trawl in seconds

(b) For each species, J

FISH(IND,J), (XLEN(IND,J,L), L = 1, NCL(J)) (Card type 3)

(F10.2,1X, 11X,6(F5.2,1X))

4.4.2 Output Produced by NUMBER

All the input data are echoed in a table labeled "Input Parameter Specification". Another table labeled "Input Data" lists the input data on the trawl catches. Tables 1-2 in Section 3 are examples of the two types of output tables.

4.5 SUBROUTINE "OUTPUT"

This subroutine is listed as card numbers 360 through 512 in Table 10. The subroutine OUTPUT prints the tables of daily predicted fish impingements

for NUM species and the total of all species. The daily fish densities and the probabilities of impingement are printed out in another set of tables. Duplicates of these results are also written out to disk files 11 and 12 for permanent storage and later use.

The output produced are tables of:

- (a) volume and temperature data for the year (printed) (Example: Table 3 in Section 3)
- (b) fish densities, estimated probabilities, volume and temperature data (unit 12)
- (c) predicted impingement (printed and written to unit 11) (Example: Table 4 in Section 3)
- (d) fish densities and estimated probabilities (printed) (Example: Table 5 in Section 3)

4.6 SUBROUTINE "IPLOT" (JFLAG, FORM)

IPLOT is given by card numbers 513 through 669 in Table 10. The subroutine IPLOT is optionally used to produce graphical outputs. The possible plots are the following:

- (a) for each species
 - (ii) estimated probability (Example: Fig. 8 in Section 3)
 - (iii) predicted impingement (Example: Fig. 5 in Section 3)
- (b) water volume pumped (Example: Fig. 2 in Section 3)
- (c) water temperature (Example: Fig. 1 in Section 3)
- (d) predicted total impingement (Example: Fig. 7 in Section 3)

If JFLAG = 1, observed impingement for every day of the year is read from unit 14 according to the format specifications stored in FORM. It is read in the order: total impingement, species 1, species 2, etc. These observed values are superimposed as a scatter on the plots of predicted impingement for each of the NUM species and the total impingement.

4.7 SUBROUTINE "SCALE" (A, M, N, X, Y)

The subroutine SCALE is used by IPLOT to set up the plot axes. It is listed as card numbers 670 through 689 in Table 10. It assigns to X the minimum of A(M) through A(N) and to Y the maximum.

4.8 SUBPROGRAM "BLOCK DATA"

The BLOCK DATA subprogram is given as card numbers 690 through 700 in Table 10. It is used to initialize some of the arrays in COMMON.

Table 10. The FORTRAN Source Listing and Input Data for the AFIMS

```

=====
CARD
NUMBER          *          FORTRAN SOURCE LISTING
=====
 1  C=====C
 2  C   THIS SOFTWARE PACKAGE WAS DEVELOPED BY ISHWAR P MURARKA,      C
 3  C   DEBORAH J. BODEAU AND TIMOTHY J. BEISSEL. FINAL VERSION      C
 4  C   WAS FINISHED IN MARCH, 1978 AT ARGONNE NAT'L LABORATORY.    C
 5  C=====C
 6  C   COMMON/FOFOUT/IMPING(365,3),FPLANT(3,4)
 7  C   COMMON/LONG/XLEN(365,3,6),YLENB(3,6),YLEND(3,6)
 8  C   COMMON/REFER/ICCODE(2,3),LABEL(10),IBEG,IEND,TEMP(365)
 9  C   COMMON/CALC/FISH(365,3),FPROB(365,3),VOLUM(365),INDX(50),
10  C   1DAYS(15),NUM,IYE,NCL(3),IFLAG(3)
11  C   DIMENSION ISEAS(3,4),FLEMDA(3),FORM(10)
12  C   DATA FLEMDA/0.,0.,0./
13  C=====C
14  C   THIS SOFTWARE SYSTEM AFIMS IS A COLLECTION OF FORTRAN SOURCE  C
15  C   STATEMENTS DEVELOPED ON AN IBM/370NCOMPUTER SYSTEM.          C
16  C   USERS CAN CALCULATE DAILY FISH IMPINGEMENTS FOR UPTO        C
17  C   THREE DIFFERENT SPECIES SIMULTANEOUSLY.                     C
18  C   DESCRIPTION OF VARIABLES                                     C
19  C   IMPING(I,J)  PREDICTED IMPINGEMENT OF SPECIES J ON DAY I    C
20  C   * FPLANT(J,K)  PLANT-SPECIFIC CORRECTION FACTOR FOR SPECIES J, C
21  C   *   FOR THE K TH SEASON.                                     C
22  C   * ISEAS(J,K)  FINAL DAY IN SEASON K, SPECIES J              C
23  C   * TEMP(I)    TEMPERATURE                                     C
24  C   * XLEN(I,J,L)  RELATIVE FREQUENCY OF LENGTH CLASS L        C
25  C   * YLEN(J,L)   AVERAGE LENGTH IN CLASS L                    C
26  C   * FISH(I,J)   OBSERVED IMPINGEMENT                          C
27  C   * FPROB(I,J)  ESTIMATED PROBABILITY                         C
28  C   * VOLUM(I)    WATER UPTAKE FOR DAY I                        C
29  C   * INDX(K)     POSTITON IN YR OF KTH OBS. FISH KILL          C
30  C   * ICODE(1,J)-(2,J)  NAME OF SPECIES J                       C
31  C   * LABEL      TITLE FOR PRINTOUT                             C
32  C   * NUM        # OF SPECIES                                    C
33  C   * NCL        # OF LENGTH CLASSES                             C
34  C   * IBEG,IEND   BEGINNING & ENDING DAYS FOR SIMULATION        C
35  C   * ISWITCH     MODEL TO BE USED                               C
36  C   *   1=EXPONENTIAL FORM OF FISH DENSITY                      C
37  C   *   2=LINEAR FORM OF FISH DENSITY                           C
38  C   * JFLAG      PLOT OPTION                                     C
39  C   *   IF JFLAG=2, NO PLOTTING (FT14FC01 & GRAPHICS DUMMY)      C
40  C   *   IF JFLAG=1, PLOT PREDICTED & OBSERVED DATA              C
41  C   *   IF JFLAG=0, PLOT PREDICTED DATA ONLY (FT14FO01 DUMMY)   C
42  C   *                                                     C
43  C   VARIABLES FLAGGED WITH * ARE READ FROM LOGICAL UNIT 5        C
44  C   C
45  C   C OUTPUT
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
46      C LOGICAL UNIT 6 C
47      C (NUMBER) ECHO CF INPUT VALUES C
48      C (NUMBER) AVG. LENGTH,DENSITY DISTRIBUTION (INTERPOLATED) C
49      C (MAIN) PREDICTED IMPINGEMENT C
50      C (MAIN) OBSERVED (INTERPOLATED) & PROBABILITY VALUES C
51      C LOGICAL UNIT 11 * W/OUT PAGE HEADINGS C
52      C LOGICAL UNIT 12 FISH DENSITY, PROBABILITIES, VOLUME, TEMPERATURE C
53      C C
54      C=====C
55      C READ THE SPECIES NAMES & TABLE HEADINGS C
56      C SPECIES NAMES MAY NOT BE OVER 8 CHARACTERS IN LENGTH C
57      C=====C
58      READ(5,250) ICODE
59      READ(5,250) LABE
60      C=====C
61      C READ IN THE PARAMETERS FOR SELECTING NUMBER OF SPECIES, FISH C
62      C DENSITY MODEL FORM, # OF LENGTH CLASSES,BEGINNING AND ENDING C
63      C DATES,THE PLANT SPECIFIC SEASONAL CORRECTION FACTORS,AND C
64      C GRAPHICS OUTPUT OPTIONS. C
65      C=====C
66      READ(5,260) NUM,ISWCH,JFLAG,IBEG,IEND,(NCL(I),I=1,NUM)
67      READ(5,265) ((ISEAS(I,J),J=1,4),I=1,NUM)
68      READ(5,270) ((FPLANT(I,J),J=1,4),I=1,NUM)
69      READ(5,280) IFLAG,(FLEMDA(I),I=1,NUM)
70      IF(JFLAG.EQ.1) READ(5,250) FORM
71      C=====C
72      C WRITE OUT THE INPUT PARAMETERS IN TABULAR FORM C
73      C=====C
74      WRITE(6,220) LABE
75      WRITE(6,230) NUM,NCL,IBEG,IEND
76      WRITE(6,235) IFLAG,((ICODE(J,I),J=1,2),FLEMDA(I),I=1,NUM)
77      WRITE(6,240) ((ICODE(J,I),J=1,2),(ISEAS(I,J),J=1,4),
78      1 (FPLANT(I,J),J=1,4),I=1,NUM)
79      C=====C
80      C USE SUBROUTINE VOLUME TO READ,CONVERT, AND INTERPOLATE DAILY C
81      C WATER PUMPING RATES AND WATER TEMPERATURES NEAR INTAKES. C
82      C=====C
83      CALL VOLUME
84      C=====C
85      C USE SUBROUTINE NUMBER TO READ FISH DENSITY AND LENGTH FREQUENCY C
86      C DATA, AND TO CALCULATE PROBABILITIES OF IMPINGEMENTS. CONVERT AND C
87      C INTERPOLATE TO DAILY FISH DENSITIES. C
88      C=====C
89      CALL NUMBER
90      C=====C
=====

```


Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
 91  C SELECT AND USE 1) LINEAR OR 2) EXPONENTIAL FISH DENSITY FUNCTION      C
 92  C AS THE MATHEMATICAL MODEL FOR COMPUTATIONS OF THE DAILY FISH          C
 93  C IMPINGEMENTS FOR EACH OF THE SPECIES.                                C
 94  C=====C
 95      GO TO (30,60),ISWICH
 96  C=====C
 97  C   EXPONENTIAL MODEL WITH FLEMDA AND FPLANT FACTORS USED                C
 98  C=====C
 99      30 DO 50 I=IBEG,IEND
100      DO 50 J=1,NUM
101      K=4
102  C=====C
103  C   LOCATE SEASON FOR THE CORRECTION FACTOR                              C
104  C=====C
105      DO 40 L=1,3
106      M=4-L
107      IF (I.LE.ISEAS(J,M)) K=M
108      40 CONTINUE
109      IMPING(I,J)=EXP(FLEMDA(J)*FISH(I,J))*VOLUM(I)*FPROB(I,J)*FPLANT(J,
110      1K)+0.5
111      IF (FISH(I,J).EQ.0.) IMPING(I,J)=0
112      50 CONTINUE
113      GO TO 90
114  C=====C
115  C   LINEAR MODEL WITH FPLANT FACTOR USED                                  C
116  C=====C
117      60 DO 80 I=IEEG,IEND
118      DO 80 J=1,NUM
119      K=4
120      DO 70 L=1,3
121      M=4-L
122      IF (I.LE.ISEAS(J,M)) K=M
123      70 CONTINUE
124      IMPING(I,J)=FPLANT(J,K)*FISH(I,J)*FPROB(I,J)*VOLUM(I)+0.5
125      80 CONTINUE
126      90 CONTINUE
127  C=====C
128  C   USE SUBROUTINE OUTPUT TO PRINT OUT THE COMPUTED FISH IMPINGE-        C
129  C   MENT VALUES, THE DAILY FISH DENSITIES,TEMPERATURE, FLOW, DAILY      C
130  C   PROBABILITIES                                                          C
131  C=====C
132      CALL OUTPUT
133  C=====C
134  C   DETERMINE IF GRAPHICAL OUTPUT IS DESIRED AND THEN USE THE              C
135  C   SUBROUTINE IPLOT TO PLOT IMPINGEMENTS, FISH DENSITIES,                C
=====

```

Table 10. Continued

```

=====
CAPD
NUMBER          FORTRAN SOURCE LISTING
=====
136      C PROBABILITY, VOLUME, AND TEMPERATURE.                      C
137      C=====C
138          IF (JFLAG.NE.2) CALL IPLOT(JFLAG,FORM)
139          STOP
140          220 FORMAT(1H1//,18X,'INPUT PARAMETER SPECIFICATIONS',13X,10A4//)
141          230 FORMAT(' # OF SPECIES      # OF LENGTH CLASSES    BEGINNING ',
142          1'ENDING',/,47X,'DAY',7X,'DAY'/8X,I1,9X,3(5X,I1),11X,I3,8X,I3)
143          235 FORMAT(/,80X,' FLAG VALUES ',3I3/,24X,' TRANSFER COEFFICIENT',
144          @ 3(/11X,2A4,5X,E'4.4))
145          240 FORMAT(/'          SEASON END DAYS',10X,'SEASONAL CORRECTION FACT
146          1ORS'/3(/1X,2A4,1X,4I4,2X,4(E8.2,2X)))
147          250 FORMAT(10A4)
148          260 FORMAT(3(I1,1X),2(I3,1X),3(I1,1X))
149          265 FORMAT(12(I3,1X))
150          270 FORMAT(4(E8.2,1X))
151          280 FORMAT(3(I',1X,3(=14.8,1X))
152          END
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
153              SUBROUTINE VOLUME
154      C=====C
155      C READ OBSERVED VOLUME & TEMPERATURE DATA AND INTERPOLATE BETWEEN      C
156      C ADJACENT VALUES TO GENERATE THE MISSING VALUES.                      C
157      C=====C
158              COMMON/CALC/FLSH(365,3),FPROP(365,3),VOLUM(365),INDX(50),
159              1IDAYS(13),NUM,IYR,NCL(3),IFLAG(3)
160              COMMON/LCNG/XLEN(365,3,6),YLENB(3,6),YLEND(3,6)
161              COMMON/REFER/ICCODE(2,3),LABLE(10),IBEG,IEND,TEMP(365)
162              IC=1
163      C=====C
164      C  READ MONTH, DAY, VOLUME, AND TEMPERATURE.  CONVERT VOLUME FROM      C
165      C  MILLION GALLONS PER MINUTE TO CUBIC FEET PER SECOND                  C
166      C=====C
167      10 READ (5,80) MO,IDAY,VOL,TEMPER
168      IF (MO.EQ.99) GO TO 50
169      JEND=IDAY+IDAYS(MC)
170      VOL=VOL/448.6
171      IF (JEND.GT.365) JEND=365
172      IF (IC.GT.1) GO TO 30
173      C=====C
174      C  FILL IN FROM BEGINNING OF YEAR TO 1ST OBSERVATION.                  C
175      C=====C
176      DO 20 I=1,JEND
177      VOLUM(I)=VOL
178      20 TEMP(I)=TEMPER
179      IC=JEND
180      V1=VOL
181      T1=TEMPER
182      GO TO 10
183      C=====C
184      C  LINEARLY INTERPOLATE BETWEEN ADJACENT OBSERVATIONS.                  C
185      C=====C
186      30 IDEL=JEND-IC
187      I=IC+1
188      DO 40 I=L,JEND
189      ALPHA=FLOAT(I-IC)/FLOAT(IDEL)
190      VOLUM(I)=(1.-ALPHA)*V1+ALPHA*VOL
191      40 TEMP(I)=(1.-ALPHA)*T1+ALPHA*TEMPER
192      V1=VOL
193      T1=TEMPER
194      IC=JEND
195      GO TO 10
196      50 IF (IC.GE.365) RETURN
197      C=====C
=====

```

Table 10. Continued

```

=====
CARD
NUMBER                                FORTFAN SOURCE LISTING
=====
198      C   FILL IN FROM LAST CES. TO END OF YEAR                                C
199      C=====C
200          DC 50 I=IC,365
201          VOLJM(I)=V1
202          60 TEMP(I)=T1
203          FETJRN
204          80 FCR1AT(2I2,F8.0,F4.0)
205          END
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTTRAN SOURCE LISTING
=====
206              SUBROUTINE NUMBER
207      C=====C
208      C  READ MODEL SPECIFICATIONS AND DATA ON FISH ABUNDANCE, FISH      C
209      C  LENGTH, AND FREQUENCY DISTRIBUTION. INTERPOLATE AND CALCULATE      C
210      C  FISH IMPINGEMENT PROBABILITY                                     C
211      C=====C
212              COMMON/REFER/ICODE(2,3),LABEL(10),IBEG,IEND,TEMP(365)
213              COMMON/LONG/XLEN(365,3,6),YLENB(3,6),YLEND(3,6)
214              DIMENSION TMIN(3),XLMIN(3),TMAX(3),XLMAX(3)
215              COMMON/CALC/FISH(365,3),FPROB(365,3),VOLUM(365),INDX(50),
216              1IDAYS(13),NUM,IYR,NCL(3),IFLAG(3)
217      C=====C
218      C  READ MINIMUM AND MAXIMUM OF TEMPERATURE AND LENGTH CLASSES.      C
219      C=====C
220              DO 10 I=1,NUM
221              WRITE(6,120)
222              NNCL=NCL(I)
223              READ(5,130) TMIN(I),XLMIN(I),TMAX(I),XLMAX(I)
224              READ(5,220) (YLENB(I,J),J=1,NNCL)
225              READ(5,220) (YLEND(I,J),J=1,NNCL)
226      C =====C
227      C  WRITE OUT THE INPUT PARAMETERS IN A TABULAR FORM.                  C
228      C =====C
229              WRITE(6,140) (ICODE(J,I),J=1,2),TMIN(I),XLMIN(I)
230              WRITE(6,170) TMAX(I),XLMAX(I)
231              WRITE(6,150) (J,J=1,NNCL)
232              WRITE(6,155)
233              WRITE(6,160) (YLENB(I,J),J=1,NNCL)
234              WRITE(6,165) (YLEND(I,J),J=1,NNCL)
235              10 CONTINUE
236              WRITE(6,180) LABEL
237      C=====C
238      C  READ THE DAILY DATA FOR THE FISH ABUNDANCE MEASUREMENTS          C
239      C=====C
240              DC 20 I=1,50
241              READ(5,190,END=30) IMON,IDAY,IYR,NWIDTH,NDEPTH,NSPEED,NTIME
242              TVOLUM=NWIDTH*NDEPTH*NSPEED*NTIME
243              INDX(I)=IDAYS(IMON)+IDAY
244              IND=INDX(I)
245              DO 20 J=1,NUM
246              NNCL=NCL(J)
247              READ(5,200) FISH(IND,J),(XLEN(IND,J,L),L=1,NNCL)
248      C =====C
249      C  WRITE OUT THE INPUT DATA ON CATCH AND FISH LENGTHS.              C
250      C =====C
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
251      WRITE (6,210) (ICODE(IP,J),IF=1,2),IMON,IDAY,IYR,FISH(IND,J),
252      1      (XLEN(IND,J,L),L=1,NNCL)
253      FISH(IND,J)=FISH(IND,J)*432./TVOLUM
254      20 CONTINUE
255      I=51
256      30 NOBS=I-2
257      C=====C
258      C PERFORM LINEAR INTERPOLATION C
259      C=====C
260      IF (INDX(1).LE.1) GO TO 50
261      C=====C
262      C FILL FROM BEGINNING OF YEAR TO 1ST OBS. C
263      C=====C
264      IDIF=INDX(1)-1
265      DO 40 KL=1,IDIF
266      DO 40 KK=1,NUM
267      FISH(KL,KK)=FISH(INDX(1),KK)
268      NNCL=NCL(KK)
269      DO 40 KJ=1,NNCL
270      XLEN(KL,KK,KJ)=XLEN(INDX(1),KK,KJ)
271      40 CONTINUE
272      50 NN=NOBS+1
273      IF (INDX(NN).GE.365) GO TO 70
274      C=====C
275      C FILL FROM FINAL OBSERVATION TO END OF THE YEAR C
276      C=====C
277      IDIF=365-INDX(NN)
278      DO 60 KL=1,IDIF
279      KLNN=KL+INDX(NN)
280      DO 60 KK=1,NUM
281      FISH(KLNN,KK)=FISH(INDX(NN),KK)
282      NNCL=NCL(KK)
283      DO 60 KJ=1,NNCL
284      XLEN(KLNN,KK,KJ)=XLEN(INDX(NN),KK,KJ)
285      60 CONTINUE
286      70 CONTINUE
287      C=====C
288      C INTERPOLATE BETWEEN ADJACENT OBSERVATIONS. C
289      C=====C
290      DO 90 K=1,NOBS
291      NK=K+1
292      IDIF=INDX(NK)-INDX(K)
293      IF (IDIF.LE.1) GO TO 90
294      DO 80 KL=1,IDIF
295      L=INDX(K)
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
296             M=INDX(NK)
297             FAT=FLOAT(KL)/FLOAT(IDIF)
298             KLK=KL+INDX(K)
299             DO 80 JJ=1,NUM
300             FISH(KLK,JJ)=FISH(L,JJ)+RAT*(FISH(M,JJ)-FISH(L,JJ))
301             NNCL=NCL(JJ)
302             DO 80 KJ=1,NNCL
303             XLEN(KLK,JJ,KJ)=XLEN(L,JJ,KJ)+RAT*(XLEN(M,JJ,KJ)-XLEN(L,JJ,KJ))
304             80 CONTINUE
305             90 CONTINUE
306             C=====C
307             C  INSURE THAT OBSERVED LENGTHS ARE WITHIN THE SPECIFIED LIMITS      C
308             C=====C
309             DO 95 LL=1,NUM
310             NNCL=NCL(LL)
311             DO 95 L=1,NNCL
312             IF (YLENB(LL,L).LT.XLMIN(LL)) YLENB(LL,L)=XLMIN(LL)
313             IF (YLEND(LL,L).LT.XLMIN(LL)) YLEND(LL,L)=XLMIN(LL)
314             IF (YLENB(LL,L).GT.XLMAX(LL)) YLEND(LL,L)=XLMAX(LL)
315             IF (YLENB(LL,L).GT.XLMAX(LL)) YLENB(LL,L)=XLMAX(LL)
316             95 CONTINUE
317             DO 110 LI=1,NUM
318             NNCL=NCL(LL)
319             TDEL=TMAX(LL)-TMIN(LL)
320             XLDEL=XLMAX(LL)-XLMIN(LL)
321             C=====C
322             C  INSURE THAT TEMPERATURE IS WITHIN SPECIFIED LIMITS      C
323             C=====C
324             DO 110 L=1,365
325             IF (TEMP(L).LT.TMIN(LL)) TEMP(L)=TMIN(LL)
326             IF (TEMP(L).GT.TMAX(LL)) TEMP(L)=TMAX(LL)
327             TAU=(TEMP(L)-TMIN(LL))/TDEL
328             XLAV=0.
329             SUM=0.0
330             C=====C
331             C  CALCULATE CONTRIBUTION OF LENGTH TO PROBABILITY FROM THE RELATIVE C
332             C  FREQUENCY DISTRIBUTION IN LENGTH CLASSES & CLASS SIZES      C
333             C=====C
334             DO 100 I=1,NNCL
335             XLAV=XLAV+((YLEND(LL,I)-YLENB(LL,I))/XLDEL)*XLEN(L,LL,I)
336             100 CONTINUE
337             IF (IFLAG(1).EQ.1) TAU=0.
338             IF (IFLAG(3).EQ.1) XLAV=0.
339             C=====C
340             C  NOW CALCULATE PROBABILITIES FOR EACH SPECIES.      C
=====

```

Table 10. Continued

```

=====
CARD.
NUMBER          FORTRAN SOURCE LISTING
=====
341      C =====C
342          FPROB(L,LL)=TAU*XI*AV-TAU*XL*AV
343      110 CONTINUE
344          RETURN
345      120 FORMAT(/1H,26X,'TEMPERATURE',4X,'AVE. LENGTH')
346      130 FORMAT(4F4.0)
347      140 FORMAT(/1X,2A4,6X,'MINIMUM',4X,4(F11.3,4X))
348      150 FORMAT(/27X,'LENGTH CLASS BOUNDARIES' /11X,6(I5,4X))
349      155 FORMAT(1H )
350      160 FORMAT(' BEGINNING ',6(F9.2,1X))
351      165 FORMAT(' ENDING',4X,6(F9.2,1X))
352      170 FORMAT(15X,'MAXIMUM',4X,4(F11.2,4X) /)
353      180 FORMAT(1H1,37X,'INPUT DATA' /25X,10A4//2X,'SPECIES',4X,'DATA',4X,
354          2'CATCH',4X,'LENGTH-RELATIVE FREQUENCY DISTRIBUTION' /)
355      190 FORMAT(6I2,I3)
356      200 FORMAT(F10.2,23X,6(F5.2,1X))
357      210 FORMAT(2X,2A4,1X,2(I2,'/' ,I2,1X,F7.2,4X,6(F5.2,1X))
358      220 FORMAT(6F4.0)
359          END
=====

```


Table 10. Continued

```

=====
CAED
NUMBER          FORTRAN SOURCE LISTING
=====
360      SUBROUTINE OUTPUT
361      C=====C
362      C  OUTPUT PRINTS THE RESULTS OF THE COMPUTATIONS. 3 TABLES ARE PRODUCED
363      C    1. TEMPERATURE AND VOLUME
364      C    2. CALCULATED IMPINGEMENT
365      C    3. FISH DENSITY AND PROBABILITY
366      C
367      C  OUIPUT ALSO WRITES TEMPERATURE, VOLUME, FISH DENSITY, AND
368      C    PROBABILITY TO UNIT 12, AND IMPINGEMENT TO UNIT 11
369      C=====C
370      COMMON/FOROUT/IMPING(365,3),FPLANT(3,4)
371      COMMON/LONG/XLEN(365,3,6),YLENB(3,6),YIFND(3,6)
372      COMMON/REFEP/ICODE(2,3),LABEL(10),IBEG,IEND,TEMP(365)
373      COMMON/CALC/FISH(365,3),FPROB(365,3),VOLUM(365),INDX(50),
374      1DAYS(13),NUM,IYR,NCL(3),IFLAG(3)
375      NLINE=53
376      M=(IEND-IBEG+1)/2
377      I1=IBEG
378      C=====C
379      C TABLE 1: WRITE OUT DAILY TEMPERATURE AND VOLUME TABLES
380      C=====C
381      DO 100 I=1,M
382      I2=I1+1
383      IF(NLINE.LE.52) GO TO 105
384      WRITE(6,270) LABEL
385      NLINE=9
386      105 PRINT 280, (J,VOLUM(J),TEMP(J),J=I1,I2)
387      NLINE=NLINE+1
388      I1=I1+2
389      100 CONTINUE
390      IF(I1.LE.IEND) PRINT 280, (J,VOLUM(J),TEMP(J),J=I1,IEND)
391      NLINE=53
392      IPAGE=0
393      ITUT=0
394      C=====C
395      C TABLE 2: WRITE OUT PREDICTED DAILY IMPINGEMENT TABLES.
396      C ALSO WRITE THE INFORMATION TO UNITS 11 AND 12 TO BE SAVED
397      C AS DISK FILES.
398      C=====C
399      DO 150 I=IBEG,IEND
400      WRITE (12,260) I, (FISH(I,J),J=1,NUM), (FPROB(I,J),J=1,NUM), VOLUM(I)
401      1, (TEMP(I),J=1,NUM)
402      IF (NLINE.LE.52) GO TO 110
403      IPAGE=IPAGE+1
404      WRITE (6,290) IPAGE,LABEL,ICODE
=====

```

Table 10. Continued

```

=====
CARD
NUMBER                                FORTRAN SOURCE LISTING
=====
405      NLINE=11
406      110 ITOT=0
407      C=====C
408      C  CALCULATE DATE FROM DAY OF THE YEAR FOR PRINTING OF THE      C
409      C  PREDICTED IMPINGEMENTS TABLES.                             C
410      C=====C
411      DO 120 JU=2,13
412      IF (I.LE.IDAYS(JU)) GO TO 130
413      120 CONTINUE
414      130 JQ=JE-1
415      IDAY=I-IDAYS(JQ)
416      DO 140 J=1,NUM
417      ITOT=ITCT+IMPING(I,J)
418      140 CONTINUE
419      ITUT=ITUT+ITOT
420      IF (NUM.EQ.1) WRITE (6,300) JQ,IDAY,IYR,IMPING(I,1),ITOT,ITUT
421      IF (NUM.EQ.2) WRITE (6,310) JQ,IDAY,IYR,(IMPING(I,K),K=1,2),ITOT,I
422      ITUT
423      IF (NUM.EQ.3) WRITE (6,320) JQ,IDAY,IYR,(IMPING(I,K),K=1,3),ITOT,I
424      ITUT
425      WRITE (11,330) I,ITOT,(IMPING(I,K),K=1,NUM)
426      NLINE=NLINE+1
427      150 CONTINUE
428      C=====C
429      C  TABLE 3: PRINT OUT THE TABLES OF DAILY FISH DENSITIES AND THE      C
430      C  PROBABILITIES.                                                 C
431      C=====C
432      PRINT 340
433      GO TO (160,180,200),NUM
434      C=====C
435      C  ONE SPECIES IMPINGEMENTS PRINTED                               C
436      C=====C
437      160 NLINE =53
438      M=(IEND-IBEG+1)/5
439      I1=IBEG
440      DO 170 K=1,M
441      I2=I1+4
442      IF(NLINE.LE.52) GO TO 165
443      WRITE(6,350) LABEL, ((ICODE(I,1),I=1,2),J=1,5)
444      NLINE=7
445      165 WRITE (6,380) (J,FISH(J,1),FPROB(J,1),J=I1,I2)
446      NLINE=NLINE+1
447      170 I1=I1+5
448      IF (I1.LE.IEND) WRITE (6,380) (J,FISH(J,1),FPROB(J,1),J=I1,IEND)
449      RETURN
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
450 C=====C
451 C          TWO SPECIES IMPINGEMENTS PRINTED          C
452 C=====C
453      180 NLINE=53
454          M=(IEND-IEEG+1)/3
455          I1=IBEG
456          DO 190 K=1,M
457              I2=I1+2
458              IF(NLINE.LE.52) GO TO 185
459              WRITE(6,370) LABEL,((ICODE(I,J),I=1,2),J=1,2),
460              @ ((ICODE(I,J),I=1,2),J=1,2),((ICODE(I,J),I=1,2),J=1,2)
461              NLINE=7
462      185 WRITE (6,400) (J,FISH(J,1),PFROR(J,1),FISH(J,2),PPROB(J,2),J=I1,I2
463              1)
464              I1=I1+3
465              NLINE=NLINE+1
466      190 CONTINUE
467          IF (I1.LE.IEND) WRITE (6,400) (J,FISH(J,1),PFROR(J,1),FISH(J,2),FP
468          1ROB(J,2),J=I1,IEND)
469          RETURN
470 C=====C
471 C          THREE SPECIES IMPINGEMENTS PRINTED          C
472 C=====C
473      200 NLINE=53
474          M=(IEND-IBEG+1)/2
475          I1=IBEG
476          DO 210 K=1,M
477              I2=I1+1
478              IF(NLINE.LE.52) GO TO 205
479              WRITE(6,410) LABEL,((ICODE(I,J),I=1,2),J=1,3),
480              @ ((ICODE(I,J),I=1,2),J=1,3)
481              NLINE=7
482      205 WRITE (6,430) (J,(FISH(J,K),PFROR(J,K),K=1,3),J=I1,I2)
483              I1=I1+2
484              NLINE=NLINE+1
485      210 CONTINUE
486          IF (I1.LE.IEND) WRITE (6,430) (J,(FISH(J,K),PFROR(J,K),K=1,3),J=I1
487          1,IEND)
488          RETURN
489 C
490      250 FORMAT(10A4)
491      260 FORMAT(I3,10E14.8)
492      270 FORMAT(1H1/11X,10A4//2(4X,'DAY',2X,'VOLUME',2X,'TEMPERATURE',2X),
493      1 /2(10X,'(CFS)',5X,'(C)',7X)/)
494      280 FORMAT(4X,I3,2(1X,F8.2),9X,I3,2(1X,F8.2))
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
495      290 FORMAT(1H1///11X,'PREDICTED DAILY FISH IMPINGEMENT',
496          110X,'PAGE ',I2/11X,10A4//18X,'FISH SPECIES',13X,'TOTAL',4X,
497          2'CUMULATIVE'/3X,'DATE',3X,3(2A4,2X),1X,'IMPINGMENT',4X,'TOTAL'/)
498      300 FORMAT(1X,2(I2,'/'),I2,1X,I7,25X,I8,2X,I10)
499      310 FORMAT(1X,2(I2,'/'),I2,1X,I7,3X,I7,15X,I8,2X,I10)
500      320 FORMAT(1X,2(I2,'/'),I2,1X,I7,2(3X,I7),5X,I8,2X,I10)
501      330 FORMAT(1X,I3,4(I8,2X))
502      340 FORMAT(1H1)
503      350 FCRMAT(1H1/46X,10A4//12X,4(2A4,17X),2A4,
504          @5('OBS. DENS. PROB.')/)
505      380 FORMAT(1X,5(6X,I3,2X,F7.2,2X,F5.2))
506      370 FORMAT(1H1/46X,10A4//2(12X,2A4),2(14X,2A4,12X,2A4)/
507          @3('OBS. DENS. PROB. DENS. PROB.'))
508      400 FORMAT(1X,3(6X,I3,2X,F7.2,2X,F5.2,3X,F7.2,2X,F5.2))
509      410 FORMAT(1H1/46X,10A4//3(12X,2A4),14X,2(2A4,12X),2A4/
510          ,2('OBS. DENS. PROB. DENS. PROB. DENS. PROB.'))
511      430 FORMAT(1X,2(6X,I3,2X,F7.2,2X,F5.2,2(3X,F7.2,2X,F5.2)))
512      .END
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
513      SUBROUTINE IPLOT(JFLAG,FORM)
514      COMMON/FORGUT/IMPING(365,3),FPLANT(3,4)
515      COMMON/LONG/XLEN(365,3,6),YLENF(3,6),YLEND(3,6)
516      COMMON/REFER/ICODE(2,3),LABLE(10),IBEG,IEND,TEMP(365)
517      COMMON/CALC/FISH(365,3),FPROP(365,3),VOLUM(365),INDX(50),
518      1IDAYS(13),NUM,IYE,NCL(3),IFLAG(3)
519      C=====C
520      C   PLCT RESULTS:                                C
521      C   (1) FOR EACH SPECIES:                        C
522      C       A. FISH DENSITY                          C
523      C       B. ESTIMATED PROBABILITY                 C
524      C       C. PREDICTED IMPINGEMENT                 C
525      C   (2) VOLUME                                    C
526      C   (3) TEMPERATURE                              C
527      C   (4) TOTAL IMPINGEMENT                       C
528      C                                                C
529      C   IF JFLAG=1, READ OESERVED DATA FOR THE FULL YEAR FROM
530      C   LOGICAL UNIT 14                              C
531      C=====C
532      C   DIMENSION X(365),Y(365),Z(365,4),ZZ(365),JHEAD(5),FORM(10)
533      C   DATA IDOL,IBL/'$ ',' '/
534      C   DO 10 I=1,365
535      C   10 X(I)=I
536      C   IF(JFLAG.NE.1)GO TO 30
537      C=====C
538      C   READ OBSERVED DATA FOR FULL YEAR, IF AVAILABLE
539      C=====C
540      C   I=NUM+1
541      C   DC 20 I=1,365
542      C   20 READ(14,FORM) (Z(I,J),J=1,4)
543      C=====C
544      C   INITIALIZE PLOTTER
545      C=====C
546      C   30 CALL STRTPL
547      C=====C
548      C   FOR EACH SPECIES:
549      C=====C
550      C   DO 90 I=1,NUM
551      C   DO 40 J=1,365
552      C   40 Y(J)=FISH(J,I)
553      C   CALL SCALE(Y,1,365,YMIN,YMAX)
554      C   YDEL=(YMAX-YMIN)/5.
555      C   CALL BGNFL(0)
556      C=====C
557      C   FISH DENSITY VS DAY OF THE YEAR
558      C=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
558      C=====C
559          CALL TITLE(' ', -1, 'DAY OF THE YEARS$', 100, 'DENSITY$', 100, 7., 5.)
560          JHEAD(1)=IBL
561          JHEAD(2)=ICODE(1,I)
562          JHEAD(3)=ICODE(2,I)
563          JHEAD(4)=IDOL
564          JHEAD(5)=IEL
565          CALL HEADIN(' FISH DENSITY$', 100, 2, 2)
566          CALL HEADIN(JHEAD, 100, 2, 2)
567          CALL XINTAX
568          CALL GRAF(1., 52., 365., YMIN, YDEL, YMAX)
569          CALL CURVE(X, Y, 365, 0)
570          CALL ENDPL(0)
571          DO 50 J=1, 365
572          50 Y(J)=FPROB(J,I)
573      C=====C
574      C ESTIMATED PROBABILITY VS DAY OF THE YEAR C
575      C=====C
576          CALL BGNPL(1)
577          CALL TITLE(' ', -1, 'DAY OF THE YEARS$', 100, 'PROBABILITY$', 100, 7., 5.)
578          CALL XINTAX
579          CALL GRAF(1., 52., 365., 0., .2, 1.)
580          JHEAD(2)=IBL
581          JHEAD(3)=ICODE(1,I)
582          JHEAD(4)=ICODE(2,I)
583          JHEAD(5)=IDOL
584          CALL HEADIN(' ESTIMATED PROBABILITY$', 100, 2, 2)
585          CALL HEADIN(JHEAD, 100, 2, 2)
586          CALL CURVE(X, Y, 365, 0)
587          CALL ENDPL(1)
588          DO 60 J=1, 365
589          60 Y(J)=IMPING(J,I)
590      C=====C
591      C PREDICTED IMPINGEMENT VS DAY OF THE YEAR C
592      C=====C
593          CALL BGNPL(2)
594          CALL SCALE(Y, 1, 365, YMIN, YMAX)
595          IF (JFLAG.NE.1) GO TO 80
596      C=====C
597      C USE OBSERVED DATA IF AVAILABLE FOR SCATTER C
598      C=====C
599          M=I+1
600          DO 70 J=1, 365
601          70 ZZ(J)=Z(J,M)
602          CALL SCALE(ZZ, 1, 365, ZMIN, ZMAX)
=====

```

Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
603             IF(ZMIN.LT.YMIN) YMIN=ZMIN
604             IF(ZMAX.GT.YMAX) YMAX=ZMAX
605             80 YDEL=(YMAX-YMIN)/5.
606             CALL TITLE(' ', -1, 'DAY OF THE YEARS$', 100, 'NUMBER OF FISH$', 100, 7.,
607             @ 5.)
608             CALL XINTAX
609             CALL GRAF(1., 52., 365., YMIN, YDEL, YMAX)
610             CALL HEADIN('      PREDICTED IMPINGEMENTS$', 100, 2, 2)
611             CALL HEADIN(JHEAD, 100, 2, 2)
612             CALL CURVE(X, Y, 365, 0)
613             IF(JFLAG.EQ.1) CALL CURVE(X, ZZ, 365, -1)
614             CALL ENDPL(2)
615             90 CONTINUE
616             C=====C
617             C  VOLUME OF WATER PUMPED VS DAY OF THE YEAR  C
618             C=====C
619             CALL BGNPL(3)
620             CALL SCALE(VOLUM, 1, 365, YMIN, YMAX)
621             YDEL=(YMAX-YMIN)/5.
622             CALL XINTAX
623             CALL TITLE('VOLUME$', -6, 'DAY OF THE YEARS$', 100, 'VOLUME', 6, 7., 5.)
624             CALL GRAF(1., 52., 365., YMIN, YDEL, YMAX)
625             CALL CURVE(X, VOLUM, 365, 0)
626             CALL ENDPL(3)
627             C=====C
628             C  TEMPERATURE VS DAY OF THE YEAR  C
629             C=====C
630             CALL BGNPL(4)
631             CALL SCALE(TEMP, 1, 365, YMIN, YMAX)
632             YDEL=(YMAX-YMIN)/5.
633             CALL XINTAX
634             CALL TITLE('TEMPERATURE$', -100, 'DAY OF THE YEARS$', 100,
635             @ 'TEMPERATURE$', 100, 7., 5.)
636             CALL GRAF(1., 52., 365., YMIN, YDEL, YMAX)
637             CALL CURVE(X, TEMP, 365, 0)
638             CALL ENDPL(4)
639             C=====C
640             C  TOTAL IMPINGEMENT VS DAY OF THE YEAR  C
641             C=====C
642             CALL BGNPL(5)
643             CALL TITLE('TOTAL IMPINGEMENT$', -100, 'DAY OF THE YEARS$', 100,
644             [ 'NUMBER OF FISH$', 100, 7., 5.)
645             DO 100 J=1, 365
646             Y(J)=0.
647             DO 100 I=1, NUM
=====

```

Table 10. Continued

```

=====
CARD
NUMBER                                FORTRAN SOURCE LISTING
=====
648      100 Y(J)=Y(J)+IMPING(J,I)
649          CALL SCALE(Y,1,365,YMIN,YMAX)
650          IF (JFLAG.NE.1) GO TO 120
651      C=====C
652      C    USF OBSERVED DATA, IF AVAILABLE, FOR SCATTER      C
653      C=====C
654          DO 110 J=1,365
655      110 ZZ(J)=Z(J,1)
656          CALL SCALE(ZZ,1,365,ZMIN,ZMAX)
657          IF (ZMIN.LT.YMIN) YMIN=ZMIN
658          IF (ZMAX.GT.YMAX) YMAX=ZMAX
659      120 YDEL=(YMAX-YMIN)/5.
660          CALL GRAF(1.,52.,365.,YMIN,YDEL,YMAX)
661          CALL CURVE(X,Y,365,0)
662          IF (JFLAG.EQ.1) CALL CURVE(X,ZZ,365,-1)
663          CALL ENDPL(5)
664      C=====C
665      C    CLOSE PLOTFILE      C
666      C=====C
667          CALL DONEPL
668          RETURN
669          END
=====

```


Table 10. Continued

```

=====
CARD
NUMBER          FORTRAN SOURCE LISTING
=====
670              SUBROUTINE SCALE(A,M,N,X,Y)
671              C=====C
672              C  SET X=MINIMUM OF A(M) THROUGH A(N)          C
673              C  SET Y=MAXIMUM OF A(M) THROUGH A(N)          C
674              C=====C
675              DIMENSION A(365)
676              IF(M.LE.0.CR.N.LI.M)GO TO 20
677              X=A(M)
678              Y=X
679              DO 10 I=M,N
680              IF(A(I).LI.X)X=A(I)
681              IF(A(I).GT.Y)Y=A(I)
682              10 CONTINUE
683              RETURN
684              20 WRITE(6,1001)M,N
685              1001 FORMAT(' INVALID INPUT TO SCALE. M=',I3,' N=',I3)
686              X=A(1)
687              Y=X
688              RETURN
689              END
=====

```

Table 10. Continued

```
=====
CARD
NUMBER                      DATA LISTING
=====
690      BLOCK DATA
691      COMMON/FCROUT/IMPING(365,3),FPLANT(3,4)
692      COMMON/LONG/XLEN(365,3,6),YLENB(3,6),YLEND(3,6)
693      COMMON/REFER/ICODE(2,3),LABLE(10),IBEG,IEND,TEMP(365)
694      COMMON/CALC/FISH(365,3),FPROB(365,3),VOLUM(365),INDX(50),
695      1IDAYS(13),NUM,IYR,NCL(3),IFLAG(3)
696      DATA IDAYS/0,31,59,90,120,151,181,212,243,273,304,334,365/
697      DATA NCL,INDX/53*0/
698      DATA TEMP,VOLUM,FISH,FPROB/2920*0./
699      DATA IMPING/1095*0/
700      END
=====
```

Table 10. Continued

CARD NUMBER	DATA LISTING	
701	ALEWIFE SMELT	Card Type A
702	ZION IMPINGEMENT SIMULATION FOR 1974	Card Type B
703	2 1 1 1 365 5 6	Card Type C
704	120 148 218 365 80 126 250 365	Card Type D
705	.50E 00 .40E 00 .65E 01 .20E 01	Card Type E
706	.15E 01 .12E 01 .10E 01 .30E 00	
707	0 1 0 .59815274E 00 10.79644404E 00	Card Type F
708	(7X,3F7.0)	Card Type G
709	0124284000.01.0	
710	0213568000.01.1	
711	0305568000.02.8	
712	0306852000.02.8	
713	0307852000.03.3	
714	0314568000.04.4	
715	03201136000.3.3	
716	03211136000.3.9	
717	0326852000.01.7	
718	03271136000.3.3	
719	03281136000.3.3	
720	0405852000.04.4	
721	0406568000.02.8	
722	0410284000.05.6	
723	0415852000.06.1	
724	04161136000.6.1	
725	04171420000.6.1	
726	0425852000.07.8	Card Type 1
727	0429852000.07.2	
728	0430852000.06.7	
729	0502852000.08.3	
730	0503852000.07.2	
731	05041136000.7.2	
732	0513852000.08.9	
733	0515852000.08.9	
734	0516852000.09.4	
735	0522852000.09.4	
736	052766000.0 8.9	
737	052866000.008.9	
738	06051136000.9.4	
739	06061136000.8.9	
740	06071136000.8.3	
741	0617852000.08.9	
742	0618852000.09.4	
743	0619852000.010.0	
744	0627852000.012.8	
745	0628852000.012.2	

Table 10. Continued

CARD NUMBER	DATA LISTING
746	0703852000.011.7
747	0709852000.011.1
748	0715852000.016.7
749	0716852000.019.4
750	0717852000.015.0
751	0725852000.017.8
752	0726852000.015.6
753	0905852000.08.3
754	08071136000.8.9
755	0808852000.012.8
756	08091136000.16.7
757	08191704000.12.8
758	08201136000.11.1
759	08211136000.9.4
760	08221136000.7.8
761	08231420000.15.0
762	0829568000.019.4
763	09041136000.17.8
764	09051420000.17.8
765	09061136000.18.9
766	09121420000.8.9
767	09161704000.15.0
768	09171704000.13.3
769	09181704000.12.8
770	09191704000.13.9
771	10031704000.11.1
772	1014852000.011.7
773	1016852000.011.1
774	10281704000.10.0
775	10291704000.10.6
776	10301704000.11.7
777	11061704000.10.0
778	11071420000.9.4
779	1108852000.08.9
780	11131704000.9.4
781	11201704000.7.8
782	1205852000.03.3
783	1206852000.04.4
784	1210852000.02.8
785	12111136000.2.8
786	12121420000.3.3
787	12161704000.2.2
788	12171704000.5.0
789	12181704000.3.9
790	12301704000.4.4

Card Type 1

Table 10. Continued

CARD NUMBER		DATA LISTING									
791	59	End of Card Type-1 Marker									
792	00.0030.21.0275.	Card Type H									
793	0. 76.127.152.178.	Card Type I									
794	76.127.152.178.260.	Card Type J									
795	00.0030.21.0300.										
796	0.102.127.152.178.230.										
797	102.127.152.178.230.300.										
798	11574210704600	Card Type 2									
799	0.00	46.00	4.00								Card Type 3
800	1.50	46.00	11.00	.56	.04	.03	.04	.35	0.		
801	12274210704600										
802	0.00	46.00	4.00								
803	0.00	46.00	11.00	.56	.04	.03	.04	.35	0.		
804	21274210704600										
805	0.00	88.00	4.00								
806	2.50	88.00	11.00	.48	.03	.02	.12	.26	.03		
807	30674210704600										
808	0.00	134.00	13.00	.06	.01	.51	.42	.01			
809	10.00	134.00	25.00	.19	.11	.30	.28	.09			.02
810	32774210704600										
811	0.00	134.00	13.00	.06	.01	.51	.42	.01			
812	63.00	134.00	25.00	.19	.11	.30	.28	.09			.02
813	40674210704600										
814	35.00	177.00	16.00	.04	.01	.67	.32	0.			
815	150.00	177.00	30.00	.11	.12	.36	.28	.09			.02
816	41674210704600										
817	430.00	177.00	16.00	.04	.01	.67	.32	0.			
818	60.00	177.00	30.00	.11	.12	.36	.28	.09			.02
819	50374210704300										
820	3210.00	222.00	26.00	.01	0.	.02	.68	.28			
821	60.00	222.00	39.00	.11	.18	.35	.27	.06			.02
822	51574210704300										
823	3233.00	222.00	26.00	.01	0.	.02	.68	.28			
824	4.00	222.00	39.00	.11	.18	.35	.27	.06			.02
825	60574210704600										
826	366.00	265.00	29.00	.06	.04	.66	.22	.01			
827	0.00	265.00	39.00	.26	.22	.27	.17	.06			.02
828	61874210704600										
829	481.00	265.00	29.00	.06	.04	.66	.22	.01			
830	0.00	265.00	39.00	.26	.22	.27	.17	.06			.02
831	70274210704600										
832	310.00	220.00	31.00	.12	.04	.72	.11	0.			
833	.50	220.00	39.00	.13	.22	.37	.21	.06			0.
834	71674210704600										
835	1012.00	220.00	31.00	.12	.04	.72	.11	0.			

Table 10. Continued

CARD NUMBER		DATA LISTING							
836	0.00	220.00	39.00	.13	.22	.37	.21	.06	0.
837	80774210704600								
838	499.00	175.00	32.00	.07	.08	.74	.12	0.	
839	0.00	175.00	39.00	.30	.29	.22	.05	.01	0.
840	82074210704600								
841	470.00	175.00	32.00	.07	.08	.74	.12	0.	
842	0.00	175.00	39.00	.30	.29	.22	.05	.01	0.
843	90474210704600								
844	0.00	134.00	33.00	.10	.08	.67	.13	0.	
845	0.00	134.00	40.00	.40	.34	.15	.07	.02	.01
846	31774210704600								
847	2.50	134.00	33.00	.10	.08	.67	.13	0.	
848	0.00	134.00	40.00	.40	.34	.15	.07	.02	.01
849	100174210704600								
850	10.00	134.00	32.00	.11	.10	.63	.15	.01	
851	45.00	134.00	39.00	.19	.28	.23	.20	.08	.02
852	101474210704600								
853	74.00	130.00	32.00	.11	.10	.63	.15	.01	
854	4.00	130.00	39.00	.19	.28	.23	.20	.08	.02
855	110674210704600								
856	27.00	90.00	29.00	.13	.11	.55	.21	.01	
857	0.00	90.00	38.00	.03	.15	.27	.31	.17	.07
858	111974210704600								
859	0.00	90.00	29.00	.13	.11	.55	.21	.01	
860	0.00	90.00	38.00	.03	.15	.27	.31	.17	.07
861	120574210704600								
862	0.00	85.00	22.00	.11	.38	.44	.08	0.	
863	.50	85.00	36.00	.04	.03	.20	.39	.06	.01
864	121674210704600								
865	0.00	85.00	22.00	.11	.38	.44	.08	0.	
866	1.00	85.00	36.00	.04	.03	.20	.39	.06	.01

5. SUMMARY AND CONCLUSIONS

In this report we have presented the results of the validation of the fish-impingement prediction model developed by Murarka.¹ Several changes were made in the mathematical form of the model, which reflect new knowledge obtained on the cause and effect relationships of environmental, plant operational, fish behavioral, and abundance variables to fish-impingement rates.

Although the number of variables used in the validation test with Zion Station data were reduced, the performance of the model in calculating daily fish impingements was satisfactory. As a result of sensitivity analyses and an examination of the different functional parts of the model, it was found that fish-density measurements constitute the most important input for enabling the model to predict fish impingements accurately. The water temperature, with its effect on determining the impingement risk to fish, is probably the most important environmental variable considered in the model; water-volume pumped seems to have a moderate effect on the model's predictive capacity.

Several important conclusions can be drawn from this model-validation effort:

- 1) Information on fish density and abundance is the most important variable in the calculation of fish-impingement rates. Therefore, we conclude that frequent determinations of fish density should be made--perhaps as often as every three or four days or at least at weekly intervals.

- 2) Data base information should be developed on additional environmental and fish behavioral variables and their functional relationships in the form of the impingement risks.

- 3) The present mathematical model is adequate in view of the very gross information available on fish factors relating to impingement. Further refinement of the model is not necessary until more quantitative data on the processes relating to fish abundance and impingement rate are developed.

Finally, the authors also feel that the impingement model may be used in conjunction with some kind of fishery-resource utilization model so that the "end use" of the modeling effort is objectively oriented towards finding the quantitative significance of fish impingement to the fisheries existent in the water body.

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