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The Effect of Stochastic Variation on Estimates of the Probability of Entrainment Mortality: Methodology, Results, and User's Guide

S. W. Christensen
D. L. DeAngelis

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1832

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

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

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

Available from

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

NUREG/CR-2533
ORNL/TM-7965
Distribution Category-RE

Contract No. W-7405-eng-26

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Manuscript Completed - May 1982
Date Published - June 1982

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NRC FIN B0165

Task: Methods to Assess Impacts on Hudson River Striped Bass

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

ACKNOWLEDGMENTS

We wish to thank Drs. L. W. Barnthouse, C. C. Coutant, W. Van Winkle, and D. S. Vaughan for their helpful comments on the manuscript. This research was supported jointly by the U.S. Nuclear Regulatory Commission under Interagency Agreement DOE 40-550-75, and by the Office of Health and Environmental Research, U.S. Department of Energy, under contract W-7405-eng-26 with Union Carbide Corporation.

ABSTRACT

CHRISTENSEN, S. W., and D. L. DeANGELIS. 1982. The effect of stochastic variation on estimates of the probability of entrainment mortality: Methodology, results, and user's guide. ORNL/TM-7965 and NUREG/CR-2533. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 88 pp.

The probability that live fish eggs or larvae, entrained in cooling water, will be killed is an important element in projecting power plant effects on fish stocks. This probability, the entrainment mortality factor, is commonly estimated with one of several relatively simple formulae which use data collected from intake and discharge water. Such biological phenomena as gear avoidance, gear-induced mortality, extrusion through nets, and the presence of dead organisms in ambient water introduce errors into estimates obtained with these formulae. An additional difficulty is that, because of small sample sizes, it is usually necessary to combine data from many samples, taken under different conditions, before applying the formula.

A Monte Carlo simulation model (ENTRAN) was developed to assess the accuracy and precision of entrainment mortality estimates derived via these formulae from field data. The biological phenomena mentioned above were included in the model as factors which could be manipulated according to the actual field situation or as model "experiments." After repeated simulation over a range of selected entrainment mortalities for varying biological conditions, the reliability of mortality estimates was evaluated by comparing the estimates with the actual mortality that was selected for the model run.

Two formulae were evaluated with several test cases. In simulations where the mean parameter values met the assumptions of one formula (the ORNL formula), the random variation alone caused biased estimates. The ORNL formula overestimated mortality when mortality was high and underestimated mortality when mortality was low. The "averaging" due to combining samples was somewhat effective in reducing the variance of this bias, but it had little effect on the magnitude of the bias. The same results were obtained for a more realistic case where the assumptions of the ORNL formula were not met. An alternative formula generally produced less desirable results.

It is recommended that ENTRAN be used, with appropriate modification of both model and input to fit specific field situations, in conjunction with field sampling programs designed to estimate entrainment mortality. The model can aid in designing the sampling program to produce more reliable estimates and also in interpreting the results.

SUMMARY

The probability that live fish eggs or larvae, entrained in cooling water, will be killed is an important element in projecting power plant effects on fish stocks. This probability, the entrainment mortality factor or f-factor, is commonly estimated with one of several relatively simple formulae that use data collected from intake and discharge water. Such biological phenomena as gear avoidance, gear-induced mortality, extrusion through nets, and the presence of dead organisms in ambient water introduce error into the estimates. An additional difficulty is that, because of small sample sizes, it is usually necessary to combine data from many samples, taken under different conditions, before estimating the f factor. A computer simulation program, ENTRAN, was developed to aid in the design of field sampling programs and in the analysis of reliability of entrainment mortality factor estimates.

The biologist's problem is to use information from entrainment sampling to estimate the f-factor. While a variety of estimators have been advanced for this purpose, two formulae seem to have been used most frequently. Both are based on comparing the proportion of organisms alive in the intake sample (P_{IS}) with the proportion of organisms alive in the discharge sample (P_{DS}). The values of P_{IS} and P_{DS} are obtained as:

$$P_{IS} \text{ (or } P_{DS}) = \frac{\text{ALIVE}}{\text{ALIVE + DEAD}} ,$$

where ALIVE is the number of live organisms in the intake or discharge net collection bottle and DEAD is the number of dead organisms.

The most commonly used formula for estimating the f-factor is

$$f = \frac{P_{IS} - P_{DS}}{P_{IS}} .$$

This formula, termed the "ORNL" formula in this report, can produce estimates ranging from - ∞ to 1. It was derived by Oak Ridge National Laboratory (ORNL) in USNRC (1975) as a means of estimating short-term mortality upon passage through a power plant's condenser cooling system.

A second formula which has been used to quantify entrainment mortality is

$$f = P_{IS} - P_{DS} .$$

This formula, termed the "OTHER" formula in this report, can take on values ranging from -1 to 1. It has deservedly fallen into disuse in recent years. There are no nontrivial sets of assumptions we can find which allow this formula to produce accurate estimates (although occasionally, by chance, it may produce correct estimates).

We developed a computer model, ENTRAN, to probe the performance of estimators of the f-factor. The utility of this model lies in its ability to simulate not only the entrainment mortality sampling process but also the estimation of the f-factor by either of the equations presented above. ENTRAN is in essence a stochastic simulation model based on a "neutral modeling" approach. The entrainment process is repeatedly simulated, with key variables allowed to vary randomly. In each repetition the true value of the entrainment mortality factor (f-factor) is selected, and it is compared with estimates of this factor obtained from the two alternate formulae discussed above. The reliability of each formula can then be evaluated by comparing the estimates of the f-factor with the corresponding true values. Ideally, a formula would always estimate the true f-factor without error. In real-world cases, however, this is impossible. ENTRAN enables an examination of the magnitude and variance of error as a function of variability introduced by various sampling phenomena.

A number of runs were made to verify the program and to illustrate ways in which it can be used. In simulations where the mean parameter values met the assumptions of the ORNL formula, the random variation alone caused biased estimates. The ORNL formula overestimated mortality when mortality was high and underestimated mortality when mortality was low. The "averaging" due to combining samples was somewhat effective in reducing the variance of this bias, but it had little effect on the magnitude of the bias. The same results were obtained for a more realistic case where the assumptions of the ORNL formula were not met. In some instances, the OTHER formula was a better estimator of the f-factor than was the ORNL formula.

The program is intended primarily for application to a specific situation, because experience has shown that the factors in the model will likely vary widely between different types of sampling gear and also between species. We intend for the program to be viewed as flexible, in that the biological assumptions built into the present version may not best describe, or even adequately describe, a particular sampling situation or species. When suitably modified to reflect what is known or suspected about the biology of the sampling situation, the designer of the sampling program can make good use of ENTRAN to address needs in several areas. The exercise of providing ranges of values for the parameters will likely indicate to the biologist where uncertainty about these parameters is greatest. In conjunction with this exercise, sensitivity analysis of the model will indicate profitable areas for further research which will be helpful in improving the reliability of estimates.

ENTRAN can also aid in determining how to design the sampling program and how to interpret the results. The program can be used to study the relative effects of estimating the f-factor from many, small samples versus fewer, larger samples, and it can indicate how reliability is influenced by small sample sizes, given uncertainty in the parameters. It can also be used in a general way to evalutate the reliability of f-factor estimates calculated from sample data. Depending on the degree of confidence in the input parameters, the program will be useful in evaluating the bias of estimates and in indicating how estimates calculated with a particular formula can best be "corrected."

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1. INTRODUCTION AND BACKGROUND

The passage of the National Environmental Policy Act of 1969 (NEPA 1970) more than a decade ago stimulated, among other things, biological studies of power plant impacts on aquatic systems. Even before that time entrainment mortality of planktonic organisms including fish eggs and larvae at power plants utilizing once-through cooling was identified as a potential source of substantial stress on some aquatic populations (Kerr 1953, Coutant 1970). Entrainment refers to the passage of organisms too small to be retained on intake screens through a power plant in the condenser cooling water. This water, and the organisms contained in the water, are heated as they pass through the heat exchanger system, and remain at a higher temperature until discharged back into the water body. This heat stress has been the principal concern at many power stations. There is also mechanical stress, and sometimes chemical stress, associated with the entrainment process.

An obviously key question in evaluating entrainment mortality is the extent of survival of entrained organisms. Early predictive models emphasized thermal effects, and they related the temperature and duration of exposure to thermal stress during entrainment to thermal bioassay data in order to predict survivorship (Coutant 1970, 1971). Recent mathematical models designed to empirically estimate entrainment impact from all causes at plant sites typically contain a term for the fraction of live organisms entering the plant that die as a result of the entrainment experience (e.g., Boreman et al. 1978 and 1981, Eraslan et al. 1976, Goodyear 1977, Lawler 1972, LMS 1975, USAEC 1972). Numerous studies have been undertaken to empirically estimate this probability of entrainment mortality (termed the f-factor). The usual approach is to collect organisms from both the intake and the discharge water using gear which imposes as little mortality as possible. Information on apparent survival of the organisms is then utilized in a formula to estimate the f-factor, typically by species and life stage. It is generally recognized that estimates of the f-factor may be biased (Barnthouse et al. 1977, Vaughan 1979, Boreman and Goodyear 1981). Such biases may arise because the particular formula used to estimate the f-factor is ill-conceived, or because assumptions implicit in the formula are violated. Given the existence of such biases, it is of interest to evaluate the accuracy of any formula used to estimate the f-factor.

While there are field and laboratory methods which can be used to test the validity of assumptions underlying particular formulae, there are also mathematical approaches that are of value in evaluating the consequences of failure to meet assumptions. A mathematical analysis of alternative formulae may lead to selection of one over another based simply on conceptual criteria and knowledge of qualitative sampling phenomena. In addition, a sensitivity analysis of a particular formula can suggest experiments and field trials which should be of maximum value in evaluating reliability of f-factor estimates.

This report describes ENTRAN, a mathematical model that uses Monte Carlo techniques to probe the efficacy of a formula, or of two alternative formulae, for estimating the f-factor from field data, given the existence of variation in sampling phenomena and in the susceptibility of organisms to capture by sampling gear and to damage by the gear. As with certain other techniques, this model can aid in determining how violations in assumptions affect the quality of estimates from a formula, and which formula is more reliable under a particular set of fixed assumptions about gear avoidance, gear-induced mortality, etc. In addition, however, ENTRAN can investigate the efficacy of making particular improvements in sampling gear, and can be used to indicate which factors associated with field sampling are most important to evaluate to obtain more reliable estimates of the f-factor. The model thus is applicable both for helping to design field sampling programs and in evaluating the reliability of f-factor estimates derived from such programs.

ENTRAN is applicable to retrospective, rather than predictive, evaluations because it simulates a site for which data are presumed to be available or obtainable. It is thus empirical in nature, being oriented to the use of actual field data. It may, however, still have application to predictive situations. For example, it can be used to help design a sampling program prior to any sampling at the site, if something is known about the biological effects of the proposed sampling gear. Also, predictive models of entrainment mortality (Ecological Analysts 1977a, Vaughan 1979) generally utilize results from field sampling programs to define baseline mortality or to validate the model, or both, and ENTRAN can be applied to the results of these field sampling programs.

2. GENERAL DESCRIPTION OF THE COMPUTER PROGRAM

The computer program ENTRAN is in essence a stochastic simulation model based on a "neutral modeling" approach (Caswell 1976). The entrainment process is repeatedly simulated, with key variables allowed to vary randomly. In each simulation, the true value of the entrainment mortality factor (f-factor) is selected, and it is compared with estimates of this factor obtained from alternate formulae that have actually been applied in the real world. The reliability of each formula can then be evaluated by comparing the estimates of the f-factor with the corresponding true (selected) values. Ideally, a formula would always estimate the true f-factor without error. In real-world cases, however, this is impossible. ENTRAN enables an examination of the magnitude and variance of error as a function of bias and variability introduced by various sampling phenomena.

Figures 2-1 and 2-2 are diagrammatic representations of the sampling process at the intake of a power plant. Although Fig. 2-1 depicts a net sampling process, our methodology is equally applicable, without modification, to alternate methods of sampling, such as with pumps and larval tables (McGroddy and Wyman 1977). Many such alternate methods are more suitable for the purpose of sampling for entrainment mortality.

COHORT in Fig. 2-2 represents organisms inhabiting ambient water which is destined to enter the sampling gear. The schematic mathematical treatment of what happens to these organisms (Fig. 2-2) corresponds to the biological representation provided in Fig. 2-1.

Backwash due to a partially clogged net is implicitly allowed for in the model. Neither the water excluded by backwash nor the organisms inhabiting that water would be expected to enter the net in a real situation, nor do they in the model. Organisms (e.g., fish larvae) in the ambient water may be either alive or dead (Cada and Hergenrader 1978). In the model (Fig. 2-2), F1 denotes the fraction of ambient organisms which are alive; [1-F1] therefore denotes the fraction dead. Some fraction (denoted FP2) of initially dead organisms are retained by the intake net and enter the sample; the rest [1-FP2] are extruded. Of the initially alive organisms, the fraction F3 will enter the intake area, while the remaining fraction [1-F3] are assumed to avoid the area. Of those entering the area, [1-FP4] avoid the sampling net, while FP4 enter the net. Of these, FP5 survive the sampling process and enter the sample as live organisms; [1-FP5] are killed. Of these net-killed organisms, [1-FP6] are extruded, while FP6 are retained and enter the sample as dead organisms. Note that the concept of retention of net-killed organisms (FP6) is similar to the concept of retention of initially dead organisms (FP2). These are made separate factors, however, because there may be substantial differences in the likelihood that an initially dead and perhaps decomposing organism will pass through a mesh, as opposed to an organism which has just been killed by encountering the mesh. These factors are summarized in the column headed "Intake" in Table 2-1.

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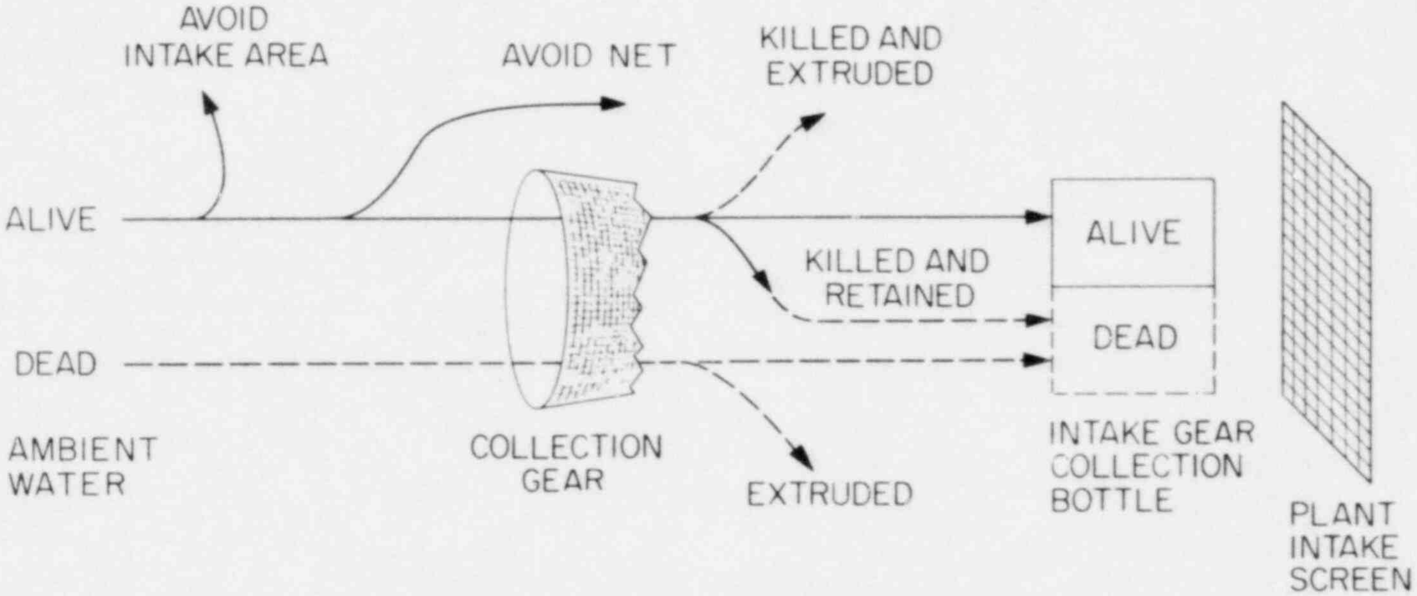

Fig. 2-1. Diagrammatic representation of the intake sampling process for entrainment mortality estimation at a power plant: biological representation.

ORNL-DWG 81-10965 ESD

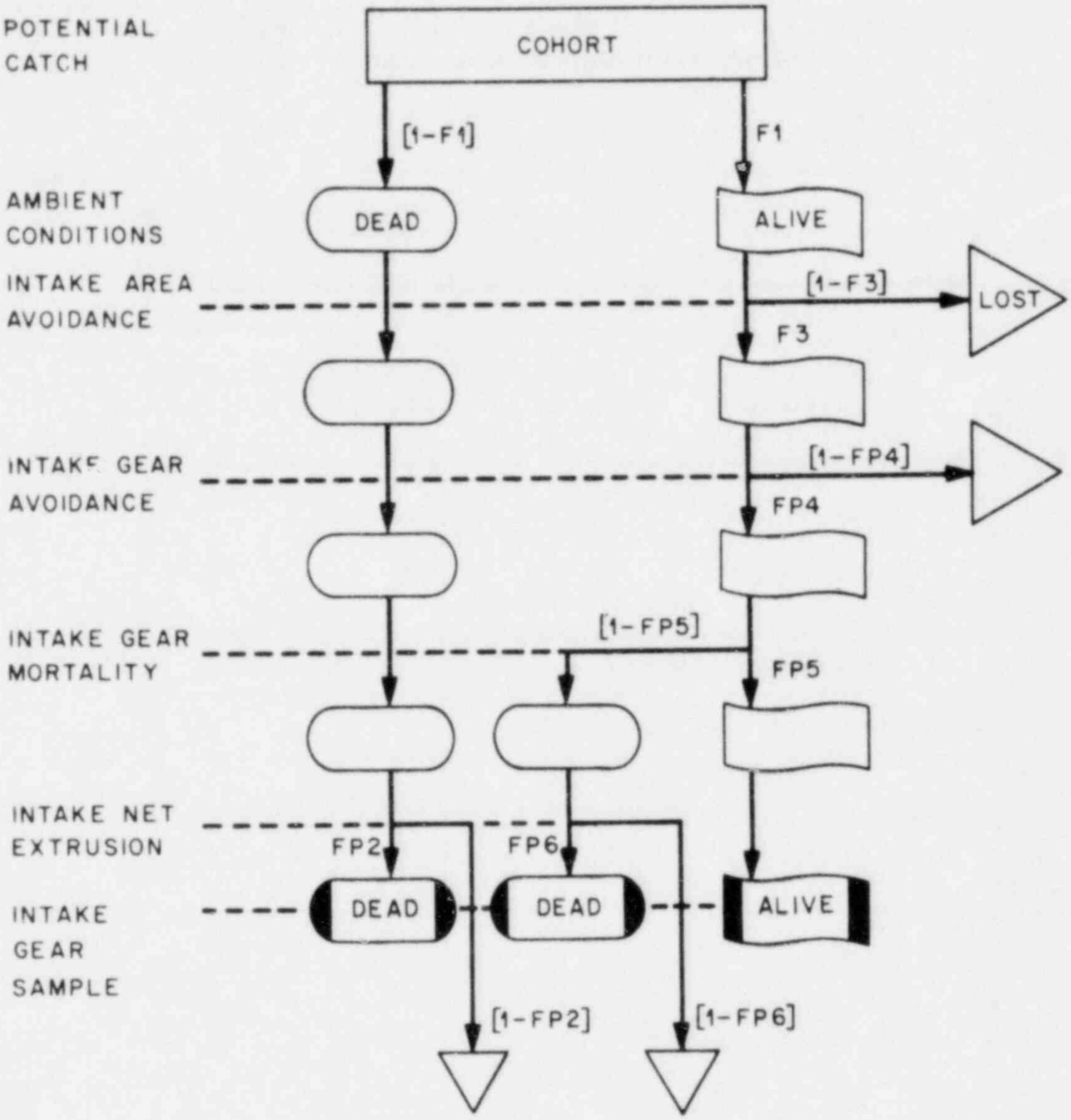

Fig. 2-2. Diagrammatic representation of the intake sampling process for entrainment mortality estimation at a power plant: mathematical representation

Table 2-1. Definition of key factors in the program ENTRAN relating to intake and discharge sampling

	Symbol for factor at:	
Factor definition	Intake	Discharge
Size of cohort	COHORT	COHORT
Fraction of ambient organisms alive	F1	F1
Fraction of ambient dead organisms retained	FP2	F2
Fraction of live organisms susceptible to intake area	F3	F3
Catchability of live organisms	FP4	F4
Fraction of live organisms surviving capture	FP5	F5
Fraction of gear-killed organisms retained	FP6	F6
Fraction of plant-killed organisms retained	---	F7
Probability of surviving entrainment	---	FSV

Figures 2-3 and 2-4 represent the analogous sampling process at the discharge. The biological phenomena incorporated are the same as those at the intake, except that the plant intervenes early in the process. Because of this, there are two additional factors. FSV denotes the fraction of live organisms surviving the power plant effect (the white arrow just to the right of the intake screen in Fig. 2-3); [1-FSV] therefore, denotes the fraction of live organisms killed by the power plant (the shaded arrow in Fig. 2-3). The entire process of sampling for entrainment mortality is motivated by the need to estimate [1-FSV], denoted the f-factor. The second new factor in the discharge sampling is F7, the fraction of plant-killed organisms retained in the sample. [1-F7], therefore, denotes the fraction of plant-killed organisms extruded through the gear. If dead organisms were thought to sink or to rise relative to live organisms before encountering the discharge net, the terms F2 and F7 could be adjusted to reflect this.

As discussed above, the biologist's problem is to use information from entrainment sampling to estimate the f-factor. While a variety of estimators, some quite bewildering (e.g., Griemsmann 1973), have been advanced for this purpose, two formulae seem to have been used most frequently. Both are based on comparing the proportion of organisms alive in the intake sample (P_{IS}) with the proportion of organisms alive in the discharge sample (P_{DS}). Referring to Fig. 2-1 or to Fig. 2-3, for example, the values of P_{IS} and P_{DS}, respectively, are obtained as:

$$\frac{\text{ALIVE}}{\text{ALIVE + DEAD}} , \qquad (2\text{-}1)$$

where ALIVE is the number of live organisms in the intake or discharge net collection bottle and DEAD is the number of dead organisms there. Throughout, "organisms" is assumed to refer to members of some life-stage of a particular species of interest. Because sample sizes for species of interest are usually very small, it is common practice to combine information from many samples, taken at different times. This is accomplished by summing the number of live organisms and summing the number of dead organisms over the samples prior to applying Equation (2-1). Note that both P_{IS} and P_{DS} can assume values ranging from 0 to 1, inclusive.

The most commonly used current formula for estimating the f-factor is

$$f = \frac{P_{IS} - P_{DS}}{P_{IS}} . \qquad (2\text{-}2)$$

This formula, termed the "ORNL" formula in this document, can produce estimates ranging from $-\infty$ to 1. (Negative estimates are due to sampling error only and are physically impossible.) It was developed by ORNL (Oak Ridge National Laboratory) in USNRC (1975) (also see Barnthouse et al. 1977, Ecological Analysts 1977b, McFadden 1977, and

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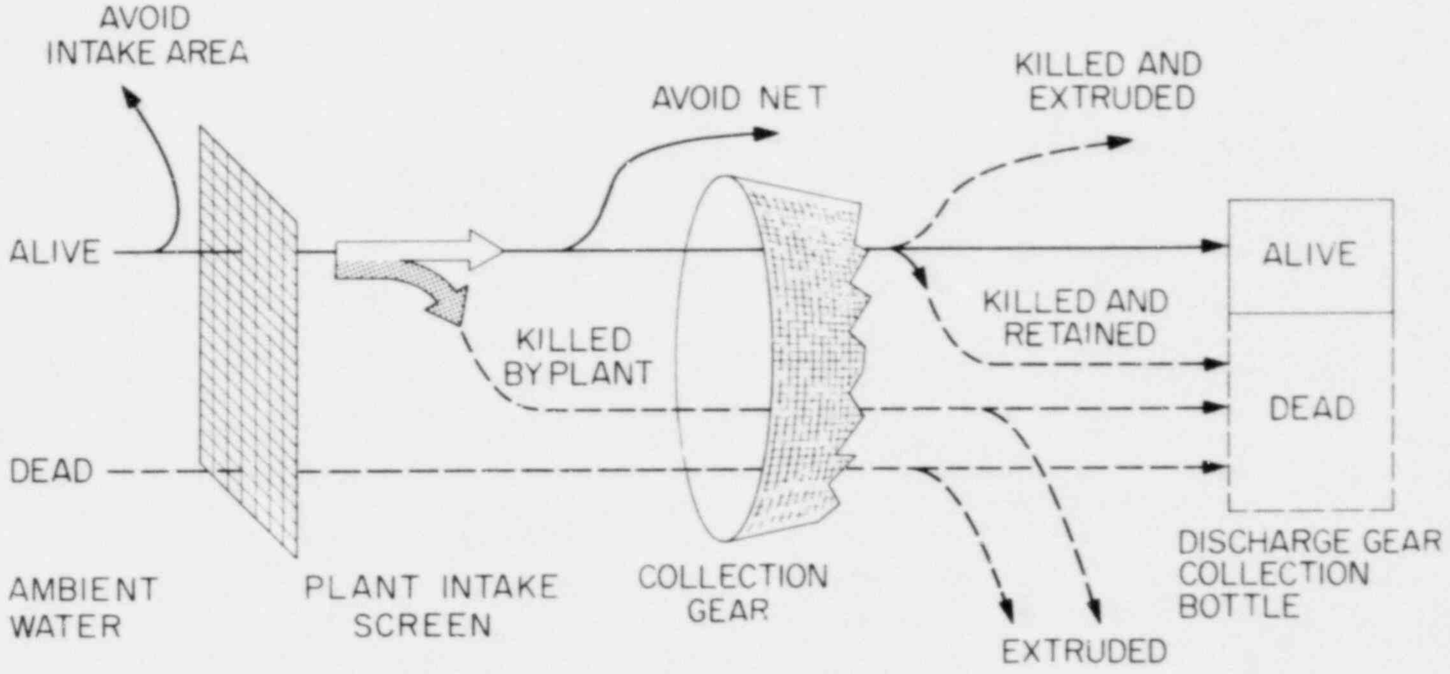

Fig. 2-3. Diagrammatic representation of the discharge sampling process for entrainment mortality estimation: biological representation.

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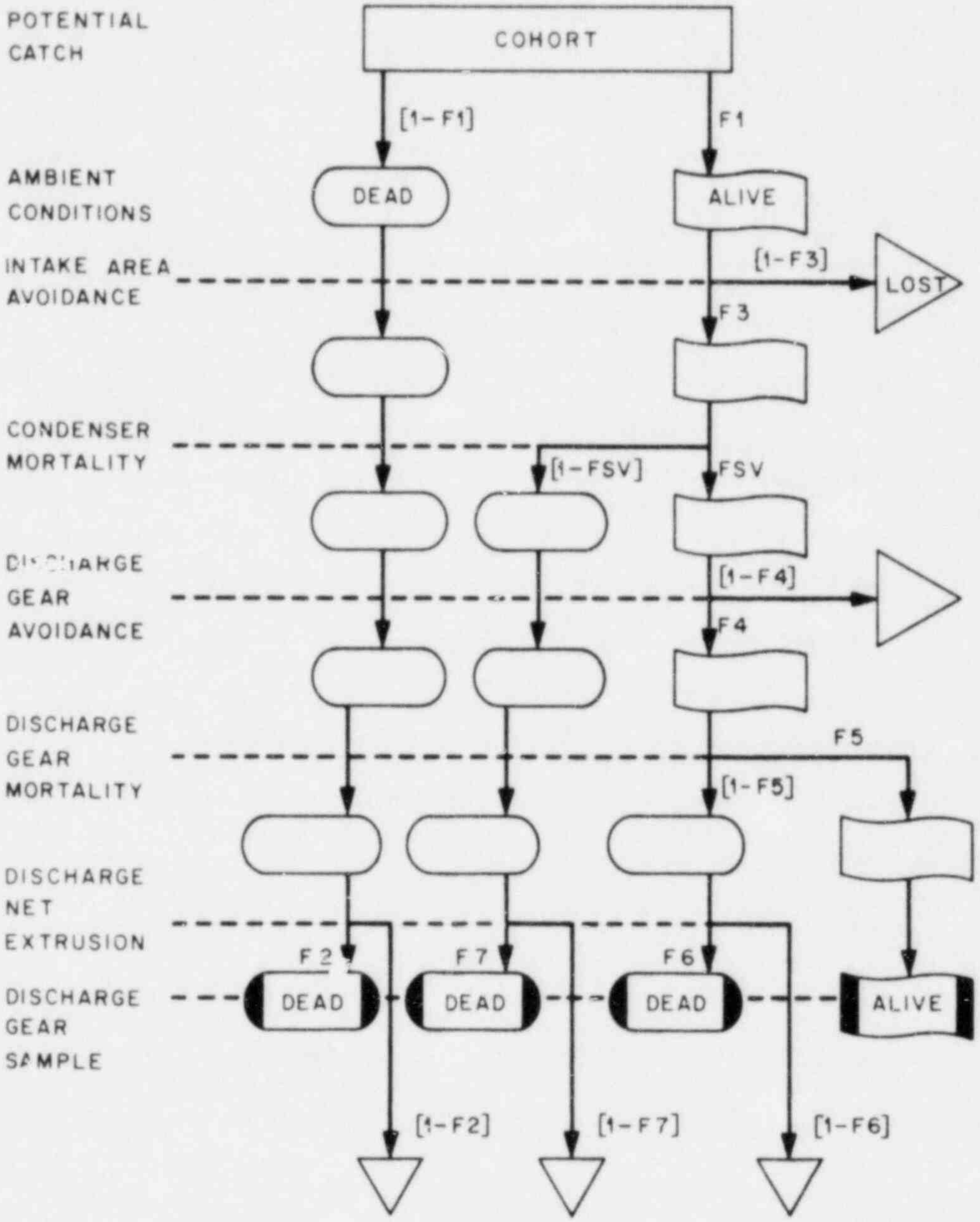

Fig. 2-4. Diagrammatic representation of the discharge sampling process for entrainment mortality estimation at a power plant: mathematical representation

Vaughan 1979, Appendix C for similar derivations) as a means of estimating short-term mortality upon passage through a power plant's condenser cooling system.

This expression is accurate if:

(a) There is no gear avoidance ($F4 = FP4 = 0$),

(b) There is no extrusion of initially live organisms ($F6 = FP6 = F7 = 0$),

(c) The degree of extrusion of initially dead organisms is the same at the intake and the discharge ($F2 = FP2$), and

(d) The degree of gear-induced mortality is the same at the intake and the discharge ($F5 = FP5$).

This set of conditions is not likely to occur in general (UNESCO 1968), and bias can be expected in the estimates.

A second formula which has been used to quantify entrainment mortality (NYU 1973, WAPORA 1975) is

$$f = P_{IS} - P_{DS} \quad (2\text{-}3)$$

This formula, termed the "OTHER" formula in this document, can take on values ranging from -1 to 1; once again, negative estimates are due to sampling error. It has deservedly fallen into disuse in recent years. There are no nontrivial sets of assumptions we can find that allow this formula to produce accurate estimates (although occasionally, by chance, it may produce correct estimates).

The utility of ENTRAN, the model we developed to probe the performance of estimators of the f-factor, lies in our ability to simulate not only the entrainment mortality sampling process but also the estimation of the f-factor by either Eq. (2-2) or Eq. (2-3). This is possible because we can write expressions for both P_{IS} and P_{DS} in terms of factors included in the model. For the intake sample, for example, the numerator of Eq. (2-1), namely, the proportion alive, is

$$F1*F3*FP4*FP5 \ , \quad (2\text{-}4)$$

where the terms are as defined in Table 2-1 and the asterisk denotes multiplication, as in FORTRAN. The denominator for the intake sample is

$$F1*F3*FP4*FP5 + F1*F3*FP4[1-FP5]*FP6 + FP2[1-F1] \ . \quad (2\text{-}5)$$

Similarly, the numerator of Eq. (2-1) for the discharge sample is

$$F1*F3*FSV*F4*F5 \quad , \tag{2-6}$$

and the denominator for the discharge sample is

$$\begin{aligned} &F1*F3*FSV*F4*F5 + F1*F3*FSV*F4(1-F5)*F6 \\ &\qquad + F1*F3(1-FSV)*F7 + F2(1-F1) \quad . \end{aligned} \tag{2-7}$$

It is therefore easy to calculate in the model, using either the ORNL formula [Eq. (2-2)] or the OTHER formula [Eq. (2-3)], the estimate of the f-factor which a biologist would obtain in the real world under the corresponding circumstances. Because the model can also easily calculate the true f-factor for any simulation, defined as [1-FSV], it is now possible to evaluate the imprecision and bias in either the ORNL or the OTHER formula. Appendix A explains how this is accomplished in the computer program, and the other appendices provide further documentation.

3. REMARKS ABOUT USE OF THE PROGRAM

This model was designed as a general purpose model, rather than for application to a particular power plant. It was also intended to provide a framework for the stochastic approach to error analysis of entrainment mortality estimates, rather than to be an off-the-shelf model ready for application. Application of the model to a particular situation should involve cooperation among one or more biologists familiar with computer programming, or working with a computer scientist familiar with biological programming, because the model will likely need modification to make it suitable to the actual biological conditions at the particular power plant. Some of these possible modifications are identified below, with discussion of how they might be implemented.

Several biological possibilities might be relevant to the model, which could be incorporated by means of "side calculations" performed on input parameters. For example, if the power plant has a long, nonturbulent canal down which the organisms must pass before encountering the discharge sampling gear, dead organisms might settle toward the bottom or float toward the surface and, depending on the location of the gear, they might be either more susceptible or less susceptible to it. If they are more susceptible, this effect translates to an increased avoidance of discharge gear by live organisms (relative to dead organisms). If dead organisms are less susceptible, one can incorporate this effect in the model by modifying F2 and F7. Define S as the fraction of dead organisms which are susceptible to capture by the discharge gear. One can then define modified values for F2 and F7 which incorporate this "passive avoidance":

$$F2' = F2*S \tag{3-1}$$

and

$$F7' = F7*S \quad , \tag{3-2}$$

where F2' and F7' are the modified values. Of course, the independent variation in S is not included in this way, and a better approach would be to revise the model structure slightly to incorporate one or two new factors for the susceptibility of ambient dead and plant-killed organisms.

Similarly, it is possible that surviving larval fish would respond to the stress of entrainment by "sounding," i.e., diving toward the bottom. This effect could be incorporated into F4 (discharge gear susceptibility), or (preferably) could be added as a new factor just after the condenser mortality.

The addition of such new factors would, of course, require minor modifications to the computer code. The dimension of the array A would need to be expanded, and the new factor or factors would need to be read in, written out, and incorporated into the calculation of P_{IS} and P_{DS}. These modifications are relatively easy to perform.

Several additional biological possibilities do not lend themselves to treatment by means of simple modification of existing input parameters and rather must be incorporated by altering the model structure. Once more, these changes are relatively easy to make once the model structure is understood (Appendix B), because they concern mainly factor input/output and the calculation of P_{IS} and P_{DS}. Differential survival during transit to the laboratory, latent mortality, and indirect mortality are examples of biological phenomena which can be accommodated by introducing new factors into the existing model structure. Attraction of live organisms to the intake area is a possibility that might be handled externally (in a population entrainment model); if so, one can accommodate this in the entrainment mortality model with an adjustment to F1 (needed only if F1 is originally estimated based on samples in the field rather than near the intake). Another possibility is to modify the model structure. Finally, there are two considerations which would require structural changes in the model. Sometimes organisms are sorted into three categories when collected: live, stunned, and dead (e.g., Ecological Analysts 1976). In the analysis, the stunned organisms may be classified as live or, alternately, as dead. The best way to handle this in the model would be to revise the structure to include stunned organisms. An alternative approach would be to make separate runs, first treating stunned organisms as alive and then treating stunned organisms as dead. The final biological consideration we mention is the likely lack of independence between the probability of surviving the condenser mortality and the probability of being captured by the gear and surviving capture. The essence of this consideration involves the way one views the underlying basis of the observed variation in surviving entrainment. Such variation is a fact; under many power plant operating conditions, some organisms, but not all organisms, are collected alive. This observation can be rationalized from two extreme views: (a) all organisms have the same tolerance for stress, but some are unfortunate enough to contact an impeller blade, the wall of a condenser tube, or the mesh of the net while in the wrong orientation, etc., or (b) organisms vary considerably in their tolerance for stress, and the live ones collected in the sample represent the hardier ones. Although our existing model structure implicitly assumes (a), some blend of these two views is likely correct. One could modify our model to incorporate this consideration by [i.e., view (b)] by revising the model structure, guided by the approach taken in Boreman and Goodyear (1981). Assuming that the "hardy" organisms are less susceptible to both power-plant-induced mortality and to gear-induced mortality, failure to include this phenomenon could lead one ultimately to underestimate power plant effects. This would be at least partially offset if the "hardier" larvae could better avoid capture or if the less hardy larvae would not have survived as well in nature.

There are other considerations when using this program. The final table printed out for each analysis is based on the absolute bias and variation of the estimates. Depending on the application, one might be more interested in the relative (percentage or proportional) bias and variation. The safest way to accomplish this would be to define new arrays for relative indices, add the appropriate calculations to the program, and modify the statements that print out the table. Another relatively easy modification would be to change the boundaries of the sorting categories if this were desired. Finally, it is a common practice, when utilizing entrainment mortality estimates in an entrainment model, to set negative estimates to 0 (Vaughan 1979). Negative entrainment mortality factors are, of course, biologically meaningless, and their use in an entrainment model would cause the "creation" of organisms within the model. However, this practice of setting negative estimates to 0, while biologically satisfying, introduces an additional bias into the estimates (due to the truncation of the distribution on one end only). An indication of the degree of this bias is provided in two lines near the beginning of the section of output headed "CALCULATION OF MEANS AND STANDARD DEVIATIONS OF ORNL AND OTHER FC VALUES." These two lines (labelled as "AVERAGE ORNL FC, NEGATIVES SET TO ZERO..." and "AVERAGE OTHER FC, NEGATIVES SET TO ZERO...") provide mean values of the respective f-factor estimates when any negative estimates have been arbitrarily set equal to 0. They can be compared with the values printed out in the two immediately preceeding lines, which give the corresponding averages without setting negative values to 0. To fully explore this practice, one would want to modify the program to examine the effects by sorting category.

In using this program, it is unlikely that relevant estimates from field or laboratory data will be available for all of the factors in the model. The biologist will need to exercise judgment in the selection of appropriate ranges for these factors. In doing so, she or he should think carefully about the meaning of the factors in relation to the biology of the organism and to the nature of the specific sampling process being used. One use of this program is to enable examination of the relative values of various possible changes in sampling gear or sampling protocols. In selecting values for factors, either to simulate an actual sampling program or to investigate the effects of making changes in the program, certain principles may be of value. For example, F2 is likely to be less than or equal to FP2, but not greater than FP2 if sampling conditions are similar, because the entrainment process is likely to add mechanical damage to already dead organisms, making them more likely to be extruded at the discharge. On the other hand, given identical through-mesh velocities, it is likely that net-killed organisms are about equally likely to be extruded whether they have survival plant passage (discharge) or have not been exposed to entrainment (intake); hence FP6 would be similar in magnitude to F6. Other relationships, such as those between FP4 and F4 or FP5 and F5, are more equivocal.

The ENTRAN program, or appropriate modifications of it, can be used to provide estimates of the bias and variance associated with conventional f-factor estimates, given the input information and assumptions. It would also be possible to use the results to provide corrected (i.e., "better") estimates. Before doing this, the biologist would be advised to explore the full range of plausible assumptions about the sampling situation and the behavior of the organisms. This program, properly used, will likely be more reliable for indicating whether the conventional formula gives overestimates or underestimates in a particular situation than it will be at enabling precise corrections for biased estimates.

4. RESULTS

This section presents results from a number of runs of ENTRAN which either verify the program or illustrate ways in which it can be used.

Table B-1 (in Appendix B) contains an input data set (Case 1) used for verifying the code. As explained in Section 2, the ORNL formula should provide perfect estimates of the f-factor when (a) there is no gear avoidance, (b) there is no extrusion of initially live organisms, (c) the degree of extrusion of initially dead organisms is the same at the intake and the discharge, and (d) the degree of gear-induced mortality is the same at the intake and the discharge. Case 1 satisfies these conditions.

The main output table from this run for the ORNL formula is contained in Appendix D. Note that the ORNL formula does in fact work "perfectly"; the estimates are unbiased. Appendix D also contains the corresponding main output table for the OTHER formula (the final part of Appendix D). Here, the estimates consistently underestimate the true f-factor, and the magnitude of this bias increases as the true f-factor value increases. Examination of the individual estimates showed that the OTHER formula always underestimated the true mortality for this case. This is to be expected, because the ORNL formula, which differs from the OTHER formula only in having a denominator (P_{IS}), estimates the true f-factor perfectly, and P_{IS} is less than 1.0 in this Case. Therefore, the OTHER formula, which equals the product of the ORNL formula and P_{IS}, will always underestimate the true f-factor in this Case.

Table 4-1 shows the input data file for Case 1H, which has variation in those parameters from Case 1 which were not restricted to the value 1.0. The same range of variation has arbitrarily been used for the intake as for the discharge, and the variation has arbitrarily been made symmetrical about the Case 1 values. The amount of variation is arbitrarily made a function of the mean value of the variable, being always plus or minus one-half of the distance from the mean value to the nearest boundary (0 or 1). Therefore, a parameter with 0.5 as the mean value varies from 0.25 to 0.75, while one with 0.9 as the mean value varies from 0.85 to 0.95. A priori, it is not obvious whether the variation will cause systematically biased estimates, or in which direction the bias might be, but variation in the bias of the individual estimates would certainly be expected even if the mean bias were 0.

Table 4-2 is the Case 1H main output table for the ORNL formula. The overall mean bias is very small (-0.008). Examination of the sorting categories in the table shows that occasional negative estimates are obtained (approximately 6% of the time), and these are sometimes fairly highly biased because the true f-factor must be ≥ 0. The ORNL formula also tends to underestimate the true f-factor by an average of 0.046 when the ORNL estimate is positive but small

Table 4-1. Input data for Case 1H, which is similar to Case 1 but with variation

```
CASE 1H
   .85   .95                F1: AMBIENT ALIVE.
   .25   .75   .25   .75    F2: RETENTION OF AMBIENT DEAD.
   .85   .95                F3: SUSCEPTIBILITY OF AMBIENT ALIVE TO INTAKE AREA.
    1.    1.    1.    1.    F4: CATCHABILITY OF LIVE.
  .625  .875  .625  .875    F5: NET SURVIVAL OF LIVE.
    1.    1.    1.    1.    F6: RETENTION OF NET-KILLED.
    1.    1.                F7: RETENTION OF PLANT-KILLED.
  0.0   1.0                PSV: PROBABILITY OF SURVIVING PLANT PASSAGE.
 09565                     IX: RANDOM NUMBER INITIATOR (I5).
  1000                     NEST: TOTAL NUMBER OF ESTIMATES (I5).
     1                     NSAMP: NUMBER OF SAMPLES FOR EACH ESTIMATE (I5).
    1. 100.                CHRTMN, CHRTMX: MIN. AND MAX. COHORT SIZES PER SAMPLE.
    50                     NZ: NUMBER OF ESTIMATES NEEDED TO FILL A SORTING CATEGORY.
```

Table 4-2. Main output table for Case 1H for the ORNL formula

ORNL ESTIMATE RANGE	MEAN ORNL DIFFER.	STD. DEV. DIFFER.	A BOUND VALUE	B BOUND VALUE	LOWER FC EST.	MEAN TRUE FC	UPPER FC EST.	MEAN ORNL FC	N	RELATIVE FREQUENCY
-0.80 TO -0.60	INSUFFICIENT NUMBER OF SAMPLES - N=0 OR N=1								0	0.0
-0.60 TO -0.40	INSUFFICIENT NUMBER OF SAMPLES - N=0 OR N=1								0	0.0
-0.40 TO -0.20	-0.3041	0.0230	-0.3501	-0.2582	-0.0197	0.0475	0.1147	-0.2566	9	0.9%
-0.20 TO -0.00	-0.1621	0.0707	-0.3036	-0.0207	-0.0234	0.0765	0.1764	-0.0856	50	5.1%
-0.00 TO 0.20	-0.0456	0.0850	-0.2155	0.1244	-0.0196	0.1552	0.3299	0.1096	50	16.4%
0.20 TO 0.40	0.0268	0.0971	-0.1674	0.2210	0.0673	0.2768	0.4862	0.3035	50	18.0%
0.40 TO 0.60	0.0277	0.0779	-0.1282	0.1836	0.2849	0.4601	0.6353	0.4878	50	20.1%
0.60 TO 0.80	0.0101	0.0422	-0.0742	0.0944	0.5351	0.6858	0.8364	0.6958	50	18.4%
0.80 TO 1.00	-0.0002	0.0172	-0.0346	0.0341	0.7707	0.9060	1.0413	0.9058	50	21.1%

TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%

FCORNL - FC : OVERALL MEAN BIAS = -0.00817 ST. DEV. = 0.08339

AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES = 0.70340

(0 to 0.2). Estimates larger than 0.2 tend to have little mean bias. However, individual estimates are fairly uncertain, as evidenced by standard deviations in the range of 0.04 to 0.09 for most categories.

Table 4-3 is the Case 1L main output table for the ORNL formula. In Case 1L, conditions are the same as for Case 1H, except that there are 10 samples per estimate rather than just one, with a constant 100 organisms per cohort. The multiple samples for each estimate would be expected to reduce variation, and it does, by roughly a factor of three. There is a concomitant reduction in the bias, both overall and within sorting categories. This is also to be expected, because the estimates are approaching conditions where the ORNL estimate should produce unbiased estimates.

Table 4-4 presents input data for Case 2, which represents a plausible set of parameters (but without variation) for a situation where larval tables with pumps are used to sample at the intake and the discharge. Table 4-5 is the main output table from this run for the ORNL formula, while Table 4-6 is the corresponding main output table for the OTHER formula. The ORNL formula consistently overestimates the true f-factor, with the bias being greater for small f-factor values. The OTHER formula tends to underestimate the true f-factor value. Estimates between 0 and 0.4 obtained with the OTHER formula tend to be less biased (although also with more variation in the bias) than such estimates obtained with the ORNL formula.

Table 4-7 shows the input data file for Case 2H, which has variation in the parameters. As was true for Case 1, the variation has been made symmetrical about the mean values (Case 2), and the amount of variation for each parameter is a function of that parameter's mean value. As a consequence, however, the range of variation here is not necessarily the same at the intake as at the discharge.

Tables 4-8 and 4-9 are the Case 2H main output tables for the ORNL and the OTHER formulae, respectively. Estimates from both formulae are considerably more variable than in Case 2. The OTHER formula now, on the average, consistently underestimates the true f-factor, while the ORNL formula usually overestimates the true value. The ORNL formula is the better estimator for large f-factor values, having both lower variance and smaller bias, but this is not true for estimates in the range of 0.2 to 0.4, where the OTHER formula performs better.

Table 4-10 is the Case 2L main output table for the ORNL formula. In Case 2L, conditions are the same as for Case 2H, except that there are 10 samples per estimate rather than just one, with a constant 100 organisms per cohort. As in Case 1, the reduced effective variation engendered by the multiple samples shows up as reduced variation of the estimates. In this case, however, there is no effective reduction in the mean bias of the estimates. In the two categories between 0 and 0.4, the mean bias actually increased when variation in the input parameters was reduced.

Table 4-3. Main output table for Case 1L for the ORNL formula

```
    ORNL              MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN      N    RELATIVE
    ESTIMATE          ORNL      DEV.      BOUND     BOUND     FC        TRUE      FC        ORNL           FREQUENCY
    RANGE             DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                            0       0.0

-0.60  TO -0.40             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                            0       0.0

-0.40  TO -0.20             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                            0       0.0

-0.20  TO -0.00  -0.0574   0.0227  -0.1028  -0.0121   0.0078   0.0288   0.0499  -0.0286   10       1.0%

-0.00  TO  0.20  -0.0058   0.0445  -0.0948   0.0831  -0.0184   0.1043   0.2270   0.0985   50      19.5%

 0.20  TO  0.40   0.0063   0.0284  -0.0505   0.0630   0.1658   0.3021   0.4389   0.3084   50      20.4%

 0.40  TO  0.60   0.0007   0.0207  -0.0408   0.0422   0.3709   0.5001   0.6293   0.5008   50      20.4%

 0.60  TO  0.80  -0.0009   0.0137  -0.0283   0.0264   0.6115   0.7093   0.8072   0.7084   50      18.2%

 0.80  TO  1.00  -0.0007   0.0049  -0.0105   0.0090   0.7956   0.9133   1.0309   0.9125   50      20.5%


    TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


    FCORNL - FC : OVERALL MEAN BIAS =     -0.00024     ST. DEV. =      0.02544


    AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.70622
```

Table 4-4. Input data for Case 2, intended to plausibly simulate a situation where larval tables with pumps are used, but with no variation

```
CASE 2
   .9   .9               F1: AMBIENT ALIVE.
   .6   .6   .4   .4     F2: RETENTION OF AMBIENT DEAD.
   .9   .9               F3: SUSCEPTIBILITY OF AMBIENT ALIVE TO INTAKE AREA.
   .7   .7  .85  .85     F4: CATCHABILITY OF LIVE.
   .8   .8   .7   .7     F5: NET SURVIVAL OF LIVE.
  .95  .95  .95  .95     F6: RETENTION OF NET-KILLED.
  .95  .95               F7: RETENTION OF PLANT-KILLED.
  0.0  1.0              PSV: PROBABILITY OF SURVIVING PLANT PASSAGE.
94993                   IX: RANDOM NUMBER INITIATOR (I5).
 1000                   NEST: TOTAL NUMBER OF ESTIMATES (I5).
    1                   NSAMP: NUMBER OF SAMPLES FOR EACH ESTIMATE (I5).
   1. 100.              CHRTMN, CHRTMX: MIN. AND MAX. COHORT SIZES PER SAMPLE.
   50                   NZ: NUMBER OF ESTIMATES NEEDED TO FILL A SORTING CATEGORY.
```

Table 4-5. Main output table for Case 2 for the ORNL formula

```
  ORNL             MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN      N    RELATIVE
  ESTIMATE         ORNL      DEV.      BOUND     BOUND     FC        TRUE      FC        ORNL           FREQUENCY
  RANGE            DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                      0      0.0

-0.60  TO -0.40           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                      0      0.0

-0.40  TO -0.20           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                      0      0.0

-0.20  TO -0.00           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                      0      0.0

-0.00  TO  0.20  0.0823   0.0007    0.0809    0.0837   -0.0061    0.0598    0.1256    0.1421   50      9.3%

 0.20  TO  0.40  0.0823   0.0013    0.0798    0.0848    0.0806    0.2057    0.3307    0.2880   50     20.0%

 0.40  TO  0.60  0.0737   0.0040    0.0658    0.0816    0.3009    0.4174    0.5340    0.4911   50     22.6%

 0.60  TO  0.80  0.0536   0.0079    0.0377    0.0695    0.4994    0.6388    0.7781    0.6924   50     23.4%

 0.80  TO  1.00  0.0210   0.0116   -0.0022    0.0442    0.7324    0.8757    1.0190    0.8967   50     24.7%


  TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


  FCORNL - FC : OVERALL MEAN BIAS =      0.05831     ST. DEV. =      0.02489


  AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.73005
```

Table 4-6. Main output table for Case 2 for the OTHER formula

```
     OTHR              MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN       N     RELATIVE
     ESTIMATE          OTHR      DEV.      BOUND     BOUND     FC        TRUE      FC        OTHR             FREQUENCY
     RANGE             DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60              INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                             0       0.0

-0.60  TO -0.40              INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                             0       0.0

-0.40  TO -0.20              INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                             0       0.0

-0.20  TO -0.00              INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                             0       0.0

-0.00  TO  0.20   0.0376   0.0134   0.0108   0.0644  -0.0189   0.0839   0.1866   0.1215    50     18.0%

 0.20  TO  0.40  -0.0307   0.0243  -0.0793   0.0179   0.1651   0.3256   0.4861   0.2949    50     27.8%

 0.40  TO  0.60  -0.1306   0.0313  -0.1933  -0.0679   0.4526   0.6304   0.8083   0.4999    50     34.1%

 0.60  TO  0.80  -0.2306   0.0244  -0.2794  -0.1817   0.7751   0.9004   1.0256   0.6698    50     20.1%

 0.80  TO  1.00              INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                             0       0.0


   TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


   FCOTHR - FC : OVERALL MEAN BIAS =      -0.09438      ST. DEV. =       0.09368


   AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.73005
```

Table 4-7. Input data for Case 2H, which is similar to Case 2 but with variation

```
CASE 2H
  .85  .95               F1: AMBIENT ALIVE.
  .4   .8   .2   .6      F2: RETENTION OF AMBIENT DEAD.
  .85  .95               F3: SUSCEPTIBILITY OF AMBIENT ALIVE TO INTAKE AREA.
  .55  .85 .775 .925     F4: CATCHABILITY OF LIVE.
  .7   .9  .55  .85      F5: NET SURVIVAL OF LIVE.
 .925 .975 .925 .975     F6: RETENTION OF NET-KILLED.
 .925 .975               F7: RETENTION OF PLANT-KILLED.
 0.0  1.0               FSV: PROBABILITY OF SURVIVING PLANT PASSAGE.
40325                   IX: RANDOM NUMBER INITIATOR (I5).
 1000                   NEST: TOTAL NUMBER OF ESTIMATES (I5).
    1                   NSAMP: NUMBER OF SAMPLES FOR EACH ESTIMATE (I5).
   1. 100.              CHRTMN, CHRTMX: MIN. AND MAX. COHORT SIZES PER SAMPLE.
   50                   NZ: NUMBER OF ESTIMATES NEEDED TO FILL A SORTING CATEGORY.
```

Table 4-8. Main output table for Case 2H for the ORNL formula

```
  ORNL               MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN       N    RELATIVE
  ESTIMATE           ORNL      DEV.      BOUND     BOUND     FC        TRUE      FC        ORNL            FREQUENCY
  RANGE              DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60            INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0     0.0

-0.60  TO -0.40            INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0     0.0

-0.40  TO -0.20            INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0     0.0

-0.20  TO -0.00  -0.1220   0.0502  -0.2225  -0.0215  -0.0249   0.0576   0.1401  -0.0644   18     1.8%

-0.00  TO  0.20  -0.0056   0.0729  -0.1515   0.1403  -0.0076   0.1284   0.2645   0.1228   50    10.8%

 0.20  TO  0.40   0.0754   0.0947  -0.1140   0.2648   0.0163   0.2142   0.4120   0.2896   50    18.5%

 0.40  TO  0.60   0.0858   0.0811  -0.0764   0.2480   0.2238   0.4107   0.5975   0.4964   50    21.9%

 0.60  TO  0.80   0.0559   0.0508  -0.0457   0.1574   0.4667   0.6323   0.7979   0.6882   50    22.5%

 0.80  TO  1.00   0.0254   0.0243  -0.0232   0.0741   0.7117   0.8695   1.0274   0.8950   50    24.5%


 TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


 FCORNL - FC : OVERALL MEAN BIAS =       0.05598     ST. DEV. =       0.07930


 AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.72965
```

Table 4-9. Main output table for Case 2H for the OTHER formula

```
    OTHR              MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN      N    RELATIVE
    ESTIMATE          OTHR      DEV.      BOUND     BOUND     FC        TRUE      FC        OTHR           FREQUENCY
    RANGE             DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                          0      0.0

-0.60  TO -0.40             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                          0      0.0

-0.40  TO -0.20             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                          0      0.0

-0.20  TO -0.00  -0.1178   0.0448  -0.2073  -0.0282  -0.0264   0.0751   0.1766  -0.0426   17      1.7%

-0.00  TO  0.20  -0.0246   0.1001  -0.2249   0.1756  -0.0404   0.1487   0.3378   0.1241   50     17.4%

 0.20  TO  0.40  -0.0202   0.1195  -0.2592   0.2188   0.0490   0.3330   0.6171   0.3128   50     28.2%

 0.40  TO  0.60  -0.0999   0.1051  -0.3101   0.1103   0.3064   0.5825   0.8587   0.4826   50     32.7%

 0.60  TO  0.80  -0.1849   0.0769  -0.3387  -0.0310   0.6897   0.8666   1.0436   0.6817   50     19.3%

 0.80  TO  1.00  -0.1443   0.0286  -0.2014  -0.0872   0.8910   0.9537   1.0165   0.8094    7      0.7%


  TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


  FCOTHR - FC : OVERALL MEAN BIAS =     -0.09000     ST. DEV. =      0.12064


  AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.72927
```

Table 4-10. Main output table for Case 2L for the ORNL formula

```
    ORNL               MEAN      STD.       A         B         LOWER     MEAN      UPPER     MEAN       N     RELATIVE
    ESTIMATE           ORNL      DEV.       BOUND     BOUND     FC        TRUE      FC        ORNL             FREQUENCY
    RANGE              DIFFER.   DIFFER.    VALUE     VALUE     EST.      FC        EST.      FC

 -0.80  TO -0.60             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0       0.0

 -0.60  TO -0.40             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0       0.0

 -0.40  TO -0.20             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0       0.0

 -0.20  TO -0.00  -0.0206   0.0047  -0.0301  -0.0111  -0.0045   0.0048   0.0141  -0.0158    3       0.3%

 -0.00  TO  0.20   0.0703   0.0439  -0.0175   0.1581  -0.0156   0.0616   0.1388   0.1319   50      13.0%

  0.20  TO  0.40   0.0952   0.0248   0.0455   0.1448   0.0704   0.1990   0.3275   0.2941   50      20.3%

  0.40  TO  0.60   0.0755   0.0236   0.0284   0.1227   0.3161   0.4350   0.5540   0.5105   50      21.1%

  0.60  TO  0.80   0.0490   0.0178   0.0134   0.0846   0.5269   0.6568   0.7868   0.7058   50      20.7%

  0.80  TO  1.00   0.0197   0.0125  -0.0052   0.0446   0.7585   0.8870   1.0154   0.9067   50      24.6%


   TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


   FCORNL - FC : OVERALL MEAN BIAS =       0.05887     ST. DEV. =       0.03542


   AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.72985
```

5. DISCUSSION

The results in Section 4 illustrate just one facet of the potential uses of the ENTRAN program. Other potential uses are also mentioned in Section 3. Here, we discuss further the applicability of the program.

The program is intended primarily for application to a specific situation, because experience has shown that the factors in the model will likely vary widely between different types of sampling gear (O'Connor and Schaffer 1977, McGroddy and Wyman 1977) and also between species (Vaughan 1979, Ecological Analysts 1977a). We intend for the program to be viewed as flexible, in that the biological assumptions built into the present version may not best describe, or even adequately describe, a particular sampling situation or species. Modification of the code, as appropriate, will require expertise in both biology (to decide on the modifications) and computer programming (to implement the modifications and to verify proper operation of the revised code). Guidance about some modifications is provided in Section 3.

When suitably modified to reflect what is known or suspected about the biology of a particlar sampling situation, the designer of the sampling program can make good use of ENTRAN in several areas. The exercise of providing ranges of values for the parameters will likely indicate to the biologist where uncertainty about these parameters is greatest. In conjunction with this exercise, sensitivity analysis of the model will indicate profitable areas for further research, or will indicate attributes of sampling gear which the designer of a sampling program should look for. In recent years, techniques have been devised to try to quantify individual factors included in the model. For example, Ecological Analysts, Inc., has used a technique of "live releases" of hatchery-reared larvae near intake sampling gear to attempt to quantify gear-induced mortality and retention, relating to factors FP5, FP6, F5, and F6 (S. W. Christensen, personal observation). Such a technique, used in conjunction with field samples, can also aid in quantifying the fraction of ambient organisms alive (F1). ENTRAN can be used to decide which such investigations will be most helpful in improving the reliability of estimates.

ENTRAN can also aid in determining how to design the sampling program and how to interpret the results. For example, although collection with pumps and larval tables may be advantageous for survival of captured organisms, sample sizes may be smaller than with nets (Ecological Analysts 1977b). The implications of this trade-off between sample size and sampling gear survival for statistical detection of entrainment mortality are explored in more detail in Vaughan and Kumar (1981). ENTRAN can be used to study the relative effects of estimating the f-factor from many small samples versus fewer larger samples, and it can indicate how reliability is influenced by small sample sizes, given uncertainty in the parameters.

ENTRAN can also be used in a general way to evaluate the reliability of f-factor estimates calculated from sample data. Depending on the degree of confidence in the input parameters, the program will be useful in evaluating the bias of estimates and in indicating how estimates calculated with a particular formula can best be "corrected." If the idea of correcting or adjusting the estimates seems repugnant, the biologist should reflect on the fact that no formula exists to properly calculate the f-factor in the presence of all realistic biological phenomena. Therefore, the correction process is needed not just to adjust for variation in the real world, but also to compensate for violating the assumptions underlying any available formula. Other related models, such as that of Boreman and Goodyear (1981), will also prove useful for this purpose.

6. CONCLUSIONS AND RECOMMENDATIONS

ENTRAN is a computer code to assist in evaluating the accuracy and precision of estimates of entrainment mortality. We have the following conclusions and recommendations concerning its use:

1. ENTRAN can be used in conjunction with sampling programs designed to estimate entrainment mortality, in order to guide the design of the sampling program and to design related experiments for improving confidence in the entrainment mortality estimates.
2. ENTRAN can be used, both by those responsible for the sampling program and by those responsible for using the resulting estimates, to evaluate the reliability of estimates and perhaps to adjust estimates of the entrainment mortality factor.
3. ENTRAN should be considered to be adaptable and flexible, and it should in fact be modified to the extent necessary to suit it to any particular situation.

7. REFERENCES

Barnthouse, L. W., J. B. Cannon, S. W. Christensen, A. H. Eraslan, J. L. Harris, K. H. Kim, M. E. LaVerne, H. A. McLain, B. D. Murphy, R. J. Raridon, T. H. Row, R. D. Sharp, and W. Van Winkle. 1977. A selective analysis of power plant operation on the Hudson River with emphasis on the Bowline Point Generating Station. ORNL/TM-5877 (vols. 1 and 2). Oak Ridge National Laboratory, Oak Ridge, Tennessee.

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

Boreman, J., C. P. Goodyear, and S. W. Christensen. 1981. An empirical methodology for estimating entrainment losses at power plants sited on estuaries. Trans. Am. Fish. Soc. 110(2):255-262.

Boreman, J., and C. P. Goodyear. 1981. Biases in the estimation of entrainment mortality. pp. 79-81. IN L. D. Jensen (ed.) Issues Associated with Impact Assessment: Proceedings of the Fifth National Workshop on Entrainment and Impingement. Ecological Analysts, Inc., Sparks, Maryland.

Cada, G. F., and G. L. Hergenrader. 1978. An assessment of sampling mortality of larval fishes. Trans. Am. Fish. Soc. 107(2):269-274.

Caswell, H. 1976. Community structure: A neutral model analysis. Ecol. Monogr. 46(3):327-354.

Coutant, C. C. 1970. Biological aspects of thermal pollution. I. Entrainment and discharge canal effects. CRC Crit. Rev. in Environ. Control 1(3):341-381.

Coutant, C. C. 1971. Effects on organisms of entrainment in cooling water: Steps toward predictability. Nucl. Saf. 12(6):600-607.

Ecological Analysts, Inc. 1976. Bowline Point Generating Station entrainment survival and abundance studies, Volume I. 1975 Annual Interpretive Report. Prepared for Orange and Rockland Utilities, Inc. Ecological Analysts, Inc., Sparks, Maryland.

Ecological Analysts, Inc. 1977a. Survival of entrained ichthyoplankton and macroinvertebrates at Hudson River power plants. Testimony prepared for Central Hudson Gas and Electric Corporation, Consolidated Edison Company of New York, Inc., and Orange and Rockland Utilities, Inc. Ecological Analysts, Inc., Sparks, Maryland.

Ecological Analysts, Inc. 1977b. A review of entrainment study methodologies: Abundance and survival. Prepared for Empire State Electrical Energy Research Corporation, 1271 Avenue of the Americas, New York City, New York.

Eraslan, A. H., W. Van Winkle, R. D. Sharp, S. W. Christensen, C. P. Goodyear, R. M. Rush, and W. Fulkerson. 1976. A computer simulation model for the striped bass young-of-the-year population in the Hudson River. ORNL/NUREG-8 (Special). Oak Ridge National Laboratory, Oak Ridge, Tennessee. 208 pp.

Goodyear, C. P. 1977. Mathematical methods to evaluate entrainment of aquatic organisms by power plants. FWS/OBS-76/20.3. U.S. Fish and Wildlife Service, Ann Arbor, Michigan. 17 pp.

Griemsmann, R. J. 1973. Testimony of Russell J. Griemsmann, M. S., on Distribution of Early Life Stages of Striped Bass near Indian Point and Mortality of Early Life Stages of Striped Bass on Passage through Indian Point. Testimony presented before the United States Atomic Energy Commission in the Matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2), Docket No. 50-247, February 19, 1973.

Kerr, J. E. 1953. Studies on fish preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Company. Fish Bulletin No. 92. California Department of Fish and Game, Sacramento, California.

Lawler, J. P. 1972. Effect of Entrainment and Impingement at Indian Point on the Population of the Hudson River Striped Bass, Modifications and Additions to Testimony of April 5, 1972. Written testimony presented on October 30, 1972, before the U.S. Atomic Energy Commission in the matter of Consolidated Edison Company of New York, Inc. (Indian Point Station, Unit No. 2), Docket No. 50-247.

Lawler, Matusky & Skelly Engineers (LMS). 1975. Report on development of a real-time, two-dimensional model of the Hudson River striped bass population. Prepared for Consolidated Edison Company of New York, Inc., New York. 71 pp.

McGroddy, P. M., and R. L. Wyman. 1977. Efficiency of nets and a new device for sampling living fish larvae. J. Fish. Res. Board Can. 34:571-574.

McFadden, J. T. (ed.). 1977. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River estuary, with emphasis on striped bass and other fish populations. Submitted to Consolidated Edison Company of New York, Inc., New York.

National Environmental Policy Act of 1969 (NEPA). 1970. Public Law 91-190, 83 Stat. 852 (January 1, 1970).

New York University Medical Center, Institute of Environmental Medicine, Laboratory for Environmental Studies (NYU). 1973. Hudson River ecosystem studies, effects of entrainment by the Indian Point Power Plant on Hudson River Estuary biota, progress report for 1971 and 1972. Prepared for Consolidated Edison Company of New York, Inc., New York.

O'Connor, J. M., and S. A. Schaffer. 1977. The effects of sampling gear on the survival of striped bass ichthyoplankton. Chesapeake Sci. 18(3):312-315.

UNESCO. 1968. Zooplankton Sampling. Monogr. Oceanogr. Methodol. 2. 174 pp.

U.S. Atomic Energy Commission (USAEC). 1972. Final Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant, Unit No. 2 (Docket No. 50-247), Vols. I and II.

U.S. Nuclear Regulatory Commission (USNRC). 1975. Final Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant, Unit No. 3. NUREG-75/002 and NUREG-75/003, Docket No. 50-286, Vols. I and II.

Vaughan, D. S. 1979. Entrainment Mortality Factors for Hudson River Ichthyoplankton at Bowline Point, Lovett, Indian Point, Roseton, and Danskammer power plants. Chapter VII. IN J. Boreman, L. W. Barnthouse, D. S. Vaughan, C. P. Goodyear, S. W. Christensen, K. D. Kumar, and B. L. Kirk (contributors), Entrainment Impact Estimates for Six Fish Populations Inhabiting the Hudson River Estuary. Written testimony presented before the U.S. Environmental Protection Agency, Region II, in the Matter of Adjudicatory Hearing Docket No. C/II-WP-77-01. 125 pp.

Vaughan, D. S., and K. D. Kumar. 1981. Detectability and precision of estimates of entrainment mortality of ichthyoplankton. ORNL/NUREG/TM-435 (NUREG/CR-1984). Oak Ridge National Laboratory, Oak Ridge, Tennessee.

WAPORA, Inc. 1975. Continuing ecological studies of the Ohio River, 1974. Submitted to Appalachian Power Company, Cincinnati Gas and Electric Company, Indiana and Michigan Electric Company, Ohio Edison Company, Ohio Power Company, and Ohio Valley Electric Corporation.

APPENDIX A. OPERATION OF THE COMPUTER PROGRAM "ENTRAN"

The computer program ENTRAN operates in the following manner:

1. The user specifies lower and upper bounds for each factor in Table 2-1 the symbol for which begins with "F." For F1 and F3 the same values apply to the intake as to the discharge; the remaining factors in this group are either not applicable to the intake (i.e., F7 and FSV) or may in general have different values at the intake than at the discharge. FSV should normally be allowed to vary over the full range from 0 to 1; the other factors will usually have a lower bound greater than 0, but may have an upper bound equal to 1.

2. The user specifies a minimum and a maximum "cohort size," denoted CHRTMN and CHRTMX, representing the range of abundances of vulnerable organisms, in relation to the volume of a sample. These numbers may be somewhat larger than the range of sizes of a typical "catch," to allow for avoidance and extrusion. Each simulated individual sample pair will utilize the same cohort size at intake and discharge, chosen from a uniform distribution bounded by CHRTMN and CHRTMX. Although organisms might logically be represented as integers in the program, it is much simpler to represent them as real numbers, presuming that the sample sizes used to comprise an "estimate" (see below) will not be extremely small.

3. The user specifies NSMPL, the number of samples to be used in constructing each estimate of the f-factor. It is common practice to sample repeatedly over many weeks to gather data for f-factor estimates and to calculate one estimate based on combining the results from the individual samples as follows:

$$\mathrm{ALIVE} = \sum_{i=1}^{\mathrm{NSMPL}} A_i \tag{A-1}$$

and

$$\mathrm{DEAD} = \sum_{i=1}^{\mathrm{NSMPL}} D_i \ , \tag{A-2}$$

where ALIVE and DEAD are as used in Eq. (2-1), and A_i and D_i are the numbers alive and dead respectively in individual sample i. For each sample, the program chooses values of the factors discussed in step 1 (i.e., most of the factors in Table 2-1) from uniform distributions bounded by the specified minimum and maximum values.

4. The user specific NEST, the total number of estimates to be generated ($1 \le NEST \le 1000$); NZ, the number of estimates needed to fill a sorting category (explained below) ($1 \le NZ \le 50$); and IX, an odd five-digit integer to initialize the random number generator.

5. In connection with the random number generator, the user must also ensure that the integer variable MMM in the program itself is set equal to an integer constant of the maximum magnitude (in standard precision) for the computer being used.

6. The program prints out the input data.

7. The program begins an analysis for ORNL (as opposed to OTHER) estimates (i.e., the ORNL estimates are the "target" estimates). NEST lines are printed, each giving the true f-factor, the f-factor estimated by both the ORNL and the OTHER formulae, and the bias for each of the estimates. Next is a section where various means and standard deviations are printed. If the number of values involved in calculating the mean is 0 or 1, an artificially very large number is intentionally calculated instead, which results in the printing of asterisks (because a valid standard deviation cannot be calculated). Most of these means and standard deviations reflect a sorting process, wherein each ORNL estimate is examined and, if possible, assigned to a category if the category does not already have NZ entries. The "sorting categories" cover the range from -0.8 to 1.0, with the upper boundary of each category being 0.2 greater than the lower boundary: -0.8 to -0.6, -0.6 to -0.4, ..., 0.8 to 1.0. Next, a table is printed out, arranged by sorting category. Within each category, the following information is provided:

   (a) "MEAN ORNL DIFFERENCE": the value of the expression

   $$\sum_{i=1}^{NZ} \frac{FCORNL_i - FCREAL_i}{NZ} , \qquad (A-3)$$

   where $FCORNL_i$ is the i^{th} f-factor estimate within the sorting category and $FCREAL_i$ is the corresponding true f-factor. This is one of the key results of the program in that it provides an indication of the degree of bias of an f-factor estimate, given that it falls within the particular category.

   (b) "STD. DEV. DIFFER.": the standard deviation of the mean difference calculted in (a).

   (c) "A BOUND VALUE": the mean difference calculated in (a), minus twice the standard deviation of this difference.

(d) "B BOUND VALUE": the mean difference calculated in (a), plus twice the standard deviation of this difference. If the number of entries in the sorting category is large enough, these two numbers, the "A BOUND VALUE" and the "B BOUND VALUE," represent approximate 95% confidence intervals for the bias, under the assumption that the biases within a sorting category are approximately normally distributed. Because this assumption has not been tested, this interpretation should be approached with considerable caution. Vaughan and Kumar (1981) demonstrate that if the sample size times the fraction collected alive at the intake is large, and estimates are different enough from 0 and from 1 that truncation effects are not important, the assumption of normality may in fact be good.

(e) "LOWER FC EST.": the mean true f-factor within the sorting category, minus twice the standard deviation of this mean true f-factor.

(f) "MEAN TRUE FC": the mean true f-factor within the sorting category. For example, if the ORNL formula were to estimate a negative f-factor (e.g., -0.72), the actual or true f-factor would still be within the range of 0 to 1 (by definition). For the first sorting category (ORNL estimates greater than -0.8 but less than or equal to -0.6), most of the true f-factor values will likely lie in the lower portion of the range of permissible true values from 0 to 1, but this is by no means certain. The "MEAN TRUE FC" indicates the mean true f-factor value, given that the ORNL estimate is within the particular sorting category.

(g) "UPPER FC EST.": the mean true f-factor within the sorting category, plus twice the standard deviation of this mean true f-factor. The values of "LOWER FC EST." and "UPPER FC EST." represent approximate 95% confidence intervals for the true f-factors corresponding to the particular category for the ORNL estimate, under the assumption that these true f-factors are approximately normally distributed. Because this assumption has not been tested and is clearly not strictly true because the true f-factor itself is bounded by values provided to the program (the widest permissible range being 0 to 1), this interpretation should be approached with considerable caution. Again, see Vaughan and Kumar (1981) for encouragement.

(h) "MEAN ORNL FC": The mean, within the sorting category, of the up-to-NZ estimates of the f-factor from the ORNL formula. This mean should obviously never lie outside of the bounds of the sorting category, because the individual estimates which comprise it must lie in the category.

(i) "N": the number of estimates in the sorting category. The maximum is determined by the input number NZ (which must not be greater than 50 unless array sizes are altered in the program). If N is less than NZ, either not enough samples were taken to fill the category or, perhaps, the estimating formula will never calculate values falling in the particular category, given the other input values. For example, when the model is run with values meeting the assumptions underlying the ORNL formula, this formula will never calculate negative estimates, and the first four categories will always be empty.

(j) "RELATIVE FREQUENCY": the percentage of all estimates from the ORNL formula which fall in the particular category. This quantity cannot be obtained from N, (see i), because N is truncated at NZ, and also because some estimates may fall outside the defined sorting categories (i.e., be less than or equal to -0.8). A perfectly performing formula would be expected to have a relative frequency of approximately 20% in each of the positive sorting categories if FSV is permitted to range from 0 to 1.

Following the table described in 7(a) through 7(j), some additional information is printed out. A line provides the "total percentage of all samples accounted for in above table"; if it is not 100%, some estimates were smaller (more negative) than the smallest sorting category. The next line prints out the mean bias and the standard deviation of this bias for all estimates made with the ORNL formula, regardless of sorting category. A final line provides the "average proportion of organisms alive in intake samples," (PLINT), calculated as:

$$\sum_{i=1}^{NEST} \frac{P_{IS_i}}{NEST} \quad , \tag{A-4}$$

where the individual P_{IS} values are combined over the individual samples comprising an estimate [i.e., applying Eqs. (A-1) and (A-2), and then Eq. (2-1)]. Biologists will find PLINT helpful in calibrating this program to specific field sampling situations.

8. The entire process described in item 7 above is repeated, but this time for estimates derived from the OTHER formula (as opposed to the ORNL formula). This analysis, if not desired, can be eliminated by altering the main DO-loop to read: "DO 950 ICHOSE = 1,1" instead of "...1,2".

APPENDIX B. PROGRAM STRUCTURE, INPUT, AND KEY VARIABLES

The ENTRAN computer program is divided into a Main Program and two subroutines, URAND and RANSET. Appendices C and D contain listings of the program and sample output, respectively. The only purpose of the subroutines is to generate pseudo-random numbers. The Main Program is described below.

The Main Program first reads in the parameter values, the bounds on the randomly chosen parameter values, and a pseudo-random number generator initiator. The parameters are chosen from a uniform distribution between the specified bounds. Next, the input information is printed out.

DO-loop 950 defines first the "ORNL" (ICHOSE=1) and second the "OTHER" (ICHOSE=2) formula as being the "target" estimate, in that the sorting categories are applied to the target estimates and the final table is applicable only to those estimates.

In DO-loop 500, the parameter sets are randomly selected. Estimates of the f-factor from the ORNL formula, "FCORN" and from the other formula, "FCOTHR" are computed for each set of parameters.

In DO-loop 500, the means of "FCORN," "FCOTHR," as well as biases, are computed.

In DO-loops 750 and 770, the standard deviations of the above quantities are calculated.

In the remainder of the Main Program, tables of values are printed out. The ORNL estimates (and later, in another pass through the program, a set of OTHER estimates) are divided into ranges, -0.80 to -0.60, -0.60 to -0.40, ..., 0.80 to 1.00, for comparison of the estimates with the true f-factor values.

Data Input

A typical input data set for the program (Case 1) is displayed in Table B-1. The data cards are described below. In general, W, X, Y, and Z should be greater than 0 and less than or equal to 1, although some factors (i.e., F2 and F6) could be equal to 0 without causing problems. Also, X and Z must be greater than or equal to Q and Y, respectively.

CARD 0

This card is skipped, and is therefore available to label the data set.

Table B-1. A listing of input cards for Case 1

```
                                                                                CARD
CASE 1                                                                            0
   .9    .9                   F1: AMBIENT ALIVE.                                  A
   .5    .5    .5    .5   F2: RETENTION OF AMBIENT DEAD.                          B
   .9    .9                   F3: SUSCEPTIBILITY OF AMBIENT ALIVE TO INTAKE AREA. C
   1.    1.    1.    1.   F4: CATCHABILITY OF LIVE.                               D
  .75   .75   .75   .75   F5: NET SURVIVAL OF LIVE.                               E
   1.    1.    1.    1.   F6: RETENTION OF NET-KILLED.                            F
   1.    1.                   F7: RETENTION OF PLANT-KILLED.                      G
  0.0   1.0                 PSV: PROBABILITY OF SURVIVING PLANT PASSAGE.          H
20469                       IX: RANDOM NUMBER INITIATOR (I5).                     I
  500                       NEST: TOTAL NUMBER OF ESTIMATES (I5).                 J
    1                       NSAMP: NUMBER OF SAMPLES FOR EACH ESTIMATE (I5).      K
   1.  100.                 CHRTMN, CHRTMX: MIN. AND MAX. COHORT SIZES PER SAMPLE. L
   50                       NZ: NUMBER OF ESTIMATES NEEDED TO FILL A SORTING CATEGORY. M
```

CARD A

W, X

FORMAT: 2F5.0

C = X - W = A(1) = Lower limit on ambient alive fish, F1

W = A(2) = Upper limit on ambient alive fish, F1

CARD B

W, X, Y, Z

FORMAT: 4F5.0

D = Z - Y = A(3) = Lower limit on retention of ambient dead, F2

Y = A(4) = Upper limit on retention of ambient dead, F2

C = X - W = A(15) = Lower limit on FP2

W = A(16) = Upper limit on FP2

CARD C

W, X

FORMAT: 2F5.0

C = X - W = A(5) = Lower limit on susceptibility of ambient live to intake area, F3

W = A(6) = Upper limit on susceptibility of ambient live to intake area, F3

CARD D

W, X, Y, Z

FORMAT: 4F5.0

D = Z - Y = A(7) = Lower limit on catchability of live, F4

Y = A(8) = Upper limit on catchability of live, F4

C = X - W = A(17) = Lower limit on FP4

W = A(18) = Upper limit on FP4

CARD E

W, X, Y, Z

FORMAT: 4F5.0

D = Z - Y = A(9) = Lower limit on net survival of live, F5

Y = A(10) = Upper limit on net survival of live, F5

C = X - W = A(19) = Lower limit on FP5

W = A(20) = Upper limit on FP5

CARD F

W, X, Y, Z

FORMAT: 4F5.0

D = Z - Y = A(11) = Lower limit of retention of net-killed, F6

Y = A(12) = Upper limit of retention of net-killed, F6

C = X - W = A(21) = Lower limit on FP6

W = A(22) = Upper limit on FP6

CARD G

W, X

FORMAT: 2F5.0

C = X - W = A(13) = Lower limit on retention of plant-killed, F7

W = A(14) = Upper limit on retention of plant-killed, F7

CARD H

W, X

FORMAT: 2F5.0

C = X - W = A(23) = Lower limit on fraction surviving plant passage, FSV

W = A(24) = Upper limit on fraction surviving plant passage, FSV

CARD I

IX

FORMAT: I5

IX = Random number initiator; must be an odd 5-digit integer (in general, it must be less than the largest integer possible for the computer)

CARD J

NEST

FORMAT: I5

NSAMP = Number of estimates to be generated (maximum: 1000)

CARD K

NSAMP

FORMAT: I5

NSAMP = Number of samples simulated for each estimate

CARD L

CHRTMN, CHRTMX

FORMAT: 2F5.0

CHRTMN = Minimum cohort size for a sample

CHRTMX = Maximum cohort size for a sample

CARD M

NZ

FORMAT: I5

NZ = Number of estimates needed to fill a sorting category.

Main Program Variables

Table B-2 lists the main program variables and provides a brief description of each. The concept of the "target" estimate was explained in step number 7 of Appendix A, and it is mentioned above in the discussion of the DO-loop 950. The array dimensions are informative about the nature of variables. Array dimensions of 1000 indicate the potential to store each estimate generated. Dimensions of (3,1000) indicate arrays storing (a) all values (first index = 1), (b) non-negative values (first index = 2), or (c) negative values (first index = 3). A dimension of (12,50) indicates an array containing "sorted" estimates or values. Here, first index values of 1 through 3 are not utilized; an array element indexed (4,n) would denote the nth occurrence in the sorting category of an estimate or factor associated with (or being) a "target" estimate in the range of -0.8 to -0.6, and an array element indexed (12,n) would denote the nth occurrence of a factor in the range of 0.8 - 1.0. The dimension limit of 50 defines the maximum permissible value for NZ. Single dimensions of 12 indicate arrays containing one entry for each sorting category (e.g., means, standard deviations).

Program Output

Appendix D contains program output for Case 1. The input is given in Table B-1. To conserve space, portions of the output have been deleted, as indicated. A detailed description of the output format has been provided in Appendix A. Case 1 is used to verify the code, as explained in Section 4.

Table B-2. Important program variables

Variable	Dimensions (if any)	Definition
A	(24)	Array used to read in limits on parameters
AA	(15)	Array by sorting category of lower bound of "error" in target estimate
BB	(15)	Array by sorting category of upper bound of "error" in target estimate
CHRTMN		Minimum cohort size for each sample pair
CHRTMX		Maximum cohort size for each sample pair
DFRAV	(15)	Mean FCORN - FCREAL
DFRVR	(15)	Standard deviation of FCORN - FCREAL
DFTAV	(15)	Mean FCOTHR - FCREAL
DFTVR	(15)	Standard deviation of FCOTHR - FCREAL
F	(7)	Randomly chosen values of parameters, F1 to F7
FCAV		Overall average true f-factor
FCVRR		Overall standard deviation of true f-factor
FC		True probability of entrainment mortality (f-factor)
FCA	(1000)	Array of true f-factor values
FCAVA	(15)	Corrected mean ORNL estimate (bias subtracted)
FC1	(1000)	Array of true f-factor values
FC2	(1000)	Array of true f-factor values when target estimate is non-negative
FC3	(1000)	Array of true f-factor values when target estimate is negative

Table B-2 (continued)

Variable	Dimensions (if any)	Definition
FCORN	(15, 50)	f-factor estimated using ORNL formula, sorted into categories
FCORNA	(3, 1000)	f-factor estimated using ORNL formula. First array index determines whether estimate is comparable to FC1, FC2, or FC3
FCORD	(15, 50)	FCORN - FCREAL by category
FCORDA	(3, 1000)	FCORN - FCREAL (overall)
FCOTD	(15, 50)	FCOTHR - FCREAL by category
FCOTDA	(3, 1000)	FCOTHR - FCREAL (overall)
FCOTH	(15, 50)	f-factor estimated using the "other" formula, sorted into categories
FCOTHA	(3, 1000)	f-factor estimated using the "other" formula (overall)
FCRAV	(15)	Mean true f-factor by sorting category
FCREAL	(15, 50)	True f-factor values, sorted into categories
FCVR	(15)	Same as FCVRR, overall standard deviation of true f-factors
FLO	(10)	Array of lower bounds for discharge parameters
FORAV	(15)	Mean FCORN by sorting category
FORVR	(15)	Standard deviation of FCORN by sorting category
FOTAV	(15)	Mean FCOTHR by sorting category
FOTVR	(15)	Standard deviation of FCOTHR by sorting category
FREQ	(15)	Percentage of all estimates, by category

Table B-2 (continued)

Variable	Dimensions (if any)	Definition
FUP	(10)	Array of upper bounds for discharge parameters
ICHOSE		Assigned value 1 for analysis of ORNL formula and 2 for analysis of "other" formula
IX		Random number initiator (an odd 5-digit integer)
NEST		Number of estimates to be generated for each comparison table
NI	(15)	Array keeping count of the number of entries in each sorting category, Midway through, 0 to 1 values are set to 2
NSMPL		Number of samples to be taken in simulation run for each estimate
NY	(15)	Same as NI, except 0 or 1 values retained
NZ		Number of estimates arbitrarily chosen to be needed to fill a category (NZ ≤ 50)
SAMPLE	(15)	Array of category sample sizes (actual number of estimates per category)
SNI	(15)	Same as SAMPLE, except it has an artifical value of 2 assigned if SAMPLE = 0 or 1
TEST		Upper boundary for a given category
TESTM		Lower boundary for a given category
TOTFRQ		Total percentage of estimates falling into fixed categories. Any missing would be very negative

APPENDIX C

This Appendix consists of a listing of the computer program ENTRAN.

```
C      ENTRAN, A SIMULATION MODEL TO PROBE THE EFFICACY OF TWO
C      FORMULAS FOR ESTIMATING THE ENTRAINMENT MORTALITY FACTOR
C      AT A POWER PLANT.
C
C      PROGRAM AUTHORS:  D. L. DEANGELIS AND S. W. CHRISTENSEN
C                        ENVIRONMENTAL SCIENCES DIVISION
C                        OAK RIDGE NATIONAL LABORATORY
C                        P.O. BOX X
C                        OAK RIDGE, TENNESSEE  37830
C
C      REFERENCE:  CHRISTENSEN, S. W. AND D. L. DEANGELIS.  1982.  THE
C            EFFECT OF STOCHASTIC VARIATION ON ESTIMATES OF THE PROBABILITY
C            OF ENTRAINMENT MORTALITY:  METHODOLOGY, RESULTS, AND
C            USER'S GUIDE.  ORNL/TM-7965, OAK RIDGE NATIONAL LABORATORY,
C            OAK RIDGE, TENNESSEE  37830.
C
C      DATE OF THIS REVISION:  12/13/81
C
       DIMENSION FC1(1000),FC2(1000),FCA(1000),FCREAL(15,50),FCRAV(12)
       DIMENSION FCORN(15,50),FCORD(15,50),FCOTH(15,50),FCOTD(15,50)
       DIMENSION SAMPLE(12),NI(12),SNI(12),F(7)
       DIMENSION FORAV(12),FOTAV(12),DFRAV(12),DFTAV(12),FCAVA(12)
       DIMENSION FLO(10), FUP(10)
       DIMENSION FCORNA(3,1000), FCORDA(3,1000), FCOTHA(3,1000),
      1FCOTDA(3,1000), A(1,24)
       DIMENSION FOTVR(12),FCVR(12),DFTVR(12),FORVR(12),DFRVR(12)
       DIMENSION AA(12), BB(12), FREQ(12),NY(12)
C      READ IN FACTOR VALUES
C      ORDER OF PARAMETERS: INTAKE MINIMUM, INTAKE MAXIMUM, DISCHARGE
C      MINIMUM, DISCHARGE MAXIMUM.
C.....READ IN F1: AMBIENT ALIVE.
       READ(5,38) W,X
   38  FORMAT(/2F5.0)
   40  FORMAT(2F5.0)
       C=X-W
       A(1,1)=C
       A(1,2)=W
C.....READ IN F2: RETENTION OF AMBIENT DEAD.
       READ(5,41) W,X,Y,Z
   41  FORMAT(4F5.0)
       C=X-W
       D=Z-Y
       A(1,3)=D
       A(1,4)=Y
       A(1,15)=C
       A(1,16)=W
C.....READ IN F3: SUSCEPTIBILITY OF AMBIENT LIVE TO INTAKE AREA.
       READ(5,40) W,X
       C=X-W
       A(1,5)=C
       A(1,6)=W
C.....READ IN F4: CATACHABILITY OF LIVE.
       READ(5,41) W,X,Y,Z
       C=X-W
       D=Z-Y
       A(1,7)=D
       A(1,8)=Y
       A(1,17)=C
       A(1,18)=W
C.....READ IN F5: GEAR SURVIVAL OF LIVE.
       READ(5,41) W,X,Y,Z
```

Appendix C. (continued)

```
      C=X-W
      D=Z-Y
      A(1,9)=D
      A(1,10)=Y
      A(1,19)=C
      A(1,20)=W
C.....READ IN F6: RETENTION OF GEAR-KILLED.
      READ(5,41)W,X,Y,Z
      C=X-W
      D=Z-Y
      A(1,11)=D
      A(1,12)=Y
      A(1,21)=C
      A(1,22)=W
C.... READ IN F7: RETENTION OF PLANT-KILLED.
      READ(5,40)W,X
      C=X-W
      A(1,13)=C
      A(1,14)=W
C.....READ IN FSV: RANGE OF PROBABILITY OF SURVIVING PLANT PASSAGE
      READ(5,40)W,X
      C=X-W
      A(1,23)=C
      A(1,24)=W
C
C.....READ IN RANDOM NUMBER INITIATOR
C
C     MMM MUST BE THE LARGEST INTEGER POSSIBLE FOR THE COMPUTER.
C     FOR IBM 3033, USE 2147483647, OR (2**31)-1
C     FOR DEC-10, USE 34359738367, OR (2**35)-1
      MMM=34359738367
C      MMM=2147483647
C     IX MUST BE AN ODD INTEGER LESS THAN MMM.
      READ(5,1001) IX
 1001 FORMAT(I5)
      WRITE(6,2017) IX,MMM
 2017 FORMAT(//,5X,'RANDOM NUMBER INITIATOR = 'I5,/,
     1'      MACHINE-SPECIFIC MAXIMUM INTEGER = ',I11)

      CALL RANSET(MMM,IX)
C
C.....READ IN THE NUMBER OF FINAL ESTIMATES
C
      READ(5,1001) NESTM
C.....READ IN THE NUMBER OF SAMPLES FOR EACH ESTIMATE
      READ(5,1001)NSMPL
C.....READ IN MINIMUM AND MAXIMUM COHORT SIZE
      READ(5,40) CHRTMN,CHRTMX
      CHRTRG=CHRTMX-CHRTMN
C.....READ IN NUMBER OF ESTIMATES PER SORTING CATEGORY
      READ(5,1001) NZ
C
C.....PRINT OUT LIMITS WITHIN WHICH PARAMETERS VARY UNIFORMLY AND RANDOMLY
C
      DO 20 J=1,7
      II=2*J
      I=II-1
      FLO(J) = A(1,II)
      FUP(J) = A(1,I) + A(1,II)
   20 CONTINUE
      FP2LO = A(1,16)
      FP2UP = A(1,15) + A(1,16)
      FP4LO = A(1,18)
      FP4UP = A(1,17) + A(1,18)
      FP5LO = A(1,20)
      FP5UP = A(1,19) + A(1,20)
```

Appendix C. (continued)

```
      FP6LO = A(1,22)
      FP6UP = A(1,21) + A(1,22)
      FSVLO = A(1,24)
      FSVUP = A(1,23) + A(1,24)
      WRITE(6,2003)NESTM,NSMPL,CHRTMN,CHRTMX
 2003 FORMAT(/,5X,'THERE ARE',I5,' OVERALL ESTIMATES OF ',
     1'THE CROPPING FACTOR',
     2/,5X,'THERE ARE',I5,' SAMPLES PER ESTIMATE'/,5X,
     1'COHORT SIZE PER SAMPLE VARIES FROM',F7.0,' TO',F7.0)
      WRITE(6,2004) FLO(1), FUP(1)
 2004 FORMAT(/,5X,'F1  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F1 = AMBIENT ALIVE.')
      WRITE(6,2005) FLO(2), FUP(2)
 2005 FORMAT(/,5X,'F2  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F2 = RETENTION OF AMBIENT DEAD.')
      WRITE(6,2006) FLO(3), FUP(3)
 2006 FORMAT(/,5X,'F3  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F3 = SUSCEPTIBILITY OF LIVE TO INTAKE.')
      WRITE(6,2007) FLO(4), FUP(4)
 2007 FORMAT(/,5X,'F4  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F4 = CATCHABILITY OF LIVE.')
      WRITE(6,2008) FLO(5), FUP(5)
 2008 FORMAT(/,5X,'F5  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F5 = NET SURVIVAL OF LIVE.')
      WRITE(6,2009) FLO(6), FUP(6)
 2009 FORMAT(/,5X,'F6  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F6 = RETENTION OF NET-KILLED.')
      WRITE(6,2010)FLO(7),FUP(7)
 2010 FORMAT(/,5X,'F7  VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; F7= RETENTION OF PLANT-KILLED.')
      WRITE(6,2011) FP2LO,FP2UP
 2011 FORMAT(/,5X,'FP2 VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; FP2 IS FACTOR 2 FOR INTAKE F/TH DISCHARGE.')
      WRITE(6,2012) FP4LO,FP4UP
 2012 FORMAT(/,5X,'FP4 VARIES FROM ',F10.5,2X,' TO ',F10.5)
      WRITE(6,2013) FP5LO,FP5UP
 2013 FORMAT(/,5X,'FP5 VARIES FROM ',F10.5,2X,' TO ',F10.5)
      WRITE(6,2014) FP6LO,FP6UP
 2014 FORMAT(/,5X,'FP6 VARIES FROM ',F10.5,2X,' TO ',F10.5)
      WRITE(6,2019) FSVLO, FSVUP
 2019 FORMAT(/,5X,'FSV VARIES FROM ',F10.5,2X,' TO ',F10.5,
     1'; FSV IS FRACTION SURVIVING PLANT PASSAGE.')
C.....LOOP FOR (1) ORNL FORMULA, AND (2) OTHER FORMULA.
      DO 950 ICHOSE=1,2
      PLINT=0.
      DO 15 I=1,12
      FREQ(I)=0.
      NI(I)=0
      NY(I)=0
   15 CONTINUE
C
 2186 FORMAT(1H1)
      WRITE(6,2186)
      WRITE(6,3108)
 3108 FORMAT(1H0,'*****************************************************',
     1'******************************')
      IF(ICHOSE.EQ.1)WRITE(6,3109)
      IF(ICHOSE.EQ.2)WRITE(6,3110)
      WRITE(6,3108)
 3109 FORMAT(1H0,'ANALYSIS FOR ORNL ESTIMATES.  "EST. FC" REFERS',
     1' TO FC ESTIMATED WITH THE ORNL FORMULA.')
 3110 FORMAT(1H0,'ANALYSIS FOR OTHR ESTIMATES.  "EST. FC" REFERS',
     1' TO FC ESTIMATED WITH THE OTHER FORMULA.')
      WRITE(6,2001)
```

Appendix C. (continued)

```
 2001 FORMAT(1H0,///20X,'COMPARISONS OF REAL FC WITH ESTIMATES OF FC',
     1//,15X,'FC',14X,'FCORNL',9X,'FC OTHER',7X,'FC ORNL - FC',5X,
     1'FC OTHER - FC',//)
C
C
C.....DO-LOOPS IN WHICH A NUMBER (NSMPL) OF PARAMETER SETS ARE SAMPLED
C     AND IN WHICH THE VALUES OF FC GIVEN BY THE ORNL FORMULA AND THE OTHER
C     FORMULA ARE COMPUTED; THIS PROCESS REPEATS NESTM TIMES.
C
      DO 500 I=1,NESTM
      ESV=URAND(DUMY)
      FSV=A(1,23)*ESV+A(1,24)
      FC=1.-FSV
      AORGL=0.
      AORGT=0.
      BORGL=0.
      BORGT=0.
C.....LOOP FOR SAMPLES.
      DO 33 K=1,NSMPL
      COHORT=CHRTMN+CHRTRG*URAND(DUMY)
      DO 35 J=1,7
      IEV = 2*J
      IOD = 2*J - 1
      E = URAND(DUMY)
      F(J) = A(1,IOD)*E + A(1,IEV)
   35 CONTINUE
      EP2 = URAND(DUMY)
      EP4 = URAND(DUMY)
      EP5 = URAND(DUMY)
      EP6 = URAND(DUMY)
      FP2 = A(1,15)*EP2 + A(1,16)
      FP4 = A(1,17)*EP4 + A(1,18)
      FP5 = A(1,19)*EP5 + A(1,20)
      FP6 = A(1,21)*EP6 + A(1,22)
      PISN = F(1)*F(3)*FP4*FP5
      PISD=F(1)*F(3)*FP4*FP5+F(1)*F(3)*FP4*FP6*(1.-FP5)+FP2*(1.-F(1))
      PDSN = F(1)*F(3)*FSV*F(4)*F(5)
      PDSD=F(7)*FC+FSV*F(4)*F(6)*(1.-F(5))+FSV*F(4)*F(5)
      PDSD=PDSD*F(1)*F(3)+F(2)*(1.-F(1))
      PIS = PISN/PISD
      PDS = PDSN/PDSD
C.....HERE, A REFERS TO INTAKE AND B TO DISCHARGE.
      ACATCH=PISD*COHORT
      BCATCH=PDSD*COHORT
      AORGL=AORGL+PIS*ACATCH
      AORGT=AORGT+ACATCH
      BORGL=BORGL+PDS*BCATCH
      BORGT=BORGT+BCATCH
   33 CONTINUE
      PIS=AORGL/AORGT
      PDS=BORGL/BORGT
      PLINT=PLINT+PIS
      DFCORN = (PIS - PDS)/PIS
      DFCOTH = PIS - PDS
      DIFORN = DFCORN - FC
      DIFOTH = DFCOTH - FC
      IF(ICHOSE .EQ. 2) GO TO 90
      DFC = DFCORN
      DFCA = DFCOTH
      GO TO 91
   90 CONTINUE
      DFCA = DFCORN
      DFC = DFCOTH
   91 CONTINUE
      TEST = -0.8
      TEST = -0.6
```

Appendix C. (continued)

```
C.....DO-LOOP TO SORT THE ESTIMATES INTO CATEGORIES.
      DO 200 J=1,12
      TESTM = TEST - 0.2
      NCHK = NI(J)
      IF(J .EQ. 1 .AND. NCHK .GE. 1000) GO TO 200
      IF(J .EQ. 2 .AND. DFC .LT. 0.0) GO TO 200
      IF(J .EQ. 2 .AND. NCHK .GE. 1000) GO TO 200
      IF(J .EQ. 3 .AND. DFC .GE. 0.0) GO TO 200
      IF(J .EQ. 3 .AND. NCHK .GE. 1000) GO TO 200
      IF(J .GT. 3 .AND. DFC .GT. TEST) GO TO 190
      IF(J .GT. 3 .AND. DFC .LE. TESTM) GO TO 190
      FREQ(J)=FREQ(J)+1.
      IF(J .GT. 3 .AND. NCHK .GE. NZ) GO TO 201
      NI(J) = NI(J) + 1
      NCHK = NI(J)
      IF(J .NE. 1) GO TO 185
      FCA(NCHK) = FC
  185 CONTINUE
      IF(J.NE.2) GO TO 155
      FC1(NCHK) = FC
  155 CONTINUE
      IF(J.NE.3) GO TO 157
      FC2(NCHK)=FC
  157 CONTINUE
      IF(J .LE. 3) GO TO 160
      FCORN(J,NCHK) = DFCORN
      FCREAL(J,NCHK) = FC
      FCORD(J,NCHK) =DIFORN
      FCOTH(J,NCHK) = DFCOTH
      FCOTD(J,NCHK) = DIFOTH
      GO TO 170
  160 CONTINUE
      FCORNA(J,NCHK) = DFCORN
      FCORDA(J,NCHK) =DIFORN
      FCOTHA(J,NCHK) = DFCOTH
      FCOTDA(J,NCHK) = DIFOTH
  170 CONTINUE
      NY(J)=NCHK
      SAMPLE(J) = NCHK
 2354 FORMAT(1H ,5X,I5,2X,F10.5)
  190 CONTINUE
      IF(J .LE. 3) GO TO 200
      TEST = TEST + 0.2
  200 CONTINUE
  201 CONTINUE
      WRITE(6,2000) FC,DFCORN,DFCOTH,DIFORN,DIFOTH
 2000 FORMAT(5X,5(F15.5,2X))
  500 CONTINUE
      DO 450 J=1,12
      NCHK = NI(J)
      IF(NCHK .GT. 1) GO TO 440
      NI(J) = 2
  440 CONTINUE
  450 CONTINUE
C
C.....CALCULATION OF THE MEANS OF 'ORNL FC', 'OTHER FC', 'ORNL FC - TRUE',
C     AND 'OTHER FC - TRUE FC'
C
      WRITE(6,2186)
      WRITE(6,3108)
      IF(ICHOSE.EQ.1) WRITE(6,3109)
      IF(ICHOSE.EQ.2)WRITE(6,3110)
      WRITE(6,3108)
      WRITE(6,2015)
 2015 FORMAT(1H0,//,5X,'CALCULATION OF MEANS AND STANDARD DEVIATIONS OF
     1 ORNL AND OTHER FC VALUES',/////)
```

Appendix C. (continued)

```
      FCAV = 0.0
      DO 530 I=1,12
      IF(NY(I).GT.0) ABC=0.
      IF(NY(I).EQ.0) ABC=1.E+30
      FCRAV(I) = ABC
      FORAV(I) = ABC
      FOTAV(I) = ABC
      DFRAV(I) = ABC
      DFTAV(I) = ABC
      SNI(I)  = NI(I)
  530 CONTINUE
      DO 600 I=1,12
      IF(NY(I).EQ.0) GO TO 600
      JFIN = NI(I)
      DO 580 J=1,JFIN
      IF(I .GT. 1) GO TO 550
C.....CALACULATE OVERALL TRUE FC
      FCAV = FCAV + (FCA(J)/SNI(I))
      FCRAV(I)=FCRAV(I)+FCA(J)/SNI(I)
  550 CONTINUE
      IF(I .LE. 3) GO TO 560
      F1 = FCORN(I,J)
      F2 = FCOTH(I,J)
      F3 = FCORD(I,J)
      F4 = FCOTD(I,J)
      GO TO 570
  560 CONTINUE
      F1 = FCORNA(I,J)
      F2 = FCOTHA(I,J)
      F3 = FCORDA(I,J)
      F4 = FCOTDA(I,J)
  570 CONTINUE
      IF(I .NE. 2) GO TO 555
      FCRAV(I) = FCRAV(I) + (FC1(J)/SNI(I))
  555 CONTINUE
      IF(I.NE.3) GO TO 557
      FCRAV(I)=FCRAV(I)+FC2(J)/SNI(I)
  557 CONTINUE
      FORAV(I) = FORAV(I) + (F1/SNI(I))
      FOTAV(I) = FOTAV(I) + (F2/SNI(I))
      DFRAV(I) = DFRAV(I) + (F3/SNI(I))
      DFTAV(I) = DFTAV(I) + (F4/SNI(I))
      IF(I .LE. 3) GO TO 575
      FCRAV(I) = FCRAV(I) + (FCREAL(I,J)/SNI(I))
  575 CONTINUE
  580 CONTINUE
  600 CONTINUE
      DO 620 I=1,12
      FCAVA(I) = FORAV(I) - DFRAV(I)
  620 CONTINUE
C.....LOOP TO CALCULATE CROPPING FACTOR ESTIMATES WHEN NEGATIVE
C     ESTIMATES ARE SET TO ZERO.
      X=0.
      Y=0.
      JFIN=NI(1)
      S=FLOAT(NI(1))
      DO 623 I=1,JFIN
      IF(FCORNA(1,I).LT.0.) GO TO 625
      X=X+FCORNA(1,I)
  625 IF(FCOTHA(1,I).LT.0.) GO TO 627
      Y=Y+FCOTHA(1,I)
  627 CONTINUE
  623 CONTINUE
      X=X/S
      Y=Y/S
      PLINT=PLINT/S
```

Appendix C. (continued)

```
      IF(ICHOSE.EQ.1)
     AWRITE(6,2002) FCAV,NY(1),FORAV(1),NY(1),FOTAV(1),NY(1),X,S,Y,S,
     [illegible]RAV(2),NY(2),FCRAV(2),NY(2),FORAV(3),NY(3),
     1D[illegible]AV(2),NY(2),DFRAV(3),NY(3)
      IF(ICHOSE.EQ.2)
     AWRITE(6,1765) FCAV,NY(1),FORAV(1),NY(1),FOTAV(1),NY(1),X,S,Y,S,
     XFCRAV(2),NY(2),
     1FOTAV(2),NY(2),FOTAV(3),NY(3),
     2DFTAV(2),NY(2),DFTAV(3),NY(3)
2002 FORMAT(///,5X,'AVERAGE TRUE FC = ',F10.5,5X,'N= ',I5,//,5X,
     W'OVERALL AVERAGE  ORNL FC = ',F10.5,5X,'N= ',I5,/,5X,
     X'OVERALL AVERAGE OTHER FC = ',F10.5,5X,'N= ',I5,//,5X,
     Y'AVERAGE  ORNL FC, NEGATIVES SET TO ZERO',F10.5,5X,'N= ',F5.0,/,
     Z5X,'AVERAGE OTHER FC, NEGATIVES SET TO ZERO',F10.5,5X,
     V'N= ',F5.0,///,5X,
     1'AVERAGE ORNL FC, 0.0 - 1.0 = ',F10.5,5X,'N= ',I5,///,5X,
     A'AVERAGE TRUE FC, WHEN ORNL FC IS POSITIVE = ',F10.5,5X,'N= ',
     BI5,///,5X,
     2'AVERAGE ORNL FC, LESS THAN 0.0 = ',F10.5,5X,'N= ',I5,///,5X,
     5'AVERAGE ORNL FC - FC, 0.0 - 1.0 = ',F10.5,5X,'N= ',I5,///,5X,
     6'AVERAGE ORNL FC - FC, LESS THAN 0.0 = ',F10.5,5X,'N= ',I5,///,5X)
1765 FORMAT(///,5X,'AVERAGE TRUE FC = ',F10.5,5X,'N= ',I5,//,5X,
     W'OVERALL AVERAGE  ORNL FC = ',F10.5,5X,'N= ',I5,/,5X,
     X'OVERALL AVERAGE OTHER FC = ',F10.5,5X,'N= ',I5,//,5X,
     Y'AVERAGE  ORNL FC, NEGATIVES SET TO ZERO',F10.5,5X,'N= ',F5.0,/,
     Z5X,'AVERAGE OTHER FC, NEGATIVES SET TO ZERO',F10.5,5X,
     V'N= ',F5.0,///,5X,
     A'AVERAGE TRUE FC, WHEN OTHR FC IS POSITIVE = ',F10.5,5X,'N= ',
     BI5,///,5X,
     3'AVERAGE OTHER FC, 0.0 - 1.0 = ',F10.5,5X,'N= ',I5,///,5X,
     4'AVERAGE OTHER FC, LESS THAN 0.0 = ',F10.5,5X,'N= ',I5,///,5X,
     7'AVERAGE OTHER FC - FC, 0.0 - 1.0 = ',F10.5,5X,'N= ',I5,///,5X,
     8'AVERAGE OTHER FC - FC, LESS THAN 0.0 = ',F10.5,5X,'N= ',I5,/////)
      IF(ICHOSE.EQ.1)
     XWRITE(6,2021) FORAV(7),NY(7),DFRAV(7),NY(7),FORAV(6),NY(6),
     1DFRAV(6),NY(6),FORAV(5),NY(5),DFRAV(5),NY(5),FORAV(4),NY(4),
     2DFRAV(4),NY(4)
      IF(ICHOSE.EQ.2)
     XWRITE(6,2021) FOTAV(7),NY(7),DFTAV(7),NY(7),FOTAV(6),NY(6),
     1DFTAV(6),NY(6),FOTAV(5),NY(5),DFTAV(5),NY(5),FOTAV(4),NY(4),
     2DFTAV(4),NY(4)
2021 FORMAT(////,5X,'AVERAGE EST. FC, 0.0 TO -0.2 = ',F10.5,5X,'N= ',
     AI5,///,5X,
     1'AVERAGE EST. FC - FC, 0.0 TO -0.2 = ',F10.5,5X,'N= ',I5,///,5X,
     2'AVERAGE EST. FC, -0.2 TO -0.4 = ',F10.5,5X,'N= ',I5,///,5X,
     3'AVERAGE EST. FC - FC, -0.2 TO -0.4 = ',F10.5,5X,'N= ',I5,///,5X,
     4'AVERAGE EST. FC, -0.4 TO -0.6 = ',F10.5,5X,'N= ',I5,///,5X,
     5'AVERAGE EST. FC - FC, -0.4 TO -0.6 = ',F10.5,5X,'N= ',I5,///,5X,
     6'AVERAGE EST. FC, -0.6 TO -0.8 = ',F10.5,5X,'N = ',I5,///,5X,
     7'AVERAGE EST. FC - FC, -0.6 TO -0.8 = ',F10.5,5X,'N= ',I5,//////)
      IF(ICHOSE.EQ.1)
     XWRITE(6,2024) FORAV(8),NY(8),DFRAV(8),NY(8),FCRAV(8),NY(8),
     AFORAV(9),NY(9),
     1DFRAV(9),NY(9),FORAV(10),NY(10),DFRAV(10),NY(10),FORAV(11),NY(11),
     2DFRAV(11),NY(11),FORAV(12),NY(12),DFRAV(12),NY(12)
      IF(ICHOSE.EQ.2)
     XWRITE(6,2024) FOTAV(8),NY(8),DFTAV(8),NY(8),FCRAV(8),NY(8),
     AFOTAV(9),NY(9),
     1DFTAV(9),NY(9),FOTAV(10),NY(10),DFTAV(10),NY(10),FOTAV(11),NY(11),
     2DFTAV(11),NY(11),FOTAV(12),NY(12),DFTAV(12),NY(12)
2024 FORMAT(////,5X,'AVERAGE EST. FC, 0.0 TO 0.2 = ',F10.5,5X,'N= ',
     AI5,///,5X,
     1'AVERAGE EST. FC - FC, 0.0 TO 0.2 = ',F10.5,5X,'N= ',I5,///,5X,
     A'AVERAGE TRUE FC, WHEN EST. FC IS 0.0  TO  0.2, = ',
     BF10.5,5X,'N= ',I5,///,5X,
```

Appendix C. (continued)

```
     2'AVERAGE EST. FC, 0.2 TO 0.4= ',F10.5,5X,'N= ',I5,///,5X,
     3'AVERAGE EST. FC - FC, 0.2 TO 0.4= ',F10.5,5X,'N= ',I5,///,5X,
     4'AVERAGE EST. FC, 0.4 TO 0.6= ',F10.5,5X,'N= ',I5,///,5X,
     5'AVERAGE EST. FC - FC, 0.4 TO 0.6= ',F10.5,5X,'N= ',I5,///,5X,
     6'AVERAGE EST. FC, 0.6 TO 0.8= ',F10.5,5X,'N= ',I5,///,5X,
     7'AVERAGE EST. FC - FC, 0.6 TO 0.8= ',F10.5,5X,'N= ',I5,///,5X,
     8'AVERAGE EST. FC, 0.8 TO 1.0= ',F10.5,5X,'N = ',I5,///,5X,
     9'AVERAGE EST. FC - FC, 0.8 TO 1.0= ',F10.5,5X,'N= ',I5,//)
C
C.....CALCULATION OF THE STANDARD DEVIATIONS OF 'ORNL FC', 'OTHER FC',
C      'ORNL FC - TRUE FC', AND 'OTHER FC - TRUE FC'
      DO 700 I=1,12
      IF(NY(I).GT.1) ABC=0.
      IF(NY(I).LT.2) ABC=1.E+30
      FORVR(I) = ABC
      FOTVR(I) = ABC
      DFTVR(I) = ABC
      DFRVR(I) = ABC
      FCVR(I) = ABC
  700 CONTINUE
      FCVRR = 0.0
      DO 750 I=1,12
      JFIN = NI(I)
C.....THE FOLLOWING STATEMENT MAY BE HELPFUL IN DEBUGGING.
C       WRITE(6,2347) JFIN,NY(I)
 2347 FORMAT(1H ,5X,'JFIN= ',I5,' ACTUAL NUMBER IN CATEGORY=',I5)
      IF(NY(I).LE.1) GO TO 750
      DO 710 J=1,JFIN
      IF(I .GT. 1) GO TO 711
      FCVRR = FCVRR + (FCA(J) - FCAV)**2
      FCVR(I)=FCVR(I)+(FCA(J)-FCAV)**2
C.....THE ABOVE IS NEEDED BEFORE THE 710 CONTINUE STATEMENT.
  711 CONTINUE
C.....THE NEXT GROUP OF STATEMENTS IS NEEDED BEFORE 710 CONTINUE,
C       ALTHOUGH NOT USED AS OUTPUT.
      IF(I.NE.2) GO TO 713
      FCVR(I)=FCVR(I)+(FC1(J)-FCRAV(I))**2
  713 CONTINUE
      IF(I.NE.3) GO TO 715
      FCVR(I)=FCVR(I)+(FC2(J)-FCRAV(I))**2
  715 CONTINUE
      IF(I .LE. 3) GO TO 720
      F1 = FCORN(I,J)
      F2 = FCOTH(I,J)
      F3 = FCORD(I,J)
      F4 = FCOTD(I,J)
      GO TO 725
  720 CONTINUE
      F1 = FCORNA(I,J)
      F2 = FCOTHA(I,J)
      F3 = FCORDA(I,J)
      F4 = FCOTDA(I,J)
  725 CONTINUE
      FORVR(I) = FORVR(I) + (F1 - FORAV(I))**2
      DFRVR(I) = DFRVR(I) + (F3 - DFRAV(I))**2
      FOTVR(I) = FOTVR(I) + (F2 - FOTAV(I))**2
      DFTVR(I) = DFTVR(I) + (F4 - DFTAV(I))**2
      FCVR(I) = FCVR(I) + (F1 - F3 - FCAVA(I))**2
C.....ALTERNATIVE WOULD BE:
C       FCVR(I)=FCVR(I)+(F2-F4-FCAVA(I))**2
  710 CONTINUE
  750 CONTINUE
      DO 770 I=1,12
      FORVR(I) = SQRT(FORVR(I)/(SNI(I) - 1.))
      FOTVR(I) = SQRT(FOTVR(I)/(SNI(I) - 1.))
```

```
      DFRVR(I) = SQRT(DFRVR(I)/(SNI(I) - 1.))
      DFTVR(I) = SQRT(DFTVR(I)/(SNI(I) - 1.))
  770 CONTINUE
      FCVRR = SQRT(FCVRR/(SNI(1) - 1.))
      IF(ICHOSE.EQ.1)
     XWRITE(6,2016) FCVRR,FORVR(2),FORVR(3),DFRVR(2),
     1DFRVR(3)
      IF(ICHOSE.EQ.2)
     XWRITE(6,2317) FCVRR,FOTVR(2),FOTVR(3),
     1DFTVR(2),DFTVR(3)
 2016 FORMAT(///,5X,'ST.DEV. TRUE FC = ',F10.5,///,5X,
     1'ST.DEV. ORNL FC, 0.0-1.0 = ',F10.5,//,5X,
     2'ST.DEV. ORNL FC, LESS THAN 0.0 = ',F10.5,///,5X,
     5'ST.DEV. ORNL FC - FC, 0.0 - 1.0 = ',F10.5,///,5X,
     6'ST.DEV. ORNL FC - FC, LESS THAN 0.0 = ',F10.5,///,5X)
 2317 FORMAT(///,5X,'ST.DEV. TRUE FC = ',F10.5,///,5X,
     3'ST.DEV. OTHER FC, 0.0-1.0 = ',F10.5,///,5X,
     4'ST. DEV. OTHER FC, LESS THAN 0.0 = ',F10.5,///,5X,
     7'ST.DEV. OTHER FC - FC, 0.0 - 1.0 = ',F10.5,///,5X,
     8'ST.DEV. OTHER FC - FC, LESS THAN 0.0 = ',F10.5,////)
      IF(ICHOSE.EQ.1)
     XWRITE(6,2028) FORVR(7), DFRVR(7),FORVR(6),DFRVR(6),FORVR(5),
     1DFRVR(5),FORVR(4),DFRVR(4)
      IF(ICHOSE.EQ.2)
     XWRITE(6,2028) FOTVR(7), DFTVR(7),FOTVR(6),DFTVR(6),FOTVR(5),
     1DFTVR(5),FOTVR(4),DFTVR(4)
 2028 FORMAT(/////,5X,'ST.DEV. EST. FC, 0.0 TO -0.2 = ',F10.5,//,5X,
     1'ST.DEV. EST. FC - FC, 0.0 TO -0.2 = ',F10.5,//,5X,
     2'ST.DEV. EST. FC, -0.2 TO -0.4 = ',F10.5,//,5X,
     3'ST.DEV. EST. FC - FC, -0.2 TO -0.4 = ',F10.5,//,5X,
     4'ST.DEV. EST. FC, -0.4 TO -0.6 = ',F10.5,//,5X,
     5'ST.DEV. EST. FC - FC, -0.4 TO -0.6 = ',F10.5,//,5X,
     6'ST.DEV. EST. FC, -0.6 TO -0.8 = ',F10.5,//,5X,
     7'ST.DEV. EST. FC - FC, -0.6 TO -0.8 = ',F10.5,//////)
      IF(ICHOSE.EQ.1)
     XWRITE(6,2029) FORVR(8),DFRVR(8),FORVR(9),DFRVR(9),FORVR(10),
     1DFRVR(10),FORVR(11),DFRVR(11),FORVR(12),DFRVR(12)
      IF(ICHOSE.EQ.2)
     XWRITE(6,2029) FOTVR(8),DFTVR(8),FOTVR(9),DFTVR(9),FOTVR(10),
     1DFTVR(10),FOTVR(11),DFTVR(11),FOTVR(12),DFTVR(12)
 2029 FORMAT(/////,5X,'ST.DEV. EST. FC, 0.0 TO 0.2 = ',F10.5,//,5X,
     1'ST.DEV. EST. FC - FC, 0.0 TO 0.2 = ',F10.5,//,5X,
     2'ST.DEV. EST. FC, 0.2 TO 0.4 = ',F10.5,//,5X,
     3'ST.DEV. EST. FC - FC, 0.2 TO 0.4 = ',F10.5,//,5X,
     4'ST.DEV. EST. FC, 0.4 TO 0.6 = ',F10.5,//,5X,
     5'ST.DEV. EST. FC - FC, 0.4 TO 0.6 = ',F10.5,//,5X,
     6'ST.DEV. EST. FC, 0.6 TO 0.8 = ',F10.5,//,5X,
     7'ST.DEV. EST. FC - FC, 0.6 TO 0.8 = ',F10.5,//,5X,
     8'ST.DEV. EST. FC, 0.8 TO 1.0 = ',F10.5,//,5X,
     9'ST.DEV. EST. FC - FC, 0.8 TO 1.0 = ',F10.5,//////)
C
C.....PRINT OUT A TABLE OF VALUES
C
      SMPSZE=FLOAT(NESTM)
      TOTFRQ=0.
      IF(ICHOSE .EQ. 2) GO TO 790
      WRITE(6,2060)
 2060 FORMAT(1H1)
      WRITE(6,2061)
 2061 FORMAT(///,6X,'ORNL',10X,'MEAN',5X,'STD.',5X,'A',8X,'B',8X,'LOWER'
     1,4X,'MEAN',5X,'UPPER',4X,'MEAN',5X,          'N',4X,'RELATIVE',/,
     26X,'ESTIMATE',6X,'ORNL',5X,'DEV.',5X,'BOUND',4X,'BOUND',4X,'FC',
     37X,'TRUE',5X,'FC',7X,'ORNL',5X,          5X,'FREQUENCY',/,
     46X,'RANGE',9X,'DIFFER.',2X,'DIFFER.',2X,    'VALUE',4X,'VALUE',4X,
     5'EST.',5X,'FC',7X,'EST.',5X,'FC',7X,          //)
```

Appendix C. (continued)

```
      UL = -1.0
      BL = -0.8
      DO 850 I=4,12
      AA(I) = +DFRAV(I) - 2.*DFRVR(I)
      BB(I) =+DFRAV(I) + 2.*DFRVR(I)
      FCAVA(I) = FORAV(I) - DFRAV(I)
      SN = NI(I)
      FCVR(I) = SQRT(FCVR(I)/(SN-1.0))
      FCESTU = FCAVA(I) + 2.*FCVR(I)
      FCESTL = FCAVA(I) - 2.*FCVR(I)
      FREQ(I)=(FREQ(I)/SMPSZE)*100.
      TOTFRQ=TOTFRQ+FREQ(I)
      GO TO 821
  821 CONTINUE
      UL = UL + 0.2
      BL = BL + 0.2
      IF(NY(I) .LT. 2) GO TO 830
      WRITE(6,2062) UL,BL,DFRAV(I),DFRVR(I),AA(I),BB(I),FCESTL,FCAVA(I),
     1FCESTU,FORAV(I),          NI(I),FREQ(I)
 2062 FORMAT(1H ,1X,F5.2,1X,' TO ',F5.2,8(2X,F7.4),I5,1X,F7.1,'%',/)
      GO TO 831
  830 CONTINUE
      WRITE(6,2064)UL,BL,NY(I),FREQ(I)
 2064 FORMAT(1H ,1X,F5.2,1X,' TO ',F5.2,10X,'INSUFFICIENT NUMBER OF SAMP
     1LES -  N=0 OR N=1',21X,I2,1X,F7.1/)
  831 CONTINUE
  850 CONTINUE
      WRITE(6,2068)TOTFRQ
 2068 FORMAT(//5X,'TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN',
     1' ABOVE TABLE =',F6.1,'%')
      WRITE(6,2070)DFRAV(1),DFRVR(1)
 2070 FORMAT(///,5X,'FCORNL - FC : OVERALL MEAN BIAS = ',
     1F12.5,5X,'ST. DEV. = ',F12.5,//)
      WRITE(6,2073)PLINT
 2073 FORMAT(1H0,4X,'AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE ',
     1'SAMPLES =',F9.5)
      GO TO 901
  790 CONTINUE
      WRITE(6,2060)
      WRITE(6,2063)
 2063 FORMAT(///,6X,'OTHR',10X,'MEAN',5X,'STD.',5X,'A',8X,'B',8X,'LOWER'
     1,4X,'MEAN',5X,'UPPER',4X,'MEAN',5X,           'N',4X,'RELATIVE',/,
     26X,'ESTIMATE',6X,'OTHR',5X,'DEV.',5X,'BOUND',4X,'BOUND',4X,'FC',
     37X,'TRUE',5X,'FC',7X,'OTHR',5X,           5X,'FREQUENCY',/,
     46X,'RANGE',9X,'DIFFER.',2X,'DIFFER.',2X,   'VALUE',4X,'VALUE',4X,
     5'EST.',5X,'FC',7X,'EST.',5X,'FC',7X,         //)
      UL = -1.0
      BL = -0.8
      DO 900 I=4,12
      SN = NI(I)
      AA(I) = +DFTAV(I) - 2.*DFTVR(I)
      BB(I) = +DFTAV(I) + 2.*DFTVR(I)
      FCAVA(I) = FORAV(I) - DFRAV(I)
      FCVR(I) = SQRT(FCVR(I)/(SN-1.0))
      FCESTU = FCAVA(I) + 2.*FCVR(I)
      FCESTL = FCAVA(I) - 2.*FCVR(I)
      FREQ(I)=(FREQ(I)/SMPSZE)*100.
      TOTFRQ=TOTFRQ+FREQ(I)
      GO TO 871
  871 CONTINUE
      UL = UL + 0.2
      BL = BL + 0.2
      IF(NY(I) .LT. 2) GO TO 880
      WRITE(6,2062) UL,BL,DFTAV(I),DFTVR(I),AA(I),BB(I),FCESTL,
     1FCAVA(I),FCESTU,FOTAV(I),          NI(I),FREQ(I)
      GO TO 881
```

Appendix C. (continued)

```
  880 CONTINUE
      WRITE(6,2064) UL,BL,NY(I),FREQ(I)
  881 CONTINUE
  900 CONTINUE
      WRITE(6,2068) TOTFRQ
      WRITE(6,2071) DFTAV(1),DFTVR(1)
 2071 FORMAT(///,5X,'FCOTHR - FC : OVERALL MEAN BIAS = ',
     1F12.5,5X,'ST. DEV. = ',F12.5,//)
      WRITE(6,2073) PLINT
  901 CONTINUE
  950 CONTINUE
      STOP
      END
      FUNCTION URAND(FRAN)
C
C
C.....E.J.MCGARTH AND D.C.IRVING.  1975. TECHNIQUES FOR EFFICIENT MONTE CARLO
C     SIMULATION. VOL. 2.  RANDOM NUMBER GENERATION FOR SELECTED PROBABILITY
C     DISTRIBUTIONS.  ORNL-RSIC-38
C
C
      DIMENSION SUM(10)
      INTEGER RAN,GEN,BASE,CARRY,SUM,PROD,HPROD
      COMMON/MIRNG/RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      DO 30 IS=1,NWRD
30    SUM(IS)=0.
      DO 1 IG=1,NWRD
      N2=NWRD-IG+1
      DO 1 IR=1,N2
      IS=IR+IG-1
      PROD=RAN(IR)*GEN(IG)
      HPROD=PROD/BASE
      LPROD=PROD-HPROD*BASE
      SUM(IS)=SUM(IS)+LPROD
      IF (IS.LT.NWRD) SUM(IS+1)=SUM(IS+1)+HPROD
1     CONTINUE
      N2=NWRD-1
      DO 5 IS=1,N2
      CARRY=SUM(IS)/BASE
      SUM(IS)=SUM(IS)-CARRY*BASE
      SUM(IS+1)=SUM(IS+1)+CARRY
5     CONTINUE
      SUM(NWRD)=SUM(NWRD)-MOD*(SUM(NWRD)/MOD)
      DO 20 IS=1,NWRD
20    RAN(IS)=SUM(IS)
      FRAN=SUM(1)
      DO 10 IS=2,NWRD
10    FRAN=FRAN/FBASE+SUM(IS)
      FRAN=FRAN/FMOD
      URAND=FRAN
      RETURN
      END
      SUBROUTINE RANSET (MAXINT,NSTRT)
C
C
C.....E.J.MCGARTH AND D.C.IRVING.  1975. TECHNIQUES FOR EFFICIENT MONTE CARLO
C     SIMULATION. VOL. 2.  RANDOM NUMBER GENERATION FOR SELECTED PROBABILITY
C     DISTRIBUTIONS.  ORNL-RSIC-38
C
C
      INTEGER RAN,GEN,BASE,CARRY,REM
      COMMON/MIRNG/ RAN(10),GEN(10),NWRD,BASE,MOD,FBASE,FMOD
      MAXI=MAXINT/4
      IB=0
      BASE=1
```

Appendix C. (continued)

```
 99     IF (BASE.GT.MAXI) GO TO 100
        BASE=BASE*4
        IB=IB+1
        GO TO 99
 100    BASE=2**IB
        FBASE=BASE
        NWRD=47/IB+1
        REM=47-IB*(NWRD-1)
        MOD=2**REM
        FMOD=MOD
        DO 101 N=1,10
        RAN(N)=0
 101    GEN(N)=0
        GEN(1)=5
        DO 200 I=1,14
        CARRY=0
        DO 190 N=1,NWRD
        GEN(N)=GEN(N)*5+CARRY
        CARRY=0
        IF (GEN(N).LT.BASE) GO TO 190
        CARRY=GEN(N)/BASE
        GEN(N)=GEN(N)-BASE*CARRY
 190    CONTINUE
 200    CONTINUE
        NSTART=NSTRT
        IF (NSTART.LE.0) NSTART=2001
        NSTART=2*(NSTART/2)+1
        DO 300 N=1,NWRD
        NTEMP=NSTART/BASE
        RAN(N)=NSTART-NTEMP*BASE
 300    NSTART=NTEMP
        RETURN
        END
```

APPENDIX D. SAMPLE OUTPUT (CASE 1)

Some of the output has been deleted from this appendix, as indicated, to save space.

```
RANDOM NUMBER INITIATOR = 20469
MACHINE-SPECIFIC MAXIMUM INTEGER = 34359738367

THERE ARE  500 OVERALL ESTIMATES OF THE CROPPING FACTOR
THERE ARE    1 SAMPLES PER ESTIMATE
COHORT SIZE PER SAMPLE VARIES FROM     1. TO   100.

F1  VARIES FROM    0.90000   TO    0.90000; F1 = AMBIENT ALIVE.

F2  VARIES FROM    0.50000   TO    0.50000; F2 = RETENTION OF AMBIENT DEAD.

F3  VARIES FROM    0.90000   TO    0.90000; F3 = SUSCEPTIBILITY OF LIVE TO INTAKE.

F4  VARIES FROM    1.00000   TO    1.00000; F4 = CATCHABILITY OF LIVE.

F5  VARIES FROM    0.75000   TO    0.75000; F5 = NET SURVIVAL OF LIVE.

F6  VARIES FROM    1.00000   TO    1.00000; F6 = RETENTION OF NET-KILLED.

F7  VARIES FROM    1.00000   TO    1.00000; F7= RETENTION OF PLANT-KILLED.

FP2 VARIES FROM    0.50000   TO    0.50000; FP2 IS FACTOR 2 FOR INTAKE B/TH DISCHARGE.

FP4 VARIES FROM    1.00000   TO    1.00000

FP5 VARIES FROM    0.75000   TO    0.75000

FP6 VARIES FROM    1.00000   TO    1.00000

FSV VARIES FROM    0.00000   TO    1.00000; FSV IS FRACTION SURVIVING PLANT PASSAGE.
```

Appendix D. (continued)

```
******************************************************************************

ANALYSIS FOR ORNL ESTIMATES.  "EST. FC" REFERS TO FC ESTIMATED WITH THE ORNL FORMULA.

******************************************************************************


              COMPARISONS OF REAL FC WITH ESTIMATES OF FC

     FC              FCORNL           FC OTHER        FC ORNL - FC     FC OTHER - FC


  0.56149           0.56149           0.39664           -0.00000         -0.16486
  0.56381           0.56381           0.39827            0.00000         -0.16554
  0.58395           0.58395           0.41250           -0.00000         -0.17145
  0.74270           0.74270           0.52464           -0.00000         -0.21806
  0.85184           0.85184           0.60174           -0.00000         -0.25011
  0.87544           0.97544           0.61841            0.00000         -0.25703
  0.04043           0.04043           0.02856           -0.00000         -0.01187
  0.13564           0.13564           0.09582           -0.00000         -0.03982
  0.28165           0.28165           0.19896            0.00000         -0.08269
  0.30263           0.30263           0.21377           -0.00000         -0.08885
  0.99535           0.99535           0.70311            0.00000         -0.29224
  0.53803           0.53803           0.38007            0.00000         -0.15797
  0.05023           0.05023           0.03548            0.00000         -0.01475
  0.84225           0.84225           0.59496            0.00000         -0.24729
  0.33336           0.33336           0.23548           -0.00000         -0.09787
  0.46717           0.46717           0.33001           -0.00000         -0.13716
  0.14504           0.14504           0.10245           -0.00000         -0.04258
  0.10250           0.10250           0.07241           -0.00000         -0.03010
  0.87176           0.87176           0.61581            0.00000         -0.25595
  0.84420           0.84420           0.59634            0.00000         -0.24786
  0.35719           0.35719           0.25232           -0.00000         -0.10487
  0.36914           0.36914           0.26076            0.00000         -0.10838
  0.61079           0.61079           0.43146           -0.00000         -0.17933
  0.67467           0.67467           0.47659            0.00000         -0.19809
  0.18971           0.18971           0.13401           -0.00000         -0.05570
  0.56594           0.56594           0.39978            0.00000         -0.16616
  0.39463           0.39463           0.27876           -0.00000         -0.11586
  0.03434           0.03434           0.02426           -0.00000         -0.01008
  0.03172           0.03172           0.02241           -0.00000         -0.00931
  0.73787           0.73787           0.52123           -0.00000         -0.21664
  0.69706           0.69706           0.49240            0.00000         -0.20466
  0.89114           0.89114           0.62950            0.00000         -0.26164
  0.59284           0.58284           0.41172           -0.00000         -0.17113
  0.59097           0.59097           0.41746            0.00000         -0.17351
  0.81294           0.81294           0.57426            0.00000         -0.23868
  0.23633           0.23633           0.16695            0.00000         -0.06939
  0.25290           0.25290           0.17865           -0.00000         -0.07425
  0.20073           0.20073           0.14180           -0.00000         -0.05894
  0.10260           0.10260           0.07248           -0.00000         -0.03012
  0.10684           0.10684           0.07547           -0.00000         -0.03137
  0.81360           0.81360           0.57473            0.00000         -0.2388[illegible]
  0.20987           0.20987           0.14825            0.00000         -0.06162
  0.21809           0.21809           0.15406           -0.00000         -0.06403
  0.00586           0.00586           0.00414           -0.00000         -0.00172
  0.99463           0.99463           0.70260            0.00000         -0.29203
  0.51436           0.51436           0.36334           -0.00000         -0.15102
  0.92885           0.92885           0.65613            0.00000         -0.27271
```

(seven pages deleted)

```
  0.63226           0.63226           0.44663            0.00000         -0.18563
  0.23172           0.23172           0.16368            0.00000         -0.06803
  0.90203           0.90203           0.63719            0.00000         -0.26484
  0.87983           0.87983           0.62150            0.00000         -0.25832
  0.57075           0.57075           0.40318            0.00000         -0.16758
  0.71007           0.71007           0.50159           -0.00000         -0.20848
  0.05575           0.05575           0.03938           -0.00000         -0.01637
  0.70678           0.70678           0.49927            0.00000         -0.20751
  0.95088           0.95088           0.67170            0.00000         -0.27918
  0.66780           0.66780           0.47173            0.00000         -0.19607
  0.06468           0.06468           0.04569           -0.00000         -0.01899
  0.88022           0.88022           0.62179            0.00000         -0.25844
```

Appendix D. (continued)

```
******************************************************************************

ANALYSIS FOR ORNL ESTIMATES.  "EST. FC" REFERS TO FC ESTIMATED WITH THE ORNL FORMULA.

******************************************************************************


    CALCULATION OF MEANS AND STANDARD DEVIATIONS OF ORNL AND OTHER FC VALUES




    AVERAGE TRUE FC =     0.50588      N=   500

    OVERALL AVERAGE  ORNL FC =     0.50588      N=   500
    OVERALL AVERAGE OTHER FC =     0.35735      N=   500

    AVERAGE  ORNL FC, NEGATIVES SET TO ZERO   0.50588      N=  500.
    AVERAGE OTHER FC, NEGATIVES SET TO ZERO   0.35735      N=  500.

    AVERAGE ORNL FC, 0.0 - 1.0 =     0.50588      N=   500

    AVERAGE TRUE FC, WHEN ORNL FC IS POSITIVE =     0.50588      N=   500

    AVERAGE ORNL FC, LESS THAN 0.0 = **********      N=     0

    AVERAGE ORNL FC - FC, 0.0 - 1.0 =   -0.00000      N=   500

    AVERAGE ORNL FC - FC, LESS THAN 0.0 = **********      N=     0



    AVERAGE EST. FC, 0.0 TO -0.2 = **********      N=     0

    AVERAGE EST. FC - FC, 0.0 TO -0.2 = **********      N=     0

    AVERAGE EST. FC, -0.2 TO -0.4 = **********      N=     0

    AVERAGE EST. FC - FC, -0.2 TO -0.4 = **********      N=     0

    AVERAGE EST. FC, -0.4 TO -0.6 = **********      N=     0
```

Appendix D. (continued)

```
AVERAGE EST. FC - FC, -0.4 TO -0.6 = ***********     N=     0

AVERAGE EST. FC, -0.6 TO -0.8 = ***********     N =     0

AVERAGE EST. FC - FC, -0.6 TO -0.8 = ***********     N=     0




AVERAGE EST. FC, 0.0 TO 0.2 =    0.09423     N=    50

AVERAGE EST. FC - FC, 0.0 TO 0.2 =   -0.00000     N=    50

AVERAGE TRUE FC, WHEN EST. FC IS 0.0  TO  0.2, =    0.09423     N=    50

AVERAGE EST. FC, 0.2 TO 0.4=    0.29871     N=    50

AVERAGE EST. FC - FC, 0.2 TO 0.4=   -0.00000     N=    50

AVERAGE EST. FC, 0.4 TO 0.6=    0.50364     N=    50

AVERAGE EST. FC - FC, 0.4 TO 0.6=   -0.00000     N=    50

AVERAGE EST. FC, 0.6 TO 0.8=    0.69419     N=    50

AVERAGE EST. FC - FC, 0.6 TO 0.8=   -0.00000     N=    50

AVERAGE EST. FC, 0.8 TO 1.0=    0.88262     N =    50

AVERAGE EST. FC - FC, 0.8 TO 1.0=   -0.00000     N=    50


ST.DEV. TRUE FC =    0.28775

ST.DEV. ORNL FC, 0.0-1.0 =    0.28775
ST.DEV. ORNL FC, LESS THAN 0.0 = ***********

ST.DEV. ORNL FC - FC, 0.0 - 1.0 =    0.00000
```

Appendix D. (continued)

```
ST.DEV. ORNL FC - FC, LESS THAN 0.0 = ***********



ST.DEV. EST. FC, 0.0 TO -0.2 = ***********
ST.DEV. EST. FC - FC, 0.0 TO -0.2 = ***********
ST.DEV. EST. FC, -0.2 TO -0.4 = ***********
ST.DEV. EST. FC - FC, -0.2 TO -0.4 = ***********
ST.DEV. EST. FC, -0.4 TO -0.6 = ***********
ST.DEV. EST. FC - FC, -0.4 TO -0.6 = ***********
ST.DEV. EST. FC, -0.6 TO -0.8 = ***********
ST.DEV. EST. FC - FC, -0.6 TO -0.8 = ***********



ST.DEV. EST. FC, 0.0 TO 0.2 =     0.05992
ST.DEV. EST. FC - FC, 0.0 TO 0.2 =     0.00000
ST.DEV. EST. FC, 0.2 TO 0.4 =     0.06480
ST.DEV. EST. FC - FC, 0.2 TO 0.4 =     0.00000
ST.DEV. EST. FC, 0.4 TO 0.6 =     0.05736
ST.DEV. EST. FC - FC, 0.4 TO 0.6 =     0.00000
ST.DEV. EST. FC, 0.6 TO 0.8 =     0.05328
ST.DEV. EST. FC - FC, 0.6 TO 0.8 =     0.00000
ST.DEV. EST. FC, 0.8 TO 1.0 =     0.05477
ST.DEV. EST. FC - FC, 0.8 TO 1.0 =     0.00000
```

Appendix D. (continued)

```
  ORNL              MEAN      STD.      A         B         LOWER     MEAN      UPPER     MEAN       N     RELATIVE
  ESTIMATE          ORNL      DEV.      BOUND     BOUND     FC        TRUE      FC        ORNL             FREQUENCY
  RANGE             DIFFER.   DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0      0.0

-0.60  TO -0.40           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0      0.0

-0.40  TO -0.20           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0      0.0

-0.20  TO -0.00           INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                               0      0.0

-0.00  TO  0.20  -0.0000   0.0000  -0.0000   0.0000  -0.0256   0.0942   0.2141   0.0942   50     19.0%

 0.20  TO  0.40  -0.0000   0.0000  -0.0000   0.0000   0.1691   0.2987   0.4283   0.2987   50     20.6%

 0.40  TO  0.60  -0.0000   0.0000  -0.0000   0.0000   0.3889   0.5036   0.6184   0.5036   50     18.2%

 0.60  TO  0.80  -0.0000   0.0000  -0.0000   0.0000   0.5876   0.6942   0.8007   0.6942   50     21.6%

 0.80  TO  1.00  -0.0000   0.0000  -0.0000   0.0000   0.7731   0.8826   0.9922   0.8826   50     20.6%


  TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%


  FCORNL - FC : OVERALL MEAN BIAS =     -0.00000      ST. DEV. =      0.00000


  AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.70640
```

Appendix D. (continued)

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************************************************************************

ANALYSIS FOR OTHR ESTIMATES.  "EST. FC" REFERS TO FC ESTIMATED WITH THE OTHER FORMULA.

************************************************************************


              COMPARISONS OF REAL FC WITH ESTIMATES OF FC

     FC              FCORNL            FC OTHER        FC ORNL - FC      FC OTHER - FC

  0.32543           0.32543           0.22988          -0.00000          -0.09555
  0.46785           0.46785           0.33048          -0.00000          -0.13736
  0.60615           0.60615           0.42818           0.00000          -0.17797
  0.43628           0.43628           0.30819           0.00000          -0.12809
  0.23591           0.23591           0.16665          -0.00000          -0.06927
  0.54082           0.54082           0.38203          -0.00000          -0.15879
  0.21500           0.21500           0.15188          -0.00000          -0.06313
  0.15928           0.15928           0.11251          -0.00000          -0.04676
  0.41715           0.41715           0.29467          -0.00000          -0.12248
  0.87717           0.87717           0.61963           0.00000          -0.25754
  0.88273           0.88273           0.62356           0.00000          -0.25917
  0.01924           0.01924           0.01359          -0.00000          -0.00565
  0.47265           0.47265           0.33388           0.00000          -0.13877
  0.72446           0.72446           0.51176           0.00000          -0.21271
  0.43617           0.43617           0.30811           0.00000          -0.12806
  0.59225           0.59225           0.41836           0.00000          -0.17389
  0.36954           0.36954           0.26104           0.00000          -0.10850
  0.57500           0.57500           0.40618          -0.00000          -0.16882
  0.89007           0.89007           0.62874           0.00000          -0.26133
  0.99800           0.99800           0.70499           0.00000          -0.29302
  0.39101           0.39101           0.27620          -0.00000          -0.11480
  0.02410           0.02410           0.01702          -0.00000          -0.00708
  0.89389           0.89389           0.63144           0.00000          -0.26245
  0.38081           0.38081           0.26900          -0.00000          -0.11181
  0.40120           0.40120           0.28341          -0.00000          -0.11779
  0.85443           0.85443           0.60356          -0.00000          -0.25086
  0.28925           0.28925           0.20433          -0.00000          -0.08493
  0.10308           0.10308           0.07282          -0.00000          -0.03027
  0.85114           0.85114           0.60124           0.00000          -0.24990
  0.46922           0.46922           0.33146          -0.00000          -0.13777
  0.52838           0.52838           0.37324           0.00000          -0.15513
  0.01478           0.01478           0.01044          -0.00000          -0.00434
  0.68946           0.68946           0.48703           0.00000          -0.20243
  0.14195           0.14195           0.10027           0.00000          -0.04168
  0.51664           0.51664           0.36495          -0.00000          -0.15169
  0.67901           0.67901           0.47965           0.00000          -0.19936
  0.41857           0.41857           0.29568           0.00000          -0.12289
  0.93335           0.93335           0.65932           0.00000          -0.27404
  0.95274           0.95274           0.67301          -0.00000          -0.27973
  0.42416           0.42416           0.29962          -0.00000          -0.12453
  0.50937           0.50937           0.35982           0.00000          -0.14955
  0.88485           0.88485           0.62506           0.00000          -0.25980
  0.43862           0.43862           0.30984          -0.00000          -0.12878
  0.57767           0.57767           0.40806           0.00000          -0.16961
  0.18591           0.18591           0.13133          -0.00000          -0.05458
  0.44035           0.44035           0.31106          -0.00000          -0.12929
  0.88663           0.88663           0.62631           0.00000          -0.26032
```

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```
  0.02830           0.02830           0.01999          -0.00000          -0.00831
  0.27293           0.27293           0.19280          -0.00000          -0.08013
  0.26879           0.26879           0.16987          -0.00000          -0.07892
  0.72303           0.72303           0.51074           0.00000          -0.21228
  0.87226           0.87226           0.61616           0.00000          -0.25610
  0.58290           0.58290           0.41176          -0.00000          -0.17114
  0.39538           0.39538           0.27929          -0.00000          -0.11609
  0.17556           0.17556           0.12402          -0.00000          -0.05155
  0.74626           0.74626           0.52716           0.00000          -0.21911
  0.38672           0.38672           0.27318           0.00000          -0.11354
  0.07849           0.07849           0.05545          -0.00000          -0.02305
  0.54019           0.54019           0.38158          -0.00000          -0.15860
```

Appendix D. (continued)

```
****************************************************************************

ANALYSIS FOR OTHR ESTIMATES.  "EST. FC" REFERS TO FC ESTIMATED WITH THE OTHER FORMULA.

****************************************************************************


     CALCULATION OF MEANS AND STANDARD DEVIATIONS OF ORNL AND OTHER FC VALUES




     AVERAGE TRUE FC =     0.47322      N=   500

     OVERALL AVERAGE  ORNL FC =     0.47322      N=   500
     OVERALL AVERAGE OTHER FC =     0.33428      N=   500

     AVERAGE  ORNL FC, NEGATIVES SET TO ZERO   0.47322      N=  500.
     AVERAGE OTHER FC, NEGATIVES SET TO ZERO   0.33428      N=  500.

     AVERAGE TRUE FC, WHEN OTHR FC IS POSITIVE =     0.47322      N=   500

     AVERAGE OTHER FC, 0.0 - 1.0 =     0.33428      N=   500

     AVERAGE OTHER FC, LESS THAN 0.0 = **********      N=     0

     AVERAGE OTHER FC - FC, 0.0 - 1.0 =   -0.13894      N=   500

     AVERAGE OTHER FC - FC, LESS THAN 0.0 = **********      N=     0




     AVERAGE EST. FC, 0.0 TO -0.2 = **********      N=     0

     AVERAGE EST. FC - FC, 0.0 TO -0.2 = **********      N=     0

     AVERAGE EST. FC, -0.2 TO -0.4 = **********      N=     0

     AVERAGE EST. FC - FC, -0.2 TO -0.4 = **********      N=     0

     AVERAGE EST. FC, -0.4 TO -0.6 = **********      N=     0
```

Appendix D. (continued)

```
AVERAGE EST. FC - FC, -0.4 TO -0.6 = ***********     N=      0

AVERAGE EST. FC, -0.6 TO -0.8 = ***********     N =      0

AVERAGE EST. FC - FC, -0.6 TO -0.8 = ***********     N=      0




AVERAGE EST. FC, 0.0 TO 0.2 =     0.08479     N=    50

AVERAGE EST. FC - FC, 0.0 TO 0.2 =   -0.03524     N=    50

AVERAGE TRUE FC, WHEN EST. FC IS 0.0  TO  0.2, =    0.12003     N=    50

AVERAGE EST. FC, 0.2 TO 0.4=    0.30506     N=    50

AVERAGE EST. FC - FC, 0.2 TO 0.4=   -0.12679     N=    50

AVERAGE EST. FC, 0.4 TO 0.6=    0.49521     N=    50

AVERAGE EST. FC - FC, 0.4 TO 0.6=   -0.20583     N=    50

AVERAGE EST. FC, 0.6 TO 0.8=    0.64734     N=    50

AVERAGE EST. FC - FC, 0.6 TO 0.8=   -0.26906     N=    50

AVERAGE EST. FC, 0.8 TO 1.0= ***********     N =      0

AVERAGE EST. FC - FC, 0.8 TO 1.0= ***********     N=      0


ST.DEV. TRUE FC =    0.28822

ST.DEV. OTHER FC, 0.0-1.0 =    0.20360

ST. DEV. OTHER FC, LESS THAN 0.0 = ***********
```

Appendix D. (continued)

```
ST.DEV. OTHER FC - FC, 0.0 - 1.0 =     0.08462

ST.DEV. OTHER FC - FC, LESS THAN 0.0 = ***********




ST.DEV. EST. FC, 0.0 TO -0.2 = ***********

ST.DEV. EST. FC - FC, 0.0 TO -0.2 = ***********

ST.DEV. EST. FC, -0.2 TO -0.4 = ***********

ST.DEV. EST. FC - FC, -0.2 TO -0.4 = ***********

ST.DEV. EST. FC, -0.4 TO -0.6 = ***********

ST.DEV. EST. FC - FC, -0.4 TO -0.6 = ***********

ST.DEV. EST. FC, -0.6 TO -0.8 = ***********

ST.DEV. EST. FC - FC, -0.6 TO -0.8 = ***********




ST.DEV. EST. FC, 0.0 TO 0.2 =     0.06039

ST.DEV. EST. FC - FC, 0.0 TO 0.2 =     0.02510

ST.DEV. EST. FC, 0.2 TO 0.4 =     0.05338

ST.DEV. EST. FC - FC, 0.2 TO 0.4 =     0.02219

ST.DEV. EST. FC, 0.4 TO 0.6 =     0.06275

ST.DEV. EST. FC - FC, 0.4 TO 0.6 =     0.02608

ST.DEV. EST. FC, 0.6 TO 0.8 =     0.03167

ST.DEV. EST. FC - FC, 0.6 TO 0.8 =     0.01316

ST.DEV. EST. FC, 0.8 TO 1.0 = ***********

ST.DEV. EST. FC - FC, 0.8 TO 1.0 = ***********
```

Appendix D. (continued)

```
     OTHR               MEAN     STD.      A         B         LOWER     MEAN      UPPER     MEAN       N     RELATIVE
     ESTIMATE           OTHR     DEV.      BOUND     BOUND     FC        TRUE      FC        OTHR             FREQUENCY
     RANGE              DIFFER.  DIFFER.   VALUE     VALUE     EST.      FC        EST.      FC

-0.80  TO -0.60             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0      0.0
-0.60  TO -0.40             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0      0.0
-0.40  TO -0.20             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0      0.0
-0.20  TO -0.00             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0      0.0
-0.00  TO  0.20  -0.0352   0.0251  -0.0854   0.0150  -0.0510   0.1200   0.2910   0.0848   50     31.4%
 0.20  TO  0.40  -0.1268   0.0222  -0.1712  -0.0824   0.2807   0.4319   0.5830   0.3051   50     29.4%
 0.40  TO  0.60  -0.2058   0.0261  -0.2580  -0.1537   0.5234   0.7010   0.8787   0.4952   50     25.2%
 0.60  TO  0.80  -0.2691   0.0132  -0.2954  -0.2427   0.8267   0.9164   1.0061   0.6473   50     14.0%
 0.80  TO  1.00             INSUFFICIENT NUMBER OF SAMPLES -  N=0 OR N=1                                0      0.0

   TOTAL PERCENTAGE OF ALL SAMPLES ACCOUNTED FOR IN ABOVE TABLE = 100.0%

   FCOTHR - FC : OVERALL MEAN BIAS =     -0.13894     ST. DEV. =      0.08462

   AVERAGE PROPORTION OF ORGANISMS ALIVE IN INTAKE SAMPLES =  0.70640
```

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