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Area-Under-The Curve Salmon Escapement Estimation Manual

J.R. Irvine, J.F.T. Morris, and L.M. Cobb

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ABSTRACT

Irvine, J. R., J. F. T. Morris, and L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Can. Tech. Rep. Fish. Aquat. Sci. 1932: 84 p.

This manual is a guide to the use of the area-under-the-curve (AUC) software package which can be employed to generate estimates of the numbers of salmon escaping marine fisheries to spawn in freshwater streams (i.e. escapement). The programs produce escapement estimates by dividing the area-under-the-curve of a graph of fish numbers versus time by the mean residence time or survey life of the fish (i.e. the average time fish are alive in the area surveyed). If visual fish count data are used, estimates of observer efficiency can be generated, and fish count data expanded accordingly. The programs can also be used to generate residence time estimates when fish have been tagged with externally visible tags and subsequent estimates of tagged fish numbers are available. The AUC software package is designed to calculate escapement estimates using data collected from stratified random, stratified index, simple random, or total stream survey designs. When data have been collected in areas selected randomly, the AUC program will calculate minimum variances for the escapement estimates.

RÉSUMÉ

Irvine, J. R., J. F. T. Morris, et L. M. Cobb. 1993. Area-under-the-curve salmon escapement estimation manual. Can. Tech. Rep. Fish. Aquat. Sci. 1932: 84 p.

Ce manuel constitue un guide d'utilisation du progiciel de calcul de l'aire sous la courbe (ASC) qui peut servir à établir des prévisions du nombre de saumons qui s'échappent des pêcheries marines pour aller frayer dans les cours d'eau douce (c.-à-d., échappée). Le progiciel permet de prévoir le nombre de saumons qui s'échappent en divisant l'aire sous la courbe d'un graphique du nombre de poissons en fonction du temps par le temps de séjour moyen ou la durée d'étude moyenne des poissons (c.-à-d., la période moyenne de vie des poissons dans l'aire à l'étude). Si l'on utilise le dénombrement visuel des poissons, il est possible d'estimer l'efficacité de l'observateur et d'ajuster les données sur le nombre de poissons en conséquence. Le progiciel peut aussi servir à établir des prévisions sur le temps de séjour moyen des poissons lorsque ceux-ci ont été étiquetés à l'aide de marques visibles de l'extérieur et qu'il existe des estimations du nombre de poissons étiquetés. Le progiciel ASC est conçu pour calculer les prévisions des échappées à l'aide des données tirées d'échantillonnages aléatoires stratifiés, d'indices stratifiés, d'échantillonnages aléatoires simples ou d'échantillonnages totaux de cours d'eau. Lorsque les données sont recueillies dans des aires choisies au hasard, le programme ASC calcule les écarts minimaux des prévisions sur les échappées.

1.0 INTRODUCTION

Most salmon stocks in the Pacific Region are managed to a fixed escapement goal, and yet the quality of our escapement data is generally poor. Salmon escapements, or the number of salmon surviving marine fisheries and returning to freshwater to spawn, can be estimated in a variety of ways including the area-under-the-curve (AUC) method (Cousens et al. 1982).

An AUC escapement estimate is calculated by plotting periodic fish population estimates against time, then dividing the area under this fish abundance curve expressed in fish-day units by the length of time in days fish are alive in the survey area. The AUC method to estimate escapement has been used for many years (e.g. Gangmark and Fulton 1952). However, until now, there has been no readily available description of how to generate estimates using the AUC method. The purpose of this report is to document the use of a user-friendly software package which is designed to generate estimates of escapement using AUC.

There are two types of data required to generate an AUC escapement estimate. First, periodic estimates of fish numbers are needed. These can be from visual counts of fish, or from any other source (e.g. mark recapture studies). If fish are counted visually, it will be necessary to expand these counts according to some observer efficiency relationship.

It is also necessary to know the fishes' residence time or survey life, which is the average time in days that fish spend in the survey area. If visual surveys are used to estimate fish numbers, residence time is the time fish are visible to surveyors in the survey area. The survey area can be as small as the spawning grounds or as large as an entire watershed. There are numerous ways to estimate residence time. One way is to tag fish with externally visible tags, plot the numbers of tagged fish alive against time, then divide the area-under-the-tag curve expressed in tag-day units by the number of tags applied.

The AUC software package can be used to estimate salmon escapements with visual survey data collected using various survey designs. The package consists of four programs written using Microsoft QuickBASIC 4.5 (Figure 1). Figure 2 illustrates the processing order of the programs in the AUC package. Which programs you run depends on your requirements. If you need to calculate observer efficiency parameters and residence times, then the four programs must be run and in the order: PARAMETS, INFILES, RESTIME, and AUC; if you want to use observer efficiency parameters and residence times from the literature or some other source, then only the INFILES and AUC programs have to be run.

The PARAMETS program (Figure 3) calculates slope and y-intercept parameters by linear regression from observer efficiency data. The INFILES program (Figure 4) constructs, from data keyed in by the user, three files that serve as input for the RESTIME and AUC programs: 1) a parameter file that contains stream stratification parameters, observer efficiency parameters either derived from the PARAMETS program or the literature, and survey dates; 2) a data file that contains the fish counts from each stratum and survey site for each survey day; and 3) a code file that is used to control processing options for fish species within the RESTIME and AUC programs. The RESTIME program (Figure 5) calculates residence times from visual tag depletion studies by the area-under-the-curve method. The principal program of the AUC software package is the AUC program (Figure 6) that calculates the escapement estimate from imported files constructed by the INFILES program, and from user-inputed residence times.

To obtain additional copies of this report or a copy of the AUC Software Package, see Appendix A.

1.1 Survey Designs

The AUC package can be used to calculate escapement estimates using data collected from stratified random (SRS), stratified index (SIS), simple random, or total stream survey designs. When an entire watershed or stream (total stream design) cannot be surveyed, the simplest approach is to use a simple random sampling design. With this design, each section of a stream has an equal probability of being selected. However, if sampling units can be divided into homogeneous groups, then stratified random sampling is generally preferable to simple random sampling, since stratification usually results in a smaller variance than that given by comparable simple random sampling (Cochran 1977).

In a stratified survey design, the watershed is divided into strata. In the examples provided in this documentation, strata were determined by tributary confluences and/or major transitions in stream gradient or some other habitat characteristic, and these strata were subdivided into survey sites. There are other ways of stratifying a watershed. The ideal variate for stratifying a watershed is fish density. However, this is generally not possible since fish densities within a system are not usually known prior to surveying. It may be possible though to stratify a watershed into particular habitat types which correlate with high and low fish densities.

If each stratum is internally homogenous with respect to fish distribution, then density estimates should vary little among the constituent survey sites within a stratum on a given survey day. The mean densities for each stratum can then be combined on a proportionally weighted basis to yield stratified mean density estimates, that are expanded to yield more precise daily population estimates for the entire watershed.

SRS and SIS designs differ in the way survey sites are selected. In a SRS design, two or more survey sites are selected randomly from each stratum on each survey day. When the SRS design is used, the AUC program can be used to estimate variances around escapement estimates.

Escapement estimates based on data collected using a SRS design should not be biased. However, if fish are highly aggregated, strata are determined geographically, and the area surveyed for fish is small relative to the total area, the SRS design has a higher probability of sampling low abundance sites than high abundance sites and therefore may under-estimate escapement.

In a SIS design, the selection of index sites should be planned to best represent the non-random distribution of fish within the watershed. If a watershed has been stratified geographically and strata contain a variety of habitat and presumably also fish densities, an effort should be made to include a range of habitat when selecting index sites from each stratum. Provided that fish densities in index sites are representative of densities in the strata, the SIS design should give reasonably accurate escapement estimates. However, the SIS design suffers from the drawback that variability around the population estimates cannot be calculated unless fish are distributed randomly within strata. In some watersheds, index sites are selected on the basis of easy access to surveyors and where fish abundances are expected or known to be high, and no attempt is made to represent the non-random distribution of fish densities. This survey design should give reliable indices of escapement, if the relative fish abundances at these index sites correlate strongly with stream populations.

The AUC software package was designed for the SRS and SIS designs, but it can be manipulated by the user to accommodate the simple random and total stream surveys. For the simple random survey, you should define the entire watershed as one stratum that is sub-divided into survey sites along its length. You can then randomly select up to seven survey sites on each survey day. For total stream surveys, you should define the watershed as one stratum that has one survey site, so that the surveyed watershed, stratum, and survey site represent the same length of stream (see 4.1).

The AUC software package is not written for survey designs other than the four mentioned. Cochran (1977) provides the statistical basis for these and other sampling designs while Satin and Shastry (1988) give a non-mathematical guide.

1.2 Black Creek Example

To illustrate the use of the AUC software package, data collected during 1989 on coho salmon (Oncorhynchus kisutch) returning to Black Creek on the east coast of Vancouver Island (Fig. 7) are provided. The Black Creek watershed was divided into six strata which were subdivided into 250 m survey sites. Two of these survey sites per strata were randomly selected on each sampling event in the SRS design, and fixed numbers of index sites per strata were surveyed for the SIS design. The watershed and study design are described in more detail in English et al. (1992) and Irvine et al. (1992).

2.0 Getting Started With The AUC Software Package[1]

The AUC software package generates estimates of escapement by the area-under-the-curve method, and includes the following four programs: PARAMETS, INFILES, RESTIME, and AUC. The distribution diskette for this package includes four executable files which were produced using Microsoft QuickBASIC version 4.5, an installation batch file, and a read.me file.

2.1 Computer Hardware Requirements

Installation of the AUC package requires an IBM-PC compatible computer with at least 350 free kilobytes on the hard drive and a CGA, EGA, VGA, or MCGA compatible video adapter board.

2.2 Installation

Install the AUC package on your hard drive as follows:

1) Insert the diskette labelled "AUC Software Package" into a disk drive.

2) Go to the disk drive where the AUC Software Package diskette now resides.

e.g. **C:\>** *A:* or **C:\>** *B:*

3) Install the contents of the AUC Software Package diskette with the command **install (from_drive) (to_drive)**, where

(from_drive) is the disk drive where the AUC Software Package resides.

(to_drive) is the hard drive where the AUC Software Package is to be copied.

e.g. **A:\>** *INSTALL A: C:* or **B:\>** *INSTALL B: C:*

This installation procedure creates a **C:\AUC** directory that contains the AUC software package including a READ.ME file. Note that if you already had a **C:\AUC** directory, this installation procedure would overwrite it.

[1]Neither the Department of Fisheries and Oceans, nor the authors of this report, make any warranties, either expressed or implied, as to any matter whatsoever, should the software prove defective. HER MAJESTY THE QUEEN IN RIGHT OF CANADA, represented by the Department of Fisheries and Oceans, c/o Pacific Biological Station, Nanaimo, British Columbia, V9R 5K6 in no way endorses, insures, or warrants any use of the software, nor accepts any liability for its use.

2.3 Setting-up

If you wish to obtain a hard copy of any of graphs generated with the AUC programs, you use the DOS graphics command. Type *GRAPHICS* before running any of the AUC programs. If you are not using a dot matrix printer, you must indicate the printer type. For instance, if you are using a Hewlett Packard LaserJet printer, you type *GRAPHICS LASERJET*. See your DOS manual for additional information. Press "Print Screen" to obtain a hard copy.

Type *CD AUC* at the **C:\>** prompt to move to the **C:\AUC** directory.

Type *TYPE READ.ME* to read the read.me file.

Create a sub-directory to store the output files from the AUC package. In this manual, the AUC package is demonstrated with coho counts from escapement surveys on Black Creek in 1989, and so we create the sub-directory **C:\AUC\BLACK** by typing *MD BLACK* at the **C:\AUC>** prompt.

In this manual, we run the PARAMETS, INFILES, RESTIME, and AUC programs, from within the **C:\AUC** directory. For an experienced user, a better way to run the AUC programs is from outside the **C:\AUC** directory, for instance from a working directory such as **C:\BLACK**. To set up this directory, insert *C:\AUC* in the **PATH** statement in the **AUTOEXEC.BAT** file and reboot, or type *PATH = C:\AUC*, type *MD BLACK* at the **C:\>** prompt to create a **C:\BLACK** directory, and type *CD BLACK* to move to the **C:\BLACK** directory. To run the PARAMETS, INFILES, RESTIME, and AUC programs, simply type the program name. In this case, when you are running the programs, you do not have to type in the full file specifications for the input and output files as is requested at the prompts, but simply type in the file name (e.g. *BLACK89.PMT*, *BLACK89.CDE*, or *BLACK89.DAT*). The AUC programs will read from and store these files within in the **C:\BLACK** sub-directory.

Type *<Ctrl> <C>* or *<Ctrl> <Break>* to cancel these programs at any time during a run.

The program issues a 'Redo from start' prompt if an incorrect response to a prompt is entered or if data are entered using an incorrect format. At this prompt, simply re-enter and proceed with the program.

3.0 The PARAMETS Program

Generally, only a portion of the fish present are seen during a visual survey. It is therefore necessary to estimate the efficiency of observation, and adjust the number of fish counted accordingly. Various methods of measuring observer efficiency (oe) are possible. To calculate oe using PARAMETS, a series of paired fish estimates is required where the number of fish present is estimated using standard visual survey techniques and compared with the 'actual' number of fish present as estimated using some other technique. Observer efficiency should be measured over the same distance or area as visual surveys are conducted. PARAMETS allows you to input these types of data and compute observer efficiency.

The number of fish observed during a visual survey can never exceed the number of fish that are really there. However, it sometimes happens when measuring oe that the 'actual' number is underestimated so that the number observed is higher than the 'actual' number. To correct for this, in PARAMETS, any estimated 'actual' number less than its respective observed number is reassigned to equal the observed number.

PARAMETS reads a set of data from observer efficiency tests (maximum number of tests permitted is 99), and calculates the y intercept (a) and slope (b) of the regression of the number of fish seen versus the number of fish present. If the raw data poorly represent a straight line, mathematical transformations can be performed on the data. In this release of the AUC Software Package, only the natural logarithmic transformation is available (i.e. ln (number of fish + 1)) where both the actual and observed fish numbers are transformed. This transformation is appropriate when there is increasing variability in the numbers of fish observed at higher densities. To assist in determining the desirability of transforming the data, PARAMETS also allows you to see a plot of the residuals (Zar 1984).

PARAMETS outputs oe parameters to an *.obs file. In INFILES, you select the most appropriate parameters to use (e.g. calculated from transformed data or not).

If you wish to use oe parameters from other sources, PARAMETS does not have to be run. You can enter oe parameters when running INFILES.

3.1 Observer Efficiency Parameter Determinations

PARAMETS fits a least squares regression line with the equation, $y = a + bx$, to a scatter of paired observer fish counts/ actual fish number observations, where y = the predicted observer fish counts, x = the 'actual' fish numbers, a = the y-intercept of the fitted line, and b = the slope of the fitted line.

Estimated observer efficiencies are the ratios of predicted observer fish counts to actual fish numbers along the fitted regression line.

PARAMETS calculates the observer efficiency coefficients, a and b, to fit the regression line. These coefficients are stored in a file with the extension *obs* (*.obs) that can serve as input for the INFILES program.

PARAMETS also calculates the coefficient of determination, r^2, which is a measure of the proportion of the total variability in the regression model that is explained by the regression of the observer fish counts on actual fish numbers, and the coefficient of correlation, r. These coefficients are displayed on the screen, but are not written to the *.obs file.

3.2 Running The PARAMETS Program

The PARAMETS program is demonstrated using observer efficiency data from the Black Creek, 1989 survey that are provided in Tables 1 and 2.

Type *PARAMETS* from the **C:\AUC** directory to begin a run.

PARAMETS reads in oe data from an existing file or collects oe data that you type in, and stores them in a new file specified by you at run-time. You are asked to specify the full filename for this new file (i.e. drive:\directory\sub-directory\base filename.extension). It is suggested that you select a base filename that identifies a survey (i.e. BLACK89.* for the Black Creek, 1989 survey), and a 3-letter file extension that identifies a fish type (i.e. *.ADS for adults, *.JKS for jacks, *.CNK for chinook, etc.). Do not give use .OBS as the extension for your file name.

The table of observer efficiency data that you construct in PARAMETS is saved in a file so that it can be used in future sessions of PARAMETS. To use an existing file for input in this PARAMETS session enter 1. The data in this imported file can be modified in this PARAMETS session. To key in the observer efficiency data enter 2: *2*

Choose name of file to store keyed in observer efficiency data.
Indicate full file specification.
(i.e. drive\dir\name.ext): *C:\AUC\BLACK\BLACK89.ADS*

If the *C:\AUC\BLACK\BLACK89.ADS* file has already been constructed in a previous PARAMETS session, you may want to import it into this PARAMETS session to add, delete, or change some observer efficiency counts in order to calculate improved parameter estimates. If this is the case, enter *1* at the first prompt and the following will appear on the screen. You then have the option of creating a new file to store the modified observer efficiency counts or re-writing the contents of the imported file.

Input existing observer efficiency data file.
Indicate full file specification.
(i.e. drive\dir\name.ext): *C:\AUC\BLACK\BLACK89.ADS*

Choose new name for the observer efficiency data file.
Indicate full file specification.
(i.e. drive\dir\name.ext)
Default is c:\auc\black\black89.ads> *<ENTER>*

Enter the type of fish for which you are determining the observer efficiency parameters: *adults*

Since option *2* at the first prompt was selected, enter the number of observer efficiency measurements conducted and key in the adult coho oe counts from Table 1 into the table displayed on the screen.

Note that an incorrect actual number for count #2 has been deliberately entered in order to demonstrate the editing routine within PARAMETS.

Enter the number of observer efficiency measurements taken. Do not include a count where both values are zero: *10*
Fill in table:

Count	Observed Number	Actual Number
1	*14*	*8*
2	*4*	*5*
3	*8*	*8*
4	*1*	*3*
5	*41*	*37*
6	*11*	*13*
7	*13*	*17*
8	*34*	*43*
9	*38*	*40*
10	*3*	*7*

PARAMETS displays the first draft of the table after all the oe counts have been entered. If option *1* at the first prompt in this PARAMETS session was selected, this table will contain the oe counts from the imported file.

Note that actual fish numbers less than their corresponding observed fish counts, have been changed to the observed fish count. In these cases, it has been assumed that the original actual fish numbers had been underestimated.

Table of Data **note: all actual numbers smaller than observed numbers were changed to equal the observed numbers**

=============

Count	Observed Number	Actual Number
1	14	14
2	4	5
3	8	8
4	1	3
5	41	41
6	11	13
7	13	17
8	34	43
9	38	40
10	3	7

The editing routine within PARAMETS that provides options to add, delete, and correct entries to this first and any subsequent drafts of this table, will now be demonstrated. First, add a count:

Enter 1 to add more observer efficiency counts, enter 2 to delete a count, enter 3 to correct any of the entries, or 4 if the data are correct and to proceed: *1*

How many more observer counts do you want to add: *1*

Enter *99* and *99* for the observed number and actual number at count #11 in the displayed table.

Continue to fill in table with new data:

Count	Observed Number	Actual Number
1	*14*	*8*
2	*4*	*5*
3	*8*	*8*
4	*1*	*3*
5	*41*	*41*
6	*11*	*13*
7	*13*	*17*
8	*34*	*43*
9	*38*	*40*
10	*3*	*7*
11		

PARAMETS displays the second draft of the table with the added count.

Table of Data

note: all actual numbers smaller than observed numbers were changed to equal the observed numbers

Count	Observed Number	Actual Number
1	14	14
2	4	5
3	8	8
4	1	3
5	41	41
6	11	13
7	13	17
8	34	43
9	38	40
10	3	7
11	99	99

Next delete the added count:

Enter 1 to add more observer efficiency counts, enter 2 to delete a count, enter 3 to correct any of the entries, or 4 if the data are correct and to proceed: *2*

Indicate the count to be deleted: *11*

PARAMETS displays the third draft of the table.

Table of Data **note: all actual numbers smaller than observed numbers were changed to equal the observed numbers**

=============

Count	Observed Number	Actual Number
1	14	14
2	4	5
3	8	8
4	1	3
5	41	41
6	11	13
7	13	17
8	34	43
9	38	40
10	3	7

Now, correct the error in count #2:

Enter 1 to add more observer efficiency counts, enter 2 to delete a count, enter 3 to correct any of the entries, or 4 if the data are correct and to proceed: *3*

Indicate the incorrect count: *2*
Re-enter the number of fish seen: *4*
Re-enter the actual number of fish: *2*

PARAMETS displays the fourth and in this example the final draft of the table.

Table of Data **note: all actual numbers smaller than observed numbers were changed to equal the observed numbers**

=============

Count	Observed Number	Actual Number
1	14	14
2	4	4
3	8	8
4	1	3
5	41	41
6	11	13
7	13	17
8	34	43
9	38	40
10	3	7

Enter 1 to add more observer efficiency counts, enter 2 to delete a count, enter 3 to correct any of the entries, or 4 if the data are correct and to proceed: *4*

PARAMETS stores the data from the final draft of the table into the specified C:\AUC\BLACK\BLACK89.ADS file (Table 3).

PARAMETS provides an option to natural log-transform both the observer and actual fish numbers by the equation, transformedata=ln(data+1), if the raw oe data points are poorly represented by a straight line. The log-transformation is especially appropriate when the variability of observer fish counts increases with fish densities.

Select transformation (1=linear(i.e. none), 2=ln(data+1), 3=both): *3*

PARAMETS calculates and displays the oe parameters for linear and log-transformed data.

Observer Efficiency Parameters Calculated for adults
==

With linear (i.e. no) transformation,
alpha (intercept) is: -1.001556
beta (slope) is: .9316609
the correlation coefficient (r) is: .9850675
the coefficient of determination (r squared) is: 0.9703581

With ln(data+1) transformation,
alpha (intercept) is: -.5774038
beta (slope) is: 1.13847
the correlation coefficient (r) is: 0.9708571
the coefficient of determination (r squared) is: 0.9425635

Press enter to continue.

PARAMETS displays a scatter diagram of the linear observer efficiency data.

Press enter to see line.

PARAMETS displays the fitted regression line to the linear observer efficiency data (Figure 8).

Press enter to continue.

PARAMETS displays a scatter diagram of the log-transformed observer efficiency data.

Press enter to see line.

PARAMETS displays the fitted regression line to the log-transformed observer efficiency data (Figure 9).

Would you like to see a plot of residuals (1=yes, 2=no)? *1*

PARAMETS displays a plot of residuals from the regression on the linear observer efficiency data (Figure 10).

Press enter to continue.

PARAMETS displays a plot of residuals from the regression on the log-transformed observer efficiency data (Figure 11).

Comparisons of the linear and log-transformed residual plots should help you determine if the transformation was appropriate. In this case, transformations did not improve the fit of the lines, or the fit of the residuals so linear regressions on the untransformed data are appropriate.

You should make a note whenever you decide that transformations are appropriate so you know which of the oe parameters calculated in PARAMETS to use when you run INFILES.

Press enter to continue.

PARAMETS presents the following menu.

Menu

1. See graph of Observed versus Actual - no transformation
2. See graph of Observed versus Actual - ln(data+1) transformation
3. See graph of Residuals - no transformation
4. See graph of Residuals - ln(data+1) transformation
5. See display of parameters
6. Go back and estimate parameters for another fish type
7. QUIT PARAMETS

Choose a menu item: *6*

PARAMETS goes back to calculate the parameters for the coho jack observer efficiency data in Table 2. The coho jack observer efficiency parameters, a and b, are written to the same BLACK89.OBS file (Table 5), but the observer efficiency data are written to the newly specified BLACK89.JKS file (Table 4).

Also, in the same session, PARAMETS can calculate oe parameters for another survey that may be identified by a different stream or year. For example, if you have also have oe counts on adult coho escapement to the French River in 1989, PARAMETS will construct a FRENCH89.ADS file containing the counts and a FRENCH89.OBS file containing the calculated parameters in addition to the BLACK89.* files (if the same nomenclature system is applied).

Observer Efficiency Parameters Calculated for jacks
==

With linear (i.e. no) transformation,
alpha (intercept) is: .9782609
beta (slope) is: .4021739
the correlation coefficient (r) is: .4672204
the coefficient of determination (r squared) is: 0.2182949

With ln(data+1) transformation,
alpha (intercept) is: -.1688305
beta (slope) is: .8901317
the correlation coefficient (r) is: 0.6576632
the coefficient of determination (r squared) is: 0.4325208

Choose a menu item: *7*

You have finished the program PARAMETS Press enter to continue...

4.0 The INFILES Program

The INFILES program constructs the following three files (Figure 4) from data that are keyed in by the user. The RESTIME and AUC programs use these files as input:

1) A *.PMT file that contains the following survey parameters: stream length, number of strata, strata lengths, numbers of survey sites within strata, lengths of survey sites, the number of surveys, the time in days from the first survey for each survey, and observer efficiency parameters.

2) A *.DAT file that contains fish count data from the surveys.

3) A *.CDE file that contains codes assigned to fish types.

4.1 The Special Cases For Total Stream And Simple Random Surveys

The AUC software package is primarily designed to calculate AUC escapement estimates for the stratified index (SIS) and random (SRS) surveys, however it can accommodate both the total stream and simple random surveys if you "de-stratify" the inputed stream parameters in INFILES as follows:

For a total stream survey, the number of strata within the stream and the number of survey sites within the stratum are set to one, so that the stream, stratum, and the survey site represent the same length of surveyed area. If the Black Creek, 1989 AUC escapement estimate was based on a total stream survey, then the stream, stratum, and survey site lengths would each be 30250 m and the number of strata and survey sites would be one.

For a simple random survey, the number of strata are set to one, so that the stream and stratum represent the same length of the surveyed area that is divided into many survey sites. INFILES will allow the user to input fish counts from up to seven randomly selected survey sites within the one stratum. If the Black Creek, 1989 AUC escapement estimate was based on a simple random survey, then both the stream and stratum lengths would be 30250 m, the one "stratum-stream" would be divided into many 250 m length survey sites, and a maximum of seven survey sites could be randomly selected from this "stratum-stream" on each survey day.

Fish counts must be inputed by the SIS method in INFILES for the total stream survey, and by the SRS method for the simple random survey.

4.2 Running The INFILES Program

The INFILES program is demonstrated with data collected from the 1989 coho escapement surveys on Black Creek. Table 6 provides the stream stratification parameters and Table 7 provides the observer counts of adult and jack coho on each survey day.

Type INFILES from the **C:\AUC** directory to begin a run.

C:\AUC> *INFILES*

Specify a base filename for the *.PMT, *.DAT, and *.CDE files to be constructed. Again, the base file name should identify a survey (ie. Black89.PMT for the Black Creek, 1989 survey) and it must be the same as the base filename of the *.OBS file containing the observer efficiency parameters that was constructed by the PARAMETS program.

Choose a name for the *.PMT file that will contain the stream parameters.
Indicate full file specification. Be sure to type the *.PMT extension.
(ie. drive:\dir\name.PMT): *C:\AUC\BLACK\BLACK89.PMT*

Choose a name for the *.DAT file that will contain the fish count data.

Indicate full file specification.
(default is c:\auc\black\black89.DAT): *<enter>*

Choose a name for the *.CDE file that will contain the fish type codes.
Indicate full file specification.
(default > c:\auc\black\black89.CDE): *<enter>*

Enter the number of fish types surveyed and a name for each type. Note: the fish type names must be the same as the ones selected in the PARAMETS run. Pay attention to the spellings.

How many fish types were surveyed: *2*

fish type code #: **1. Enter name:** *adults*
fish type code #: **2. Enter name:** *jacks*

Enter the most suitable of either the linear or natural log-transformed oe parameters for each fish type. INFILES acquires the calculated oe parameters from the *.obs file (ie. black89.obs) constructed by PARAMETS and these are the defaults.

You also have the option of entering alternative oe parameters. For example, if you wish to run the program assuming that a certain percentage of fish is seen by the observers and the relationship between the percentage seen and fish density is linear, enter the proportion seen as the slope (e.g. 75% observer efficiency means a slope of 0.75) and enter 0.0 for the intercept.

Indicate the best oe parameters for adults.
(1=linear(i.e. none), 2=ln(data+1)): *1*
Enter both observer efficiency parameters for adults.
First enter the slope. (Default is 0.9316609): *<enter>*
Now enter the intercept. (Default is -1.001556): *<enter>*

Indicate the best oe parameters for jacks.
(1=linear(i.e. none), 2=ln(data+1)): *2*
Enter both observer efficiency parameters for jacks.
First enter the slope. (Default is .8901317): *<enter>*
Now enter the intercept. (Default is -.1688305): *<enter>*

Enter the information on stream stratification for Black Creek that is in Table 6. This includes survey (stream) length in metres, number of strata, strata lengths, numbers of survey sites within strata, and survey site lengths.

The total length of the stream for which the escapement is to be estimated should be entered, and not just that extent of the stream that was accessible to the surveyors. For example, even if only 30,000 m of the 30,250 m length of Black Creek was surveyed, you should still enter 30,250 m for the survey length to obtain an escapement estimate for all of Black Creek.

If the sum of the strata lengths is less than the survey length, then it is recommended that some strata lengths that can represent sections of the unsurveyed stream with common habitat characteristics and hence with expected similar fish densities, should be expanded before input, to compensate for the unsurveyed length of the stream. If this expansion is not done, the AUC program will apply the average fish density to the unsurveyed stream length.

If fish congregate in certain locations (e.g. spawning sites), and your count data are from these locations only, the survey length is the sum of the lengths of these locations. In this case, if you were to give the total length of the stream as your survey length, escapement estimates would be positively biased.

Enter the survey length which is the length of stream for which the escapement is to be estimated (meters): *30250*

Enter the number of strata: *6*

Enter the length of stratum #1 : *4750*
Enter the length of stratum #2 : *4500*
Enter the length of stratum #3 : *3500*
Enter the length of stratum #4 : *5000*
Enter the length of stratum #5 : *8500*
Enter the length of stratum #6 : *4000*

The number of sites surveyed for each stratum is the greater of the maximum number of index sites in the SIS design and the maximum number of survey sites in the SRS design for all survey days within the AUC escapement survey. For example, in the Black Creek, 1989 AUC escapement survey, since stratum 2 had just one index site in the SIS design and two survey sites in the SRS design that were surveyed, you should enter 2; and since stratum 4 had three index sites in the SIS design and just two survey sites in the SRS design that were surveyed, you should enter 3. It is, however, recommended that a minimum of two sites per stratum should be surveyed.

Enter the number of sites surveyed in stratum #1: *2*
Enter the number of sites surveyed in stratum #2: *2*
Enter the number of sites surveyed in stratum #3: *2*
Enter the number of sites surveyed in stratum #4: *3*
Enter the number of sites surveyed in stratum #5: *2*
Enter the number of sites surveyed in stratum #6: *2*

Enter the survey site length (m) for stratum # 1: *250*
Enter the survey site length (m) for stratum # 2 : (Default= 250):

Enter the survey site length (m) for stratum # 3 : (Default= 250):
Enter the survey site length (m) for stratum # 4 : (Default= 250):
Enter the survey site length (m) for stratum # 5 : (Default= 250):
Enter the survey site length (m) for stratum # 6 : (Default= 250):

Enter the number of surveys conducted during the escapement period. Include as survey day #1, the first day that you estimate that fish moved into the survey area even though fish may not have been counted that day. The last survey day is the day when there are no longer any fish in the survey area. Add an extra survey day if fish were counted on your last real survey: *10*

For the dates of each survey day, enter the numerical values of the month, day, and year separated by commas (e.g. 12,25,93):

Survey dates for the Black Creek coho escapement survey in 1989 are provided in Table 7. The Jan-05,1990 date for survey #10 was estimated by extrapolating the fish counts to the day when there should no longer be any fish in the stream.

If it takes two consecutive days to complete a survey, assume that it takes one day and enter either the first or second date on a consistent basis.

Single digit month numbers and days must be proceeded with a zero. If you make an error entering dates, you can type *<Ctrl><C>* or *<Ctrl><Break>* to cancel and begin again. Alternatively, you can edit your files later using an MS-DOS or other editor

Enter the date (mm,dd,yy) for survey day #1 (i.e. the date that fish moved into the survey area but were not counted): *10,20,89*

Enter the date (mm,dd,yy) for survey day #2: *10,28,89*
Enter the date (mm,dd,yy) for survey day #3: *11,06,89*
Enter the date (mm,dd,yy) for survey day #4: *11,13,89*
Enter the date (mm,dd,yy) for survey day #5: *11,22,89*
Enter the date (mm,dd,yy) for survey day #6: *11,30,89*
Enter the date (mm,dd,yy) for survey day #7: *12,11,89*
Enter the date (mm,dd,yy) for survey day #8: *12,18,89*
Enter the date (mm,dd,yy) for survey day #9: *12,27,89*

Enter the date (mm,dd,yy) for survey day #10 (i.e. the date of the end of the survey when there were zero fish left): *01,05,90*

If your fish abundance estimates are from another source (e.g. mark recapture studies), enter these data into the tables that appear on the screen. In our example, we will enter the adult coho and jack counts from Table 7 into the survey day tables.

The tables for the first and last survey days do not appear because the fish counts for these survey days are assumed to be zero.

Sites that were not surveyed on a survey day (i.e. missing values) are represented by -1's.

INFILES will interpolate a fish count for these -1's from the fish counts on previous and subsequent survey days. However, if a survey site is not surveyed on those survey days that span the peak of the run and you have counts from just the beginning or end of the survey period, then you should eliminate this survey site from the AUC escapement estimation. Otherwise, INFILES will substitute low counts for the -1's during this middle period when high numbers of fish are probably present.

If a survey site was not surveyed at all during the survey period and you have entered -1 for missing values in the tables for each survey day that pops up on the screen, INFILES will convert the assumed zero counts to -1's for the first and last survey days.

Note that an incorrect count has been deliberately entered for stratum 1, site 2 to demonstrate the editing routine within INFILES.

When surveying fish type: adults, did you use the SIS method (1=yes,2=no)? *1*

Fill table for adults for survey day # 2, using the SIS method.

strata	site 1	site 2	site 3
1	*1*	*0*	
2	*0*	*-1*	
3	*7*	*1*	
4	*1*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Would you like to correct any of the data in this table (1=yes,2=no)? *1*

Indicate which strata: *1*

Fill table for adults for survey day # 2, using the SIS method.

strata	site 1	site 2	site 3
1			
2	*0*	*-1*	
3	*7*	*1*	
4	*1*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Re-enter with the correct counts for strata 1, sites 1 and 2.

Fill table for adults for survey day # 2, using the SIS method.

strata	site 1	site 2	site 3
1	*1*	*1*	
2	*0*	*-1*	
3	*7*	*1*	
4	*1*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Would you like to correct any of the data in this table (1=yes,2=no)? *2*

Fill table for adults for survey day # 3, using the SIS method.
Fill table for adults for survey day # 4, using the SIS method.
Fill table for adults for survey day # 5, using the SIS method.
Fill table for adults for survey day # 6, using the SIS method.
Fill table for adults for survey day # 7, using the SIS method.
Fill table for adults for survey day # 8, using the SIS method.
Fill table for adults for survey day # 9, using the SIS method.

When surveying fish type: adults, did you use the SRS method (1=yes,2=no)? *1*

Fill table for adults for survey day # 2, using the SRS method.
Fill table for adults for survey day # 3, using the SRS method.
Fill table for adults for survey day # 4, using the SRS method.
Fill table for adults for survey day # 5, using the SRS method.

Fill table for adults for survey day # 6, using the SRS method.
Fill table for adults for survey day # 7, using the SRS method.
Fill table for adults for survey day # 8, using the SRS method.
Fill table for adults for survey day # 9, using the SRS method.

When surveying fish type: jacks, did you use the SIS method (1=yes,2=no)? *1*

Fill table for jacks for survey day # 2, using the SIS method.
Fill table for jacks for survey day # 3, using the SIS method.
Fill table for jacks for survey day # 4, using the SIS method.
Fill table for jacks for survey day # 5, using the SIS method.
Fill table for jacks for survey day # 6, using the SIS method.
Fill table for jacks for survey day # 7, using the SIS method.
Fill table for jacks for survey day # 8, using the SIS method.
Fill table for jacks for survey day # 9, using the SIS method.

When surveying fish type: jacks, did you use the SRS method (1=yes,2=no)? *1*

Fill table for jacks for survey day # 2, using the SRS method.
Fill table for jacks for survey day # 3, using the SRS method.
Fill table for jacks for survey day # 4, using the SRS method.
Fill table for jacks for survey day # 5, using the SRS method.
Fill table for jacks for survey day # 6, using the SRS method.
Fill table for jacks for survey day # 7, using the SRS method.
Fill table for jacks for survey day # 8, using the SRS method.
Fill table for jacks for survey day # 9, using the SRS method.

Your stream parameters are in the file C:\AUC\BLACK\BLACK89.PMT

Your fish count data are in the file C:\AUC\BLACK\BLACK89.DAT

Your fish code data are in the file C:\AUC\BLACK\BLACK89.CDE

You have finished the program INFILES   Press enter to continue...

Tables 8, 9, and 10 show the contents of files constructed by INFILES for the Black Creek, 1989 survey and describes their formats.

Remember, you can correct any input errors created during INFILES by editing these files with an MS-DOS or other editor.

5.0 The RESTIME Program

RESTIME estimates residence time or survey life, defined as the average time in days fish spend in the surveyed area and are available to be counted by surveyors, from counts of visually tagged fish. Residence time should not be confused with stream life which is the time that fish remain alive after entering a system. If a system includes areas where fish hold up but are not counted (e.g. lakes or deep pools within the watershed), the stream life includes the time spent by fish in these areas and hence is longer than residence time or survey life. We have found in our research on coho salmon returning to the Chase River, Nanaimo that stream life calculated from tagged carcass recoveries was 18.3 d while residence time calculated from floy tag resightings was only 8.5 d. Escapement estimates generated using AUC are very sensitive to residence time estimates.

There are various ways to estimate residence time. In our example, an escapement pulse is marked with externally visible tags on an initial date, t_1. On subsequent survey days, surveyors record the counts of sightings of tagged fish on the survey sites. These counts are corrected for observer efficiency and tag retention (which is assumed to include tag loss and tagging induced mortality), then expanded by stratum to estimate the number of marked fish in the stream on each survey day.

RESTIME displays graphs of the numbers of marked fish in the survey area versus time. You have the option of selecting from two graphs that differ in the assumed number of tagged fish in the survey area at t_1. The total tag curve assumes that the number of tagged fish at t_1 equals the number of tags applied, which compensates for a recommended survey shortly after tagging that is often not conducted because the fish runs tend to coincide with dangerously high water and strong flows. The observed tag curve assumes that the number of tagged fish at t_1 equals zero. RESTIME estimates residence times by dividing the area under the curves by the number of tags applied.

English et al. (1992) found that AUC escapement estimates based on "observed residence times" were sensitive to variability in survey timing, observer efficiency, and tag retention, while those based on "total residence times" were more robust, and hence were generally preferred. In general, if visual surveys are conducted soon after tagged fish are released, differences between residence time estimates using the two types of curves will be small.

In some surveys, a number of timing segments of the run may be marked with color-coded external tags to estimate an average residence time. RESTIME has the capability to estimate residence times for any number of timing runs in one session. However, it is your task to calculate the average or, as an option, select the most reasonable residence time estimate.

RESTIME does not have to be run if you elect to use residence times from similar systems or the literature. However, Perrin and Irvine (1990) in their review of residence time estimates, recommend that residence times should be determined on a site specific basis each time the AUC method is used to estimate escapement.

5.1 Detailed Calculations

RESTIME calculates daily tag abundance estimates, area-under-the-curve estimates for the tag curves, and residence time estimates with the formulae presented in this section.

5.1.1 Daily tag abundance estimates

Daily estimates of the number of tagged fish in the surveyed area are calculated by correcting the number of tagged fish observed at each survey site for observer efficiency and tag retention, and expanding the weighted mean tag count per survey site to the survey area as follows.

First, the mean density of tagged fish *tag* per survey site for each stratum and survey day is estimated by,

$$\overline{tag}_{ih} = \left(\sum_{j=1}^{ns} to_{ihj} \cdot oe_{ihj}^{-1} \cdot tr^{-1}\right) \cdot (ns_{ih}^{-1}) \qquad (1)$$

where *to* is the number of tagged fish observed and *oe* is the observer efficiency factor at survey site *j*, in stratum *h*, and on survey day *i*; *tr* is the tag retention factor; and *ns* is the number of sites surveyed for each stratum and survey day.

Next, the stratified mean density tag_{st} of tagged fish for each survey day is estimated by,

$$\overline{tag}_{st_i} = \sum_{h=1}^{L} \overline{tag}_{ih} \cdot W_h \qquad (2)$$

where *W* is a stratification weighting factor that is calculated by,

$$W_h = N_h \cdot \left(\sum_{h=1}^{L} N_h\right)^{-1} \qquad (3)$$

where N_h is the total number of survey sites per stratum (those surveyed plus those not surveyed) and *L* is the number of strata in the stream.

In the last step, the daily estimates of the number of tagged fish in the stream, TAG_i is calculated by,

$$TAG_i = (\sum_{h=1}^{L} N_h) \cdot \overline{tag}_{st_i} \tag{4}$$

5.1.2 Residence time estimates

The daily estimates of the number of tagged fish in the stream are plotted against survey days, and the area under the tag curve auc_g is estimated from the sum of the rectangular areas that approximate the area under the curve. This is expressed mathematically as,

$$auc_g = 0.5 \cdot \sum_{i=2}^{n} (t_i - t_{i-1}) \cdot (TAG_i + TAG_{i-1}) \tag{5}$$

where t_i is the number of days from the tagging date defined here as t_1 to the nth survey day inclusive. In the observed tag method, TAG_1 is set at zero; and in the total tag method, TAG_1 is set to equal the number of tags applied.

The residence time rt, which is the average time in days tagged fish remain in the survey area, is estimated by,

$$rt = auc_g \cdot rel_g^{-1} \tag{6}$$

where rel_g is the number of tagged fish in the group released.

5.2 Running The RESTIME Program

The RESTIME program is demonstrated with counts of visual tag sightings from the Black Creek, 1989 survey in Table 11. Two run timing segments were tagged: 102 blue tags were applied on Oct 24 and 85 red tags were applied on Dec 2; and two survey designs were evaluated: SIS and SRS. Therefore, we have four sets of tag sighting counts: 1) blue, SIS; 2) blue, SRS; 3) red, SIS; and 4) red, SRS.

The estimated residence times for the "blue tag, SIS design' data set will be calculated first.

Type RESTIME from the C:\AUC directory to begin a run.

C:\AUC> *RESTIME*

RESTIME requires the following three files that are constructed by INFILES: the *.PMT file containing the observer efficiency parameters and stream parameters including stream lengths, numbers of strata, strata lengths, numbers of index sites within strata, and index site lengths; the *.DAT file containing dates of the survey days; and a *.CDE file containing codes for fish type.

Input the *.PMT file that contains the stream and oe parameters.
Indicate full file specification.
(i.e. drive:\dir\name.PMT): *C:\AUC\BLACK\BLACK89.PMT*

Input the *.DAT file that contains the survey day
dates and fish count data.
Indicate full file specification.
(i.e. drive:\dir\name.DAT).
(default> C:\AUC\BLACK\BLACK89.DAT: *<enter>*

Input the *.CDE file that contains the fish codes.
Indicate full file specification.
(i.e. drive:\dir\name.CDE).
(default> C:\AUC\BLACK\BLACK89.CDE: *<enter>*

RESTIME presents the following menu:

Fish Code Choices
1 = adults
2 = jacks
3 = QUIT

Enter a fish code or quit RESTIME program: *1*

Enter the survey type (SIS=1 or SRS=2): *1*

RESTIME provides an option to label the tag count data sets that is particularly useful when a number of timing segments of a run are marked with color-coded tags. For Black Creek, 1989, the following labels have been selected: 1) BLUE,SIS; 2) BLUE, SRS; 3) RED, SIS; and 3) RED, SRS

Enter a label for the tag group: *BLUE SIS*

Enter the date that you applied the tags (mm,dd,yy): *10,24,89*

Estimating Residence Time for ADULTS

Enter the number of fish tagged: *102*

RESTIME provides the option to import an existing file that contains the inputed tag counts from a previous RESTIME session or a previous run within the current RESTIME session. You may want to repeat a RESTIME session or run with the same tag count data set to 1) print hard copies of the graphs following activation of the MSDOS GRAPHICS command, 2) to re-estimate residence times with other observer efficiency parameters and tag retention factors, and 3) to re-estimate residence times with an alternate selection between the total and observed curve methods.

If the option to import an existing tag count file is selected, RESTIME prompts for the full file name, by-passes the tag count entry and editing routines that are described below, and returns at the prompt "**Enter the transformation for the observer efficiency parameters selected in INFILES (1=linear(i.e. none), 2=ln(data+1)):**"

For Black Creek, 1989, the full file specification for one of the tag count files is "C:\AUC\BLACK\BLACK89.BLI", where the extension "BLI" represents "blue tags, SIS design".

Do you have an existing file containing the inputed tag counts for
this tag group from a previous RESTIME session (1=no, 2=yes): *2*

Input the existing tag count file.
Indicate the full file specification.
(i.e. c:\auc\black\black89.* : *C:\AUC\BLACK\BLACK89.BLI*

If this is the first RESTIME run for the tag count data set and so no file exists, select *1*.

Do you have an existing file containing the inputed tag counts for
this tag group from a previous RESTIME session (1=no, 2=yes): *1*

Enter the counts of visual tag sightings from Table 11 into the survey day tables that pop up on the screen. The table for the tagging day, t_1, does not appear on the screen, because it is assumed that either the number of tagged fish is equal to the number of tags applied for the total tag curve method or the number of tagged fish is zero for the observed tag curve method. The table for the last survey day does not appear on the screen because the number of tagged fish is assumed to be zero.

Missing values are represented by -1's and are for survey sites that were not surveyed on a particular survey day.

RESTIME will interpolate a tag count for these -1's from the tag counts on previous and subsequent survey days. However, if a survey site is not surveyed on those survey days that span the peak of the tagged run and you have counts from just the beginning or end of the tagged run, then you should eliminate this survey site from the AUC escapement estimation.

Otherwise, RESTIME will substitute low tag counts for the -1's during this middle period when high numbers of tagged fish are probably present.

If a survey site was not surveyed at all during the survey period and you entered -1 for missing values for that survey site for every survey day table that pops up on the screen, RESTIME will convert the assumed zero tag counts for the first and last survey days to -1's.

Note that an incorrect count has been deliberately entered for stratum 1, site 2 to demonstrate the editing routine within RESTIME.

Estimating Residence Time for ADULTS

Fill in the table with the number of tagged fish sighted on day: 2

strata	site 1	site 2	site 3
1	*0*	*1*	
2	*0*	*-1*	
3	*5*	*1*	
4	*0*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Would you like to correct any of the data in this table (1=yes,2=no)? *1*
Indicate which strata: *1*

Fill in the table with the number of tagged fish sighted on day: 2

strata	site 1	site 2	site 3
1			
2	*0*	*-1*	
3	*5*	*1*	
4	*0*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Re-enter with the correct counts for strata 1, sites 1 and 2.

Fill in the table with the number of tagged fish sighted on day: 2

strata	site 1	site 2	site 3
1	*0*	*0*	
2	*0*	*-1*	
3	*5*	*1*	
4	*0*	*0*	*0*
5	*0*	*0*	
6	*0*	*0*	

Would you like to correct any of the data in this table (1=yes,2=no)? *2*

Fill in the table with the number of tagged fish sighted on day: 3
Fill in the table with the number of tagged fish sighted on day: 4
Fill in the table with the number of tagged fish sighted on day: 5
Fill in the table with the number of tagged fish sighted on day: 6
Fill in the table with the number of tagged fish sighted on day: 7
Fill in the table with the number of tagged fish sighted on day: 8
Fill in the table with the number of tagged fish sighted on day: 9

Store the inputed counts from the tag depletion study in a file that may be used again in another RESTIME session or run. To name this file, enter a 3-letter extension that identifies the study (e.g. by tag color; RED, BLU, YEL, GRN, WHI, ORG): *BLI*

The following extensions for the tag count files were selected for Black Creek, 1989: "BLI" for blue tags, SIS design; "BLR" for blue tags, SRS design; "RDI" for red tags, SIS design; and "RDR" for red tags, SRS design.

The inputed tag counts will be stored in C:\AUC\BLACK\BLACK.BLI

Press enter to continue...<*enter*>

RESTIME imports from the *.PMT file the linear or natural log-transformed observer efficiency parameters that were selected as the most suitable in INFILES. However, RESTIME cannot recognize the oe parameters in the *.PMT file as being derived from linear or log-transformed data, therefore you must identify the oe parameters and make certain that the RESTIME and INFILES selections are consistent.

Enter the transformation for the observer efficiency parameters selected in INFILES (1=linear(i.e. none), 2=ln(data+1)): *1*

The counts of tagged sightings may be corrected by a tag retention factor that must be greater than 0 and less than or equal to 1.0, where 0 represents 100% tag loss and 1.0 represents no tag loss.

The tag retention factor you provide should incorporate tag loss and tagging mortality.

Enter the tag retention factor that must be 0 > and <= 1 (e.g. 0.8, 0.95, 1.0): *1*

Select either or both the observed tag and total tag curve methods.

RESTIME displays graphs for the number of observed tagged fish in the stream versus time for one or both of the total tag and the observed tag curves (Figures 12 and 13). The Total Tag Curve graph also displays the Observed Tag Curve with a line drawn from the tagging day to the next survey day's data point.

Estimating Residence Time for ADULTS

Select the methods for the residence time estimation. (1 = Total Tag Curve, 2 = Observed Tag Curve, 3 = BOTH): *3*

The Total Tag Curve graph for the "blue tag, SIS" data set is displayed first if option #3 is selected (Figure 12).

If the Total Tag Curve does not have any dips due to zero counts as is the case for the "blue tag, SIS" data set, the following two prompts are by-passed.

If the Total Tag Curve dips due to zero counts as is the case for the "blue tag, SRS" and the "red tag, SIS" data sets, then RESTIME will draw a line between the daily tag count for the survey day preceding and the daily tag count for the survey day following the zero counts and present you with an option to calculate the area under the curve and residence time from the original or drawn curve.

Enter with: 1 = accept this area, 2 = calculate AUC+RT ignoring zero value: *2*

RESTIME calculates the AUC and RT from the drawn total curve with selection of option #2.

Enter either: 1 = go back to original graph, 2 = accept this area: *2*

press enter to continue... *<enter>*

The Observed Tag Curve for the "blue tag, SIS" data set is displayed next if both methods were selected (Figure 13).

If the Observed Tag Curve does not have any dips due to zero counts as is the case for the "blue tag, SIS" data set, the following two prompts are by-passed.

Enter with: 1 = accept this area, 2 = calculate AUC+RT ignoring zero value: *2*

RESTIME calculates the AUC and RT from the drawn observed curve with selection of option #2.

Enter either: 1 = go back to original graph, 2 = accept this area: *2*

press enter to continue...<*enter*>

If you selected both the Total and Observed Tag Curve methods, you can toggle back and forth between the total and observed tag curves which may help you to decide which method gives the most appropriate residence time estimation.

Do you want to see the TOTAL TAG CURVE again (1=yes, 2=no)?:

If yes, the Total Tag Curve graph is presented again.

If no, RESTIME writes both the total and observed residence time estimations on the screen and returns you to the main menu.

Do you want to see the OBSERVED TAG CURVE again (1=yes, 2=no)?:

If yes, the Observed Tag Curve graph is presented again.

If no, RESTIME writes both the total and observed residence time estimations on the screen and returns you to the main menu.

The estimated residence time using a Total Tag Curve is: 22.36114
The estimated residence time using an Observed Tag Curve is: 20.36114
Press enter to continue...

RESTIME again presents the main menu.

Select option #1 to go through additional runs within the RESTIME session to calculate the residence time estimates for the following tag groups: 1) blue tag, SRS design; 2) red tag, SIS design; and 3) red tag, SRS design. No tag depletion study was conducted on coho jacks for Black Creek, 1989.

If option #3 to quit the RESTIME session is selected, RESTIME prompts for the full file name of the *.RES file that will store the calculated residence time estimates for each tag group (Table 13), and displays the contents of the *.res file on the screen. The *.RES file is not used as input for the AUC program.

Fish Code Choices
1 = adults
2 = jacks
3 = QUIT

Select a fish code or quit RESTIME session: *3*

Enter the name of the file that will store the calculated residence times from the RESTIME session. Indicate full file specification (i.e. drive\dir\name.RES).
DEFAULT> C:\AUC\BLACK\BLACK89.RES : *<enter>*

FISH TYPE: adults
DATA SET: BLUE SIS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 22.36114
OBSERVED CURVE ESTIMATION: 20.36114

FISH TYPE: adults
DATA SET: BLUE SRS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 7.275181
OBSERVED CURVE ESTIMATION: 5.275181

FISH TYPE: adults
DATA SET: RED SIS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 14.947
OBSERVED CURVE ESTIMATION: 10.447

FISH TYPE: adults
DATA SET: RED SRS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 9.088671
OBSERVED CURVE ESTIMATION: 4.588671

You have finished the program RESTIME Press enter to continue...

6.0 The AUC Program

The AUC program imports the *.PMT, *.DAT, and *.CDE files constructed by INFILES, and calculates the AUC escapement estimate by expanding the stratified mean fish density per survey site for each survey day to the stream length to yield daily population estimates, then dividing the area under the daily population curve by the residence time. AUC stores the calculated escapement estimates and associated statistics in a *.AUC file.

6.1 Detailed AUC Calculations

The AUC program calculates daily stream population estimates, the area under the population curve, and the AUC escapement with the formulae presented in this section.

6.1.1 Daily stream population estimates

The daily stream population estimates are calculated in the following steps in which the fish counts at each survey site are corrected for observer efficiency, the estimated mean fish density per survey site for each stratum is calculated, the stratified mean density per survey site for the stream is calculated, and the stratified mean density per survey site is expanded to the stream length:

First, the mean density y of fish per survey site for each stratum and survey day is estimated by,

$$\overline{y}_{ih} = \left(\sum_{j=1}^{ns_{ih}} fo_{ihj} \cdot oe_{ihj}^{-1}\right) \cdot ns_{ih}^{-1} \tag{7}$$

where *fo* is the number of fish observed and *oe* is the observer efficiency factor at survey site (*j*), in stratum (*h*), on survey day (*i*); and *ns* is the number of sites that were surveyed.

Next, the stratified mean density y_{st} for each survey day is estimated by,

$$\overline{y}_{st_i} = \sum_{h=1}^{L} \overline{y}_{ih} \cdot W_h \tag{8}$$

where W is a stratification weighting factor that is calculated by,

$$W_h = N_h \cdot \left(\sum_{h=1}^{L} N_h\right)^{-1} \tag{9}$$

where N_h is the total number of survey sites in stratum h (those surveyed plus those not surveyed) and L is the number of strata in the stream.

In the final step, the stratified mean density is multiplied by the total number of survey sites in the stream to obtain an estimate of the daily population p_i in the stream,

$$p_i = \left(\sum_{h=1}^{L} N_h\right) \cdot \overline{y}_{st_i} \tag{10}$$

6.1.2 Area under the population curve estimates

The daily population estimates are plotted against time, and the *auc* is estimated by the sum of the rectangular areas that approximate the area under the escapement curve. This is expressed mathematically as,

$$auc = 0.5 \cdot \sum_{i=2}^{n} (t_i - t_{i-1}) \cdot (p_i + p_{i-1}) \tag{11}$$

where t_i is the number of days from the first survey day to the ith survey day inclusive. The surveys range from the first survey day to the last (nth) survey day when p_1 and p_n should be equal to zero. If the survey had not started just prior to when the fish started entering the stream and some fish were counted on the first visual survey, then the date for the first survey day should be extrapolated backwards. In this case, the first visual survey would be defined as survey day 2. If the end of the survey had not been extended to a survey day when zero counts were observed, the date for the last survey day should be extrapolated forwards to when it is assumed that fish are no longer in the stream.

6.1.3 AUC escapement estimates

Finally, the AUC escapement estimate is calculated by,

$$Escapement = auc \cdot rt^{-1} \tag{12}$$

where rt is the residence time.

6.2 Detailed Calculation Of Variance Statistics For The SRS Survey

In a SRS survey where the selection of survey sites is random, the AUC program calculates minimum variances for the population estimates with formulae derived in Cochran

(1977), and writes these statistics to the *.AUC file. When calculating variability around escapement estimates, it is assumed that the values for residence time and observer efficiency are known exactly. Since this is not true, all measures of variability calculated including variances, underestimate the true variability.

The estimate of the variance, VAR_i, of the stratified mean density per survey site for each survey day is calculated by,

$$VAR(\bar{y}_{st})_i = \sum_{h=1}^{L} \frac{W_h^2 \cdot s_{ih}^2}{ns_{ih}} - \sum_{h=1}^{L} \frac{W_h s_{ih}^2}{N} \tag{13}$$

where N is the total number of survey sites in the stream. The unbiased estimate of the true variance of the mean density per survey site within each strata is,

$$s_{ih}^2 = \frac{1}{ns_{ih}-1} \sum_{j=1}^{n_{ih}} (y_{ihj} - \bar{y}_{ih})^2 \tag{14}$$

An approximation for the effective degrees of freedom DF for the variance of the stratified mean density for each survey day is given by,

$$DF_i = \frac{(\sum g_{ih} s_{ih}^2)^2}{\sum \frac{g_{ih}^2 s_{ih}^4}{ns_{ih}-1}} \tag{15}$$

where

$$g_{ih} = \frac{N_h (N_h - ns_{ih})}{ns_{ih}} \tag{16}$$

The effective DF will lie between the lowest of the $(ns_h\text{-}1)$ values and their sum, and as seen in the AUC output will often be a non-integer. The approximation takes account of the fact that the true variance of the mean density may vary among strata and assumes that the numbers of fish at the survey sites are normally distributed (Cochran 1977).

To compute confidence limits, use the effective DF and read the t-value from tables of Student's t.

The standard deviation of the daily population estimates, *POPSD$_i$*, is given by,

$$POPSD_i = \sqrt{VAR_i} \cdot N \tag{17}$$

The variance of the AUC escapement population, *POPVAR*, is calculated by,

$$POPVAR = \frac{\sum_{i=2}^{n-1} (POPSD_i)^2 \cdot (t_{i+1}-t_{i-1})^2 \cdot 4^{-1}}{rt^2} \tag{18}$$

The standard deviation of the AUC escapement population, *POPSD*, is given by,

$$POPSD = \sqrt{POPVAR} \tag{19}$$

The standard error of the AUC escapement population, *POPSE*, is given by,

$$POPSE = POPSD \cdot (\sqrt{n-2})^{-1} \tag{20}$$

where *n* is the number of survey days.

The coefficient of variation, *CV*, for the AUC escapement population is given by,

$$CV = POPSD \cdot POP^{-1} \tag{21}$$

where *POP* is the AUC escapement population.

6.3 Running The AUC Program

Type AUC from the C:\AUC directory to begin a run.

C:\AUC> *AUC*

Provide AUC with the full filenames (drive:\dir\filename.ext) of the *.PMT, *.DAT, and *.CDE files constructed by INFILES, and the full filename of the output *.AUC file.

Input the *.CDE file that contains the fish codes.
Indicate full file specification.
(i.e. drive:\dir\name.CDE): *C:\AUC\BLACK\BLACK89.CDE*

**Input the *.PMT file that contains the stream
and observer efficiency parameters.
Indicate full file specification.
(default > C:\AUC\BLACK\BLACK89.PMT):** *<enter>*

**Name the *.AUC output file where the calculated AUC population
estimates and associated statistics will be stored.
Indicate full file specification.
(i.e. drive:\dir\name.AUC)
(default > C:\AUC\BLACK\BLACK89.AUC):** *<enter>*

**Input the *.DAT file that contains the fish counts.
Indicate full file specification.
(i.e. drive:\dir\name.DAT)
(default > C:\AUC\BLACK\BLACK89.DAT):** *<enter>*

AUC reads in the observer efficiency parameters from the *.PMT file that was constructed in INFILES but it can not determine if they are derived from linear or natural log-transformed data. Therefore, you must identify the observer efficiency parameters, and make certain that the AUC and INFILES selections are consistent.

**Enter the transformation for the observer efficiency parameters
selected in INFILES for adults (1=linear(i.e. none), 2=ln(data+1)):** *1*

**Enter the transformation for the observer efficiency parameters
selected in INFILES for jacks (1=linear(i.e. none), 2=ln(data+1)):** *2*

For the 1989 Black Creek example, we use a residence time of 15 days for both adult and jack coho.

Enter a zero for residence time if no SIS or SRS survey was conducted.

**Enter residence times for adults
for both index sampling and random sampling,
respectively (separate rt's with a comma):** *15,15*

**Enter residence times for jacks
for both index sampling and random sampling,
respectively (separate rt's with a comma):** *15,15*

AUC provides an option to compare the calculated AUC escapement estimate with a true escapement from a fence count, or an estimate from another enumeration method.

Compare to other estimates? (1=yes, 2=no): *2*

AUC displays the AUC graph for the "adult coho, SIS" Black Creek, 1989 survey (Figure 14).

press enter to continue...

AUC displays the AUC graph for the "coho jacks, SIS" Black Creek, 1989 survey (Figure 15).

press enter to continue...

AUC displays the AUC graph for the "adult coho, SRS" Black Creek, 1989 survey (Figure 16).

press enter to continues...

AUC displays the AUC graph for the "coho jacks, SRS" Black Creek, 1989 survey (Figure 17).

See file C:\AUC\BLACK\BLACK89.AUC for calculated AUC population estimates and associated statistics.

You have finished the program AUC - press enter to continue...

6.4 AUC Output

To view the AUC output, type

TYPE BLACK89.AUC from the C:\AUC\BLACK directory.

A hard copy can be obtained by typing

PRINT BLACK89.AUC from the C:\AUC\BLACK directory.

Table 14 shows the BLACK89.AUC file outputted by the AUC program. The first table in this *.AUC file provides daily population estimates. It lists, for each survey day, the stratified mean density which is the mean number of fish per survey site for the stream and the stream population estimate; and for the SRS design only, the variance for the stratified mean density estimate and the associated degrees of freedom, and the standard deviation of the stream population estimate.

If the lengths of the survey sites are different among strata, the stratified mean density estimate will not be meaningful, but this will not invalidate AUC program's estimates of the daily stream population and the AUC escapement.

The second table in the *.AUC file provides the AUC escapement population, and for the SRS design only, the variance, standard deviation, standard error, and the coefficient of variance of the escapement estimate.

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Table 1. Observer efficiency data for adult coho from the Black Creek, 1989 survey.

TEST #	OBSERVER COUNT	ACTUAL COUNT
1	14	8
2	4	2
3	8	8
4	1	3
5	41	37
6	11	13
7	13	17
8	34	43
9	38	40
10	3	7

Table 2. Observer efficiency data for coho jacks from the Black Creek, 1987-89 surveys. An insufficient number of observer efficiency tests were conducted during 1989 so the two previous years' data are included.

TEST #	OBSERVER COUNT	ACTUAL COUNT
1	2	3
2	1	3
3	0	1
4	5	2
5	1	7
6	4	1
7	3	3
8	3	6
9	2	1
10	0	1
11	3	4
12	2	1
13	4	4
14	3	3

Table 3. Output from the PARAMETS program: BLACK89.ADS file.

Format: Observer adult coho counts, PARAMETS corrected actual counts.

14	14
4	4
8	8
1	3
41	41
11	13
13	17
34	43
38	40
3	7

Table 4. Output from the PARAMETS program: BLACK89.JKS file.

Format: Observer coho jack counts, PARAMETS corrected actual counts.

2	3
1	3
0	1
5	5
1	7
4	4
3	3
3	6
2	2
0	1
3	4
2	2
4	4
3	3

Table 5. Output from the PARAMETS program: BLACK89.OBS file.

Format: y-intercept, slope, transformation (1=linear, 2=log), fish type.

-1.001556	.9316609	1	adults
-.5774038	1.13847	2	adults
.9782609	.4021739	1	jacks
-.1688305	.8901317	2	jacks

Table 6. Stratified sampling parameters for Black Creek.

STRATA	STRATA LENGTHS m	# SURVEY SITES	SURVEY SITE LENGTHS m
1	4750	2	250
2	4500	2	250
3	3500	2	250
4	5000	3	250
5	8500	2	250
6	4000	2	250
STREAM LENGTH = 30250 m			

Table 7. Adult and jack coho counts at each site on the Black Creek, 1989 survey. Data series starts with the second survey date since zero counts are assumed for Oct-20 when fish are first entering the survey area and for Jan-05 at the end of the escapement period when there are no longer any fish in the survey area.

Sampling method	Survey day	Date	Stratum 1 Site 1	Stratum 1 Site 2	Stratum 2 Site 1	Stratum 2 Site 2	Stratum 3 Site 1	Stratum 3 Site 2	Stratum 4 Site 1	Stratum 4 Site 2	Stratum 4 Site 3	Stratum 5 Site 1	Stratum 5 Site 2	Stratum 6 Site 1	Stratum 6 Site 2
ADULTS															
SIS	2	Oct-28	1	1	0	-1	7	1	1	0	0	0	0	0	0
	3	Nov-06	0	5	0	-1	19	3	9	0	0	0	0	0	0
	4	Nov-13	1	7	1	-1	29	2	13	0	0	0	0	0	0
	5	Nov-22	0	0	0	-1	7	2	10	0	0	0	0	0	0
	6	Nov-30	0	2	2	-1	10	2	11	0	0	0	0	0	0
	7	Dec-11	0	13	0	-1	52	6	41	13	11	0	0	155	8
	8	Dec-18	0	13	0	-1	42	4	27	7	18	0	1	95	5
	9	Dec-27	0	0	0	-1	4	2	6	0	3	0	0	1	0
SRS	2	Oct-28	2	0	0	0	0	0	0	0	-1	0	0	0	0
	3	Nov-06	0	1	0	0	6	0	3	0	-1	0	0	0	0
	4	Nov-13	1	0	0	1	5	0	2	0	-1	0	0	0	0
	5	Nov-22	0	1	0	0	0	0	1	0	-1	0	0	0	0
	6	Nov-30	2	0	0	0	1	0	0	0	-1	0	0	0	0
	7	Dec-11	3	1	0	1	8	10	16	0	-1	4	4	133	0
	8	Dec-18	0	5	0	0	8	18	35	5	-1	3	8	110	1
	9	Dec-27	0	0	0	0	0	0	15	0	-1	0	0	0	0
JACKS															
SIS	2	Oct-28	0	0	0	-1	0	0	0	0	0	0	0	0	0
	3	Nov-06	0	1	0	-1	1	0	0	0	0	0	0	0	0
	4	Nov-13	0	0	1	-1	2	0	4	0	0	0	0	0	0
	5	Nov-22	0	0	0	-1	0	0	4	0	0	0	0	0	0
	6	Nov-30	0	0	0	-1	0	0	2	0	0	0	0	0	0
	7	Dec-11	0	0	0	-1	1	0	2	0	0	0	0	14	2
	8	Dec-18	0	0	0	-1	0	0	0	0	0	0	0	0	0
	9	Dec-27	0	0	0	-1	0	0	0	0	1	0	0	1	0
SRS	2	Oct-28	0	0	0	0	0	0	0	0	-1	0	0	0	0
	3	Nov-06	0	0	0	0	0	0	0	0	-1	0	0	0	0
	4	Nov-13	0	0	0	0	0	0	0	0	-1	0	0	0	0
	5	Nov-22	0	0	0	0	0	0	0	0	-1	0	0	0	0
	6	Nov-30	0	0	0	0	0	0	0	0	-1	0	0	0	0
	7	Dec-11	0	1	0	0	0	0	0	0	-1	0	0	7	0
	8	Dec-18	0	0	0	0	0	0	1	0	-1	0	0	6	0
	9	Dec-27	0	0	0	0	0	0	1	0	-1	0	0	0	0

Table 8. Output from the INFILES program: BLACK89.CDE file.

Format: line #1 - number of fish types; lines #2 and #3 - descriptions.

```
2
adults
jacks
```

Table 9. Output from the INFILES program: BLACK89.PMT file.

Format: line #1 - number of survey days, survey length, number of strata, slope and intercept pairs for each fish type.

line #2 - survey site lengths.

line #3 - number of survey sites within each strata

line #4 - strata lengths

line #5 - number of days from first survey for each survey, when the first survey counts as day one.

```
10, 30250, 6, 0.932,-1.002, 0.890,-0.169
250,  250,  250,  250,  250,  250
2, 2, 2, 3, 2, 2
4750, 4500, 3500, 5000, 8500, 4000
1,  9, 17, 24, 33, 41, 52, 59, 68, 76
```

Table 10. Output from the INFILES program: BLACK89.DAT file.

Format: survey #, date, survey method (1 = SIS, 2 = SRS), fish code (1 = adult coho, 2 = coho jacks), counts at each survey site.

```
 1,102089,1,1,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 2,102889,1,1,  1.0,  1.0,  0.0, -1.0,  7.0,  1.0,  1.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 3,110689,1,1,  0.0,  5.0,  0.0, -1.0, 19.0,  3.0,  9.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 4,111389,1,1,  1.0,  7.0,  1.0, -1.0, 29.0,  2.0, 13.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 5,112289,1,1,  0.0,  0.0,  0.0, -1.0,  7.0,  2.0, 10.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 6,113089,1,1,  0.0,  2.0,  2.0, -1.0, 10.0,  2.0, 11.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 7,121189,1,1,  0.0, 13.0,  0.0, -1.0, 52.0,  6.0, 41.0, 13.0, 11.0,  0.0,  0.0, 155.0,  8.0
 8,121889,1,1,  0.0, 13.0,  0.0, -1.0, 42.0,  4.0, 27.0,  7.0, 18.0,  0.0,  1.0,  95.0,  5.0
 9,122789,1,1,  0.0,  0.0,  0.0, -1.0,  4.0,  2.0,  6.0,  0.0,  3.0,  0.0,  0.0,   1.0,  0.0
10,010590,1,1,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 1,102089,2,1,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 2,102889,2,1,  2.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 3,110689,2,1,  0.0,  1.0,  0.0,  0.0,  6.0,  0.0,  3.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 4,111389,2,1,  1.0,  0.0,  0.0,  1.0,  5.0,  0.0,  2.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 5,112289,2,1,  0.0,  1.0,  0.0,  0.0,  0.0,  0.0,  1.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 6,113089,2,1,  2.0,  0.0,  0.0,  0.0,  1.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 7,121189,2,1,  3.0,  1.0,  0.0,  1.0,  8.0, 10.0, 16.0,  0.0, -1.0,  4.0,  4.0, 133.0,  0.0
 8,121889,2,1,  0.0,  5.0,  0.0,  0.0,  8.0, 18.0, 35.0,  5.0, -1.0,  3.0,  8.0, 110.0,  1.0
 9,122789,2,1,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, 15.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
10,010590,2,1,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 1,102089,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 2,102889,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 3,110689,1,2,  0.0,  1.0,  0.0, -1.0,  1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 4,111389,1,2,  0.0,  0.0,  1.0, -1.0,  2.0,  0.0,  4.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 5,112289,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  4.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 6,113089,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  2.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 7,121189,1,2,  0.0,  0.0,  0.0, -1.0,  1.0,  0.0,  2.0,  0.0,  0.0,  0.0,  0.0,  14.0,  2.0
 8,121889,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 9,122789,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  1.0,  0.0,  0.0,   1.0,  0.0
10,010590,1,2,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,   0.0,  0.0
 1,102089,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 2,102889,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 3,110689,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 4,111389,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 5,112289,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 6,113089,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
 7,121189,2,2,  0.0,  1.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   7.0,  0.0
 8,121889,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  1.0,  0.0, -1.0,  0.0,  0.0,   6.0,  0.0
 9,122789,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  1.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
10,010590,2,2,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0, -1.0,  0.0,  0.0,   0.0,  0.0
```

Table 11. Sightings of tagged fish at each site on the Black Creek, 1989 survey. The data series start with the first survey day after the tagging date. Zero counts are assumed for Jan-05 at the end of the escapement period when live fish are no longer in the survey area.

Sampling method	Survey day	Date	Stratum 1		Stratum 2		Stratum 3		Stratum 4			Stratum 5		Stratum 6	
			Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 3	Site 1	Site 2	Site 1	Site 2
BLUE PETERSEN TAGS APPLIED TO 102 ADULT COHO ON OCT-24, 1989															
SIS	2	Oct-28	0	0	0	-1	5	1	0	0	0	0	0	0	0
	3	Nov-06	0	1	0	-1	6	0	2	0	0	0	0	0	0
	4	Nov-13	0	2	0	-1	2	0	2	0	0	0	0	0	0
	5	Nov-22	0	0	0	-1	0	0	1	0	0	0	0	0	0
	6	Nov-30	0	0	1	-1	1	0	1	0	0	0	0	0	0
	7	Dec-11	0	0	0	-1	0	0	0	0	0	0	0	3	0
	8	Dec-18	0	0	0	-1	0	0	0	0	0	0	0	0	0
	9	Dec-27	0	0	0	-1	0	0	0	0	0	0	0	0	0
SRS	2	Oct-28	0	0	0	0	0	0	0	0	-1	0	0	0	0
	3	Nov-06	0	0	0	0	3	0	1	0	-1	0	0	0	0
	4	Nov-13	0	0	0	0	0	0	0	0	-1	0	0	0	0
	5	Nov-22	0	0	0	0	0	0	0	0	-1	0	0	0	0
	6	Nov-30	0	0	0	0	0	0	0	0	-1	0	0	0	0
	7	Dec-11	0	0	0	0	0	0	0	0	-1	0	0	3	0
	8	Dec-18	0	0	0	0	0	0	0	0	-1	0	0	0	0
	9	Dec-27	0	0	0	0	0	0	0	0	-1	0	0	0	0
RED PETERSEN TAGS APPLIED TO 85 ADULT COHO ON DEC-02, 1989															
SIS	7	Dec-11	0	1	0	-1	0	0	0	1	0	0	0	5	0
	8	Dec-18	0	0	0	-1	0	0	0	0	0	0	0	0	0
	9	Dec-27	0	0	0	-1	0	0	0	0	1	0	0	0	0
SRS	7	Dec-11	0	0	0	0	0	0	0	0	-1	1	0	3	0
	8	Dec-18	0	0	0	0	0	0	0	0	-1	0	0	0	0
	9	Dec-27	0	0	0	0	0	0	0	0	-1	0	0	0	0

Table 12. Output from the RESTIME program. These files store the inputed tag sightings and can serve as input for another RESTIME session.

Format: line #1 - tag group label, tagging date, number of tags.
lines #2-11 - survey #, tag sightings at each survey site.

BLACK89.BLI file:

```
"BLUE PETERSEN SIS",241089,102
 1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
 2, 0, 0, 0, -1, 5, 1, 0, 0, 0, 0, 0, 0, 0
 3, 0, 1, 0, -1, 6, 0, 2, 0, 0, 0, 0, 0, 0
 4, 0, 2, 0, -1, 2, 0, 2, 0, 0, 0, 0, 0, 0
 5, 0, 0, 0, -1, 0, 0, 1, 0, 0, 0, 0, 0, 0
 6, 0, 0, 1, -1, 1, 0, 1, 0, 0, 0, 0, 0, 0
 7, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 3, 0
 8, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
 9, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
10, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
```

BLACK89.BLR file:

```
"BLUE PETERSEN SRS",241089,102
 1, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 2, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 3, 0, 0, 0, 0, 3, 0, 1, 0, -1, 0, 0, 0, 0
 4, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 5, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 6, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 7, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 3, 0
 8, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 9, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
10, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
```

BLACK89.RDI file:

```
"RED PETERSEN SIS",21289,85
 6, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
 7, 0, 1, 0, -1, 0, 0, 0, 1, 0, 0, 0, 5, 0
 8, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
 9, 0, 0, 0, -1, 0, 0, 0, 0, 1, 0, 0, 0, 0
10, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, 0
```

BLACK89.RDR file:

```
"RED PETERSEN SRS",21289,85
 6, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 7, 0, 0, 0, 0, 0, 0, 0, 0, -1, 1, 0, 3, 0
 8, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
 9, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
10, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0
```

Table 13. Output from the RESTIME program: BLACK89.RES file.

FISH TYPE: adults
DATA SET: BLUE SIS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 22.36114
OBSERVED CURVE ESTIMATION: 20.36114

FISH TYPE: adults
DATA SET: BLUE SRS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 7.275181
OBSERVED CURVE ESTIMATION: 5.275181

FISH TYPE: adults
DATA SET: RED SIS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 14.947
OBSERVED CURVE ESTIMATION: 10.447

FISH TYPE: adults
DATA SET: RED SRS
RESIDENCE TIME:
TOTAL CURVE ESTIMATION: 9.088671
OBSERVED CURVE ESTIMATION: 4.588671

Table 14. Output from the AUC program: BLACK89.AUC file.

OUTPUT CALCULATED FROM AUC PROGRAM
==================================

*** note: AUC returns N/A 's for all undefined values.

Daily Survey Calculations:

DAY	DATE	FISH TYPE	SURVEY TYPE	MEAN DENSITY	VAR	DF	DAILY POP	POPSD
1	102089	adults	index	0.0	N/A	N/A	0	N/A
2	102889	adults	index	1.1	N/A	N/A	130	N/A
3	110689	adults	index	2.6	N/A	N/A	313	N/A
4	111389	adults	index	4.0	N/A	N/A	489	N/A
5	112289	adults	index	1.3	N/A	N/A	161	N/A
6	113089	adults	index	2.3	N/A	N/A	280	N/A
7	121189	adults	index	20.6	N/A	N/A	2496	N/A
8	121889	adults	index	14.9	N/A	N/A	1809	N/A
9	122789	adults	index	1.3	N/A	N/A	156	N/A
10	10590	adults	index	0.0	N/A	N/A	0	N/A
1	102089	adults	random	0.0	0.00	0.00	0	0
2	102889	adults	random	0.3	0.06	1.00	31	29
3	110689	adults	random	1.0	0.30	2.28	116	66
4	111389	adults	random	1.0	0.23	2.75	117	58
5	112289	adults	random	0.3	0.05	1.99	42	28
6	113089	adults	random	0.4	0.07	1.44	46	32
7	121189	adults	random	14.4	81.18	1.05	1746	1090
8	121889	adults	random	15.9	59.78	1.29	1929	936
9	122789	adults	random	1.4	1.81	1.00	172	163
10	10590	adults	random	0.0	0.00	0.00	0	0

OUTPUT CALCULATED FROM AUC PROGRAM
==================================

*** note: AUC returns N/A 's for all undefined values.

Daily Survey Calculations:

DAY	DATE	FISH TYPE	SURVEY TYPE	MEAN DENSITY	VAR	DF	DAILY POP	POPSD
1	102089	jacks	index	0.0	N/A	N/A	0	N/A
2	102889	jacks	index	0.0	N/A	N/A	0	N/A
3	110689	jacks	index	0.2	N/A	N/A	27	N/A
4	111389	jacks	index	0.8	N/A	N/A	94	N/A
5	112289	jacks	index	0.4	N/A	N/A	43	N/A
6	113089	jacks	index	0.2	N/A	N/A	21	N/A
7	121189	jacks	index	2.1	N/A	N/A	252	N/A
8	121889	jacks	index	0.0	N/A	N/A	0	N/A
9	122789	jacks	index	0.2	N/A	N/A	24	N/A
10	10590	jacks	index	0.0	N/A	N/A	0	N/A
1	102089	jacks	random	0.0	0.00	0.00	0	0
2	102889	jacks	random	0.0	0.00	0.00	0	0
3	110689	jacks	random	0.0	0.00	0.00	0	0
4	111389	jacks	random	0.0	0.00	0.00	0	0

Table 14 Continued.

5	112289	jacks	random	0.0	0.00	0.00	0	0
6	113089	jacks	random	0.0	0.00	0.00	0	0
7	121189	jacks	random	0.9	0.52	1.06	108	87
8	121889	jacks	random	0.8	0.38	1.09	94	75
9	122789	jacks	random	0.1	0.02	1.00	16	16
10	10590	jacks	random	0.0	0.00	0.00	0	0

Definitions:

MEAN DENSITY is the stratified mean density or the mean number of fish per survey site for the stream on each survey day, VAR is the variance of the stratified mean density, DF is the degrees of freedom for the variance estimate for the stratified mean density, DAILY POP is the daily stream population estimate, and POPSD is the standard deviation for the daily stream population estimate.

OUTPUT CALCULATED FROM AUC PROGRAM

*** note: AUC returns N/A 's for all undefined values.

Stratified Escapement Estimates:

SURVEY TYPE	FISH TYPE	RESTIME (DAYS)	ESCAPEMENT POPULATION	POPSD	POPSE	POPVAR	CV	AUC/EST
index	adults	15.0	3306	N/A	N/A	N/A	N/A	N/A
index	jacks	15.0	266	N/A	N/A	N/A	N/A	N/A
random	adults	15.0	2363	830	293	688302	0.351	N/A
random	jacks	15.0	124	66	23	4412	0.535	N/A

Definitions:

POPSD, POPSE, POPVAR, and CV are the standard deviation, standard error, variance, and coefficient of variance for the AUC escapement estimate, respectively; and AUC/EST is a comparison coefficient between the AUC escapement and an independent estimate or fence count.

Figure 1. The component programs of the AUC software package.

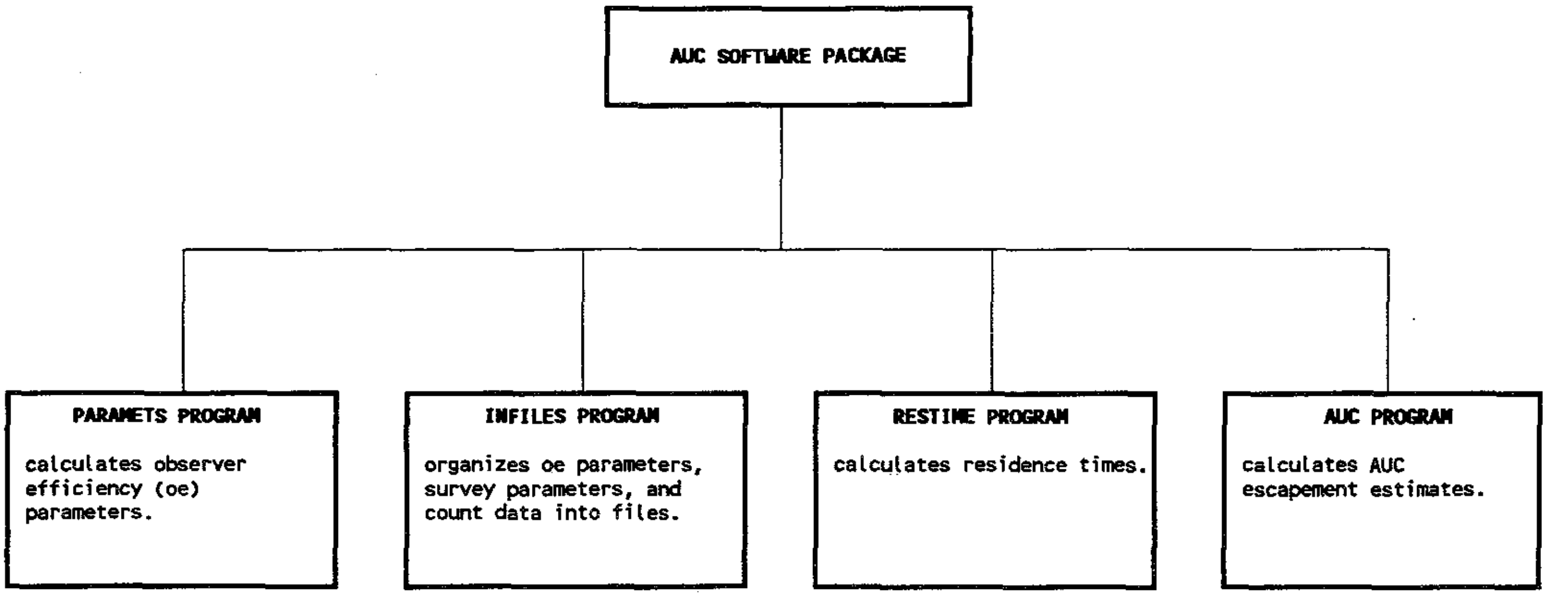


Figure 2. Flow chart for the AUC package, where the abbreviations oe's and RT stand for observer efficiency parameters and residence time.

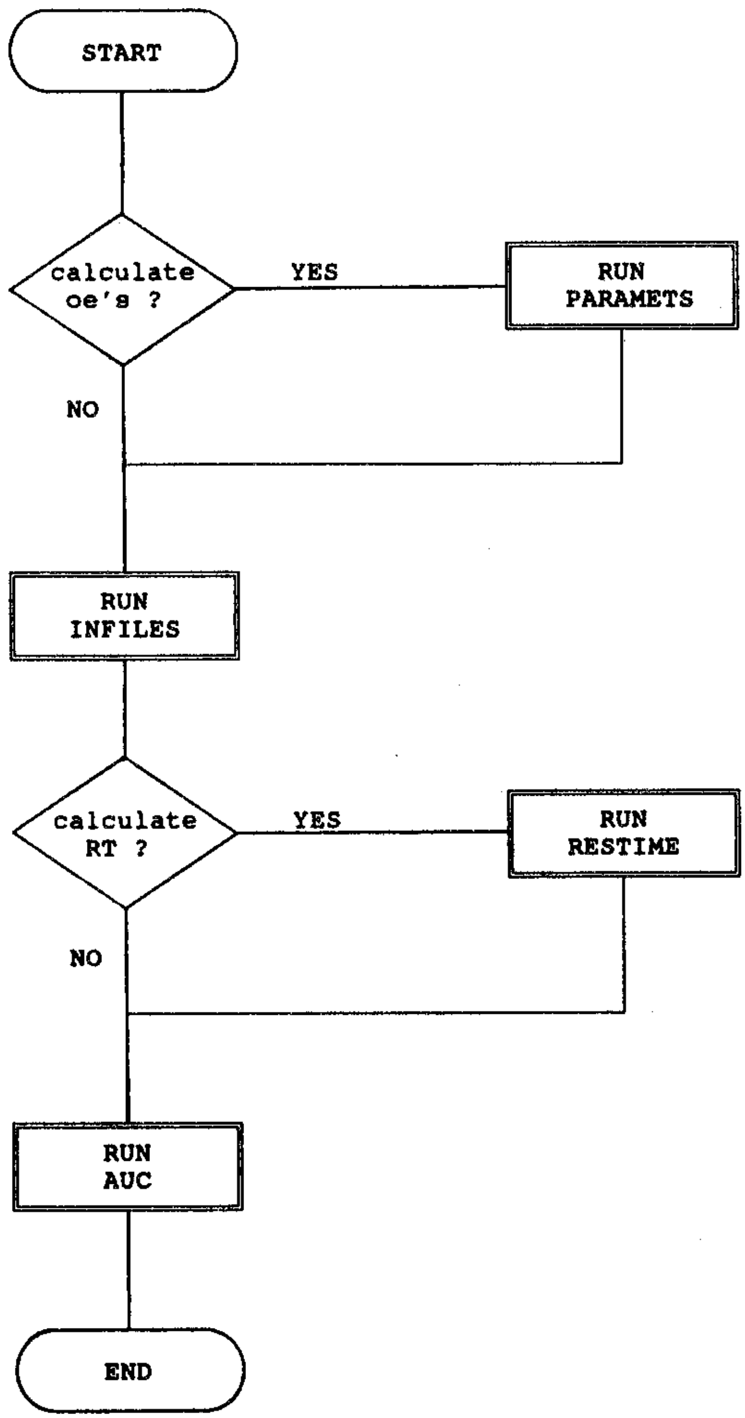


Figure 3. Flow chart for the PARAMETS program.

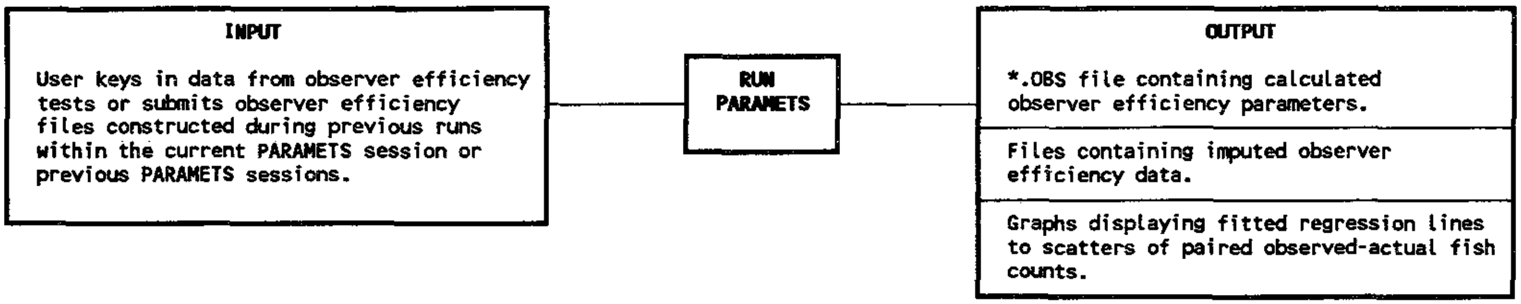


Figure 4. Flow chart for the INFILES program.

INPUT

User keys in the following stream parameters: stream length, number of strata, strata lengths, number of survey sites per strata, lengths of survey sites.

User submits *.OBS file containing observer efficiency parameters calculated by PARAMETS or keys in observer efficiency parameters from the literature.

User keys in survey dates and observer fish counts for one or both stratified index (SIS) and stratified random (SRS) designs.

RUN INFILES

OUTPUT

*.PMT file containing the imputed stream and observer efficiency parameters.

*.CDE file containing codes for the number of fish species and types enumerated on the survey. This file controls processing options during RESTIME and AUC runs.

*.DAT file containing the imputed observer fish counts at each survey site for each survey day.

Figure 5. Flow chart for the RESTIME program.

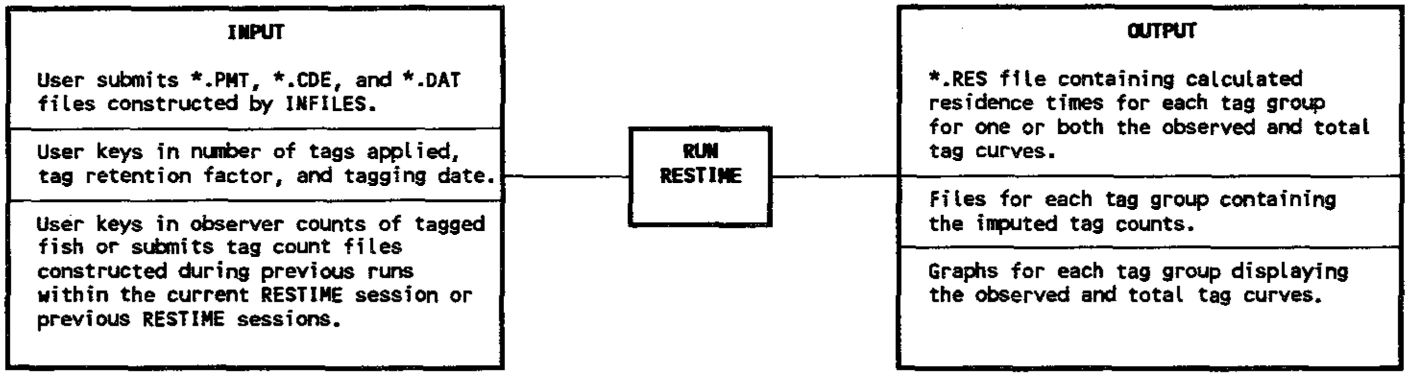


Figure 6. Flow chart for the AUC program.

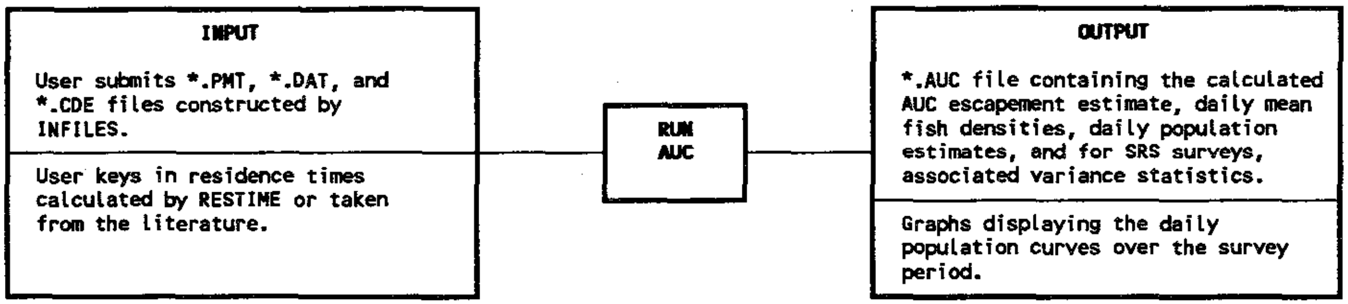


Figure 7. Map of Black Creek drainage showing location of strata (1-6), index sites (•), and the fish counting fence. Inset shows location of study area on the east coast of Vancouver Island.

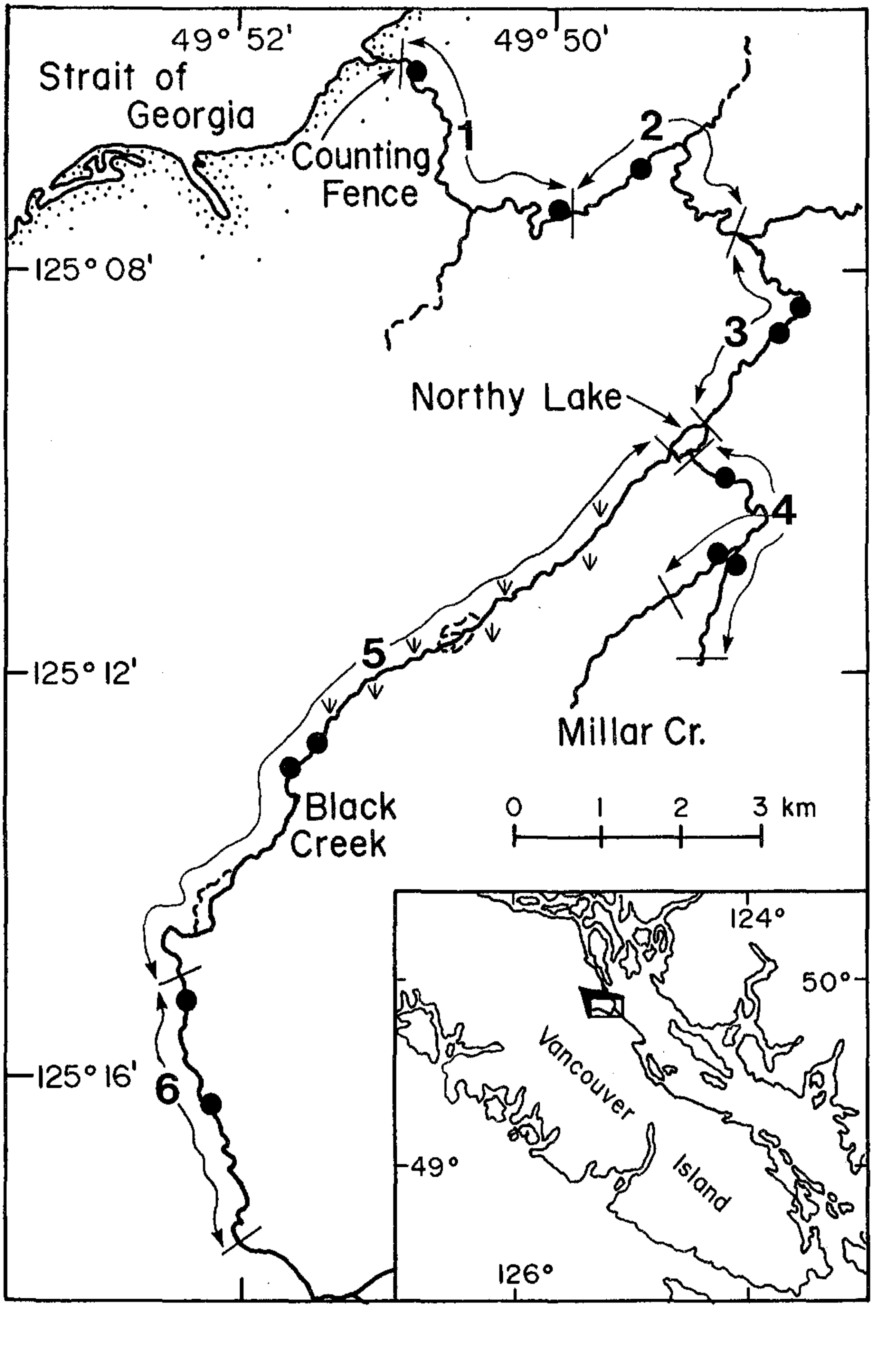

49° 52'
49° 50'
Strait of Georgia
Counting Fence
1
2
3
4
5
6
125° 08'
125° 12'
125° 16'
Northy Lake
Millar Cr.
Black Creek
0 1 2 3 km
124°
50°
Vancouver Island
49°
126°

Figure 8. Output graph of PARAMETS. Plot of data points with line of best fit for number of fish observed during visual surveys versus actual number present.

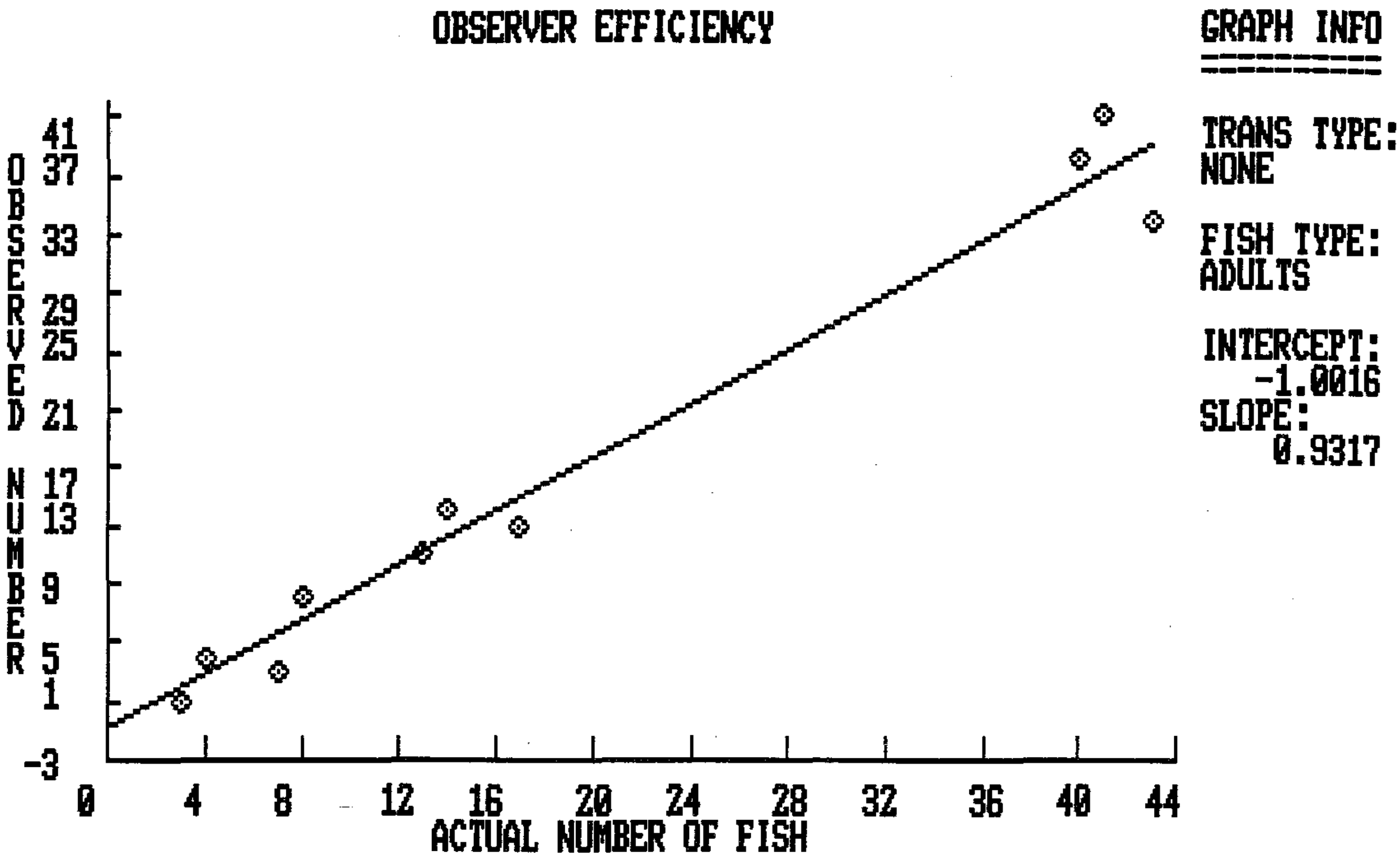

OBSERVER EFFICIENCY
GRAPH INFO
TRANS TYPE: NONE
FISH TYPE: ADULTS
INTERCEPT: -1.0016
SLOPE: 0.9317
OBSERVED NUMBER
41
37
33
29
25
21
17
13
9
5
1
-3
0
4
8
12
16
20
24
28
32
36
40
44
ACTUAL NUMBER OF FISH

Figure 9. Output graph from PARAMETS program. Line of best fit using 1n(data+1) transformation.

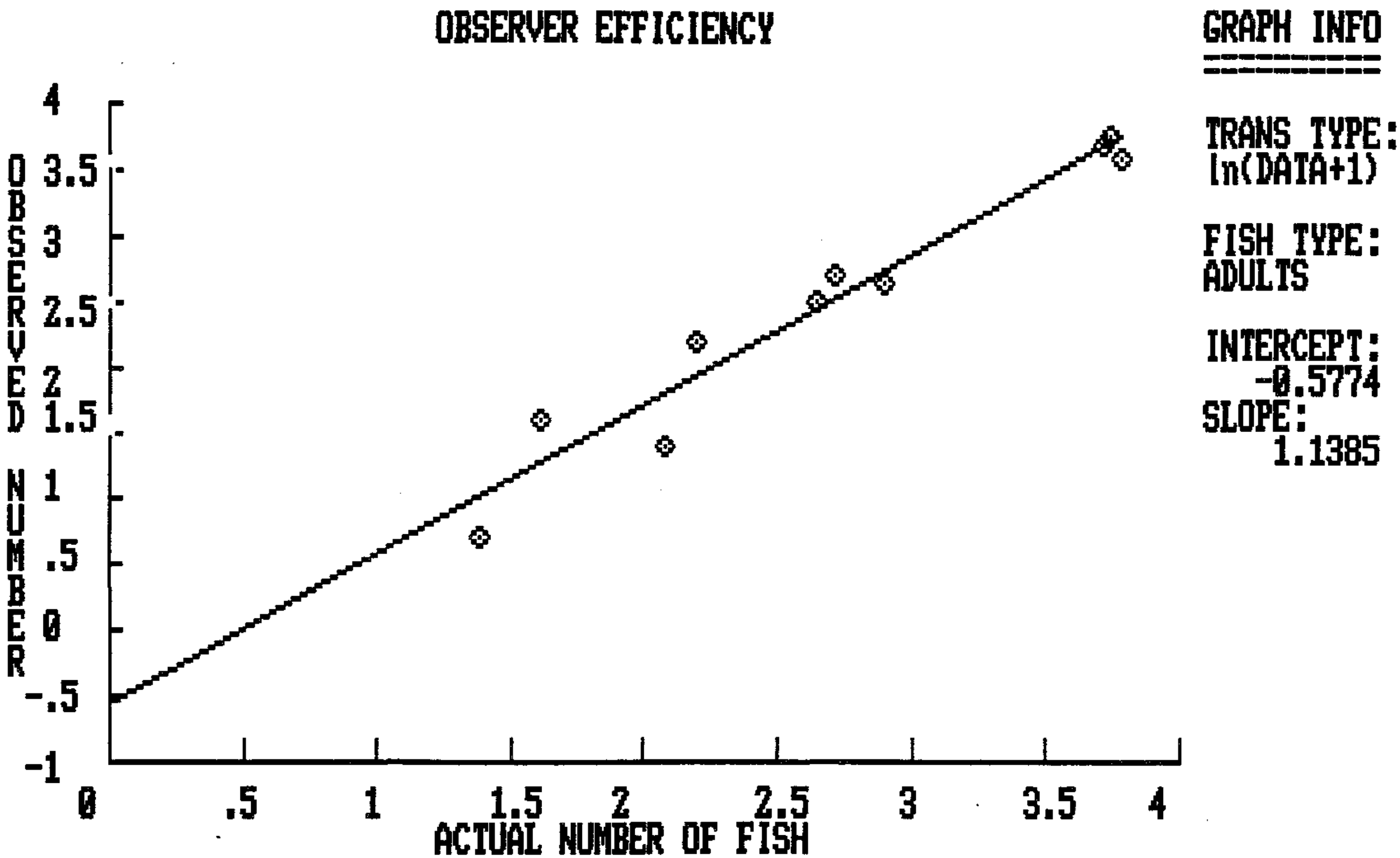

OBSERVER EFFICIENCY
OBSERVED NUMBER
ACTUAL NUMBER OF FISH
4
3.5
3
2.5
2
1.5
1
.5
0
-.5
-1
0
.5
1
1.5
2
2.5
3
3.5
4
GRAPH INFO
TRANS TYPE:
ln(DATA+1)
FISH TYPE:
ADULTS
INTERCEPT:
-0.5774
SLOPE:
1.1385

Figure 10. Output graph from PARAMETS program. Residuals $(Y - \hat{Y})$ using no transformation.

RESIDUALS FOR NO TRANSFORMATION

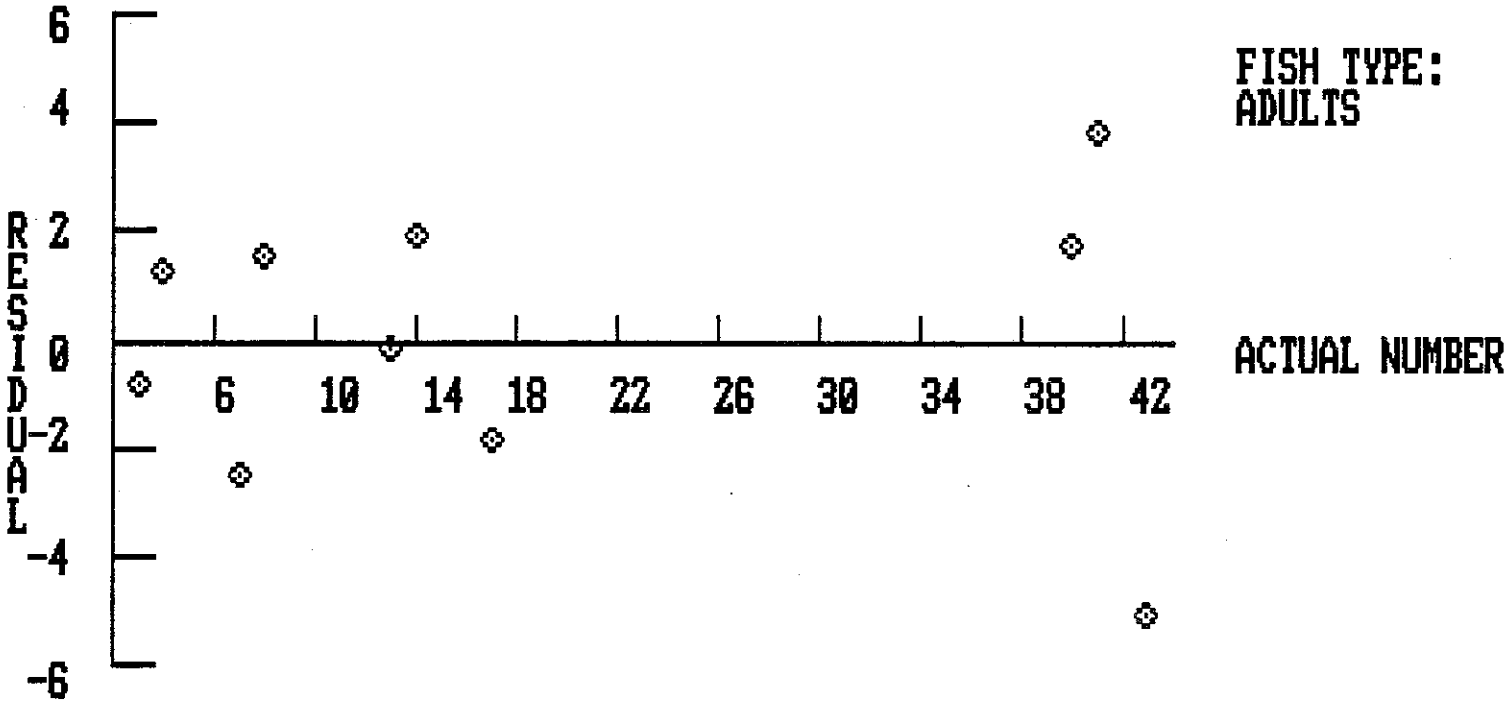


Figure 11. Output graph from PARAMETS program. Residuals ($Y - \hat{Y}$) using ln(data+1) transformation.

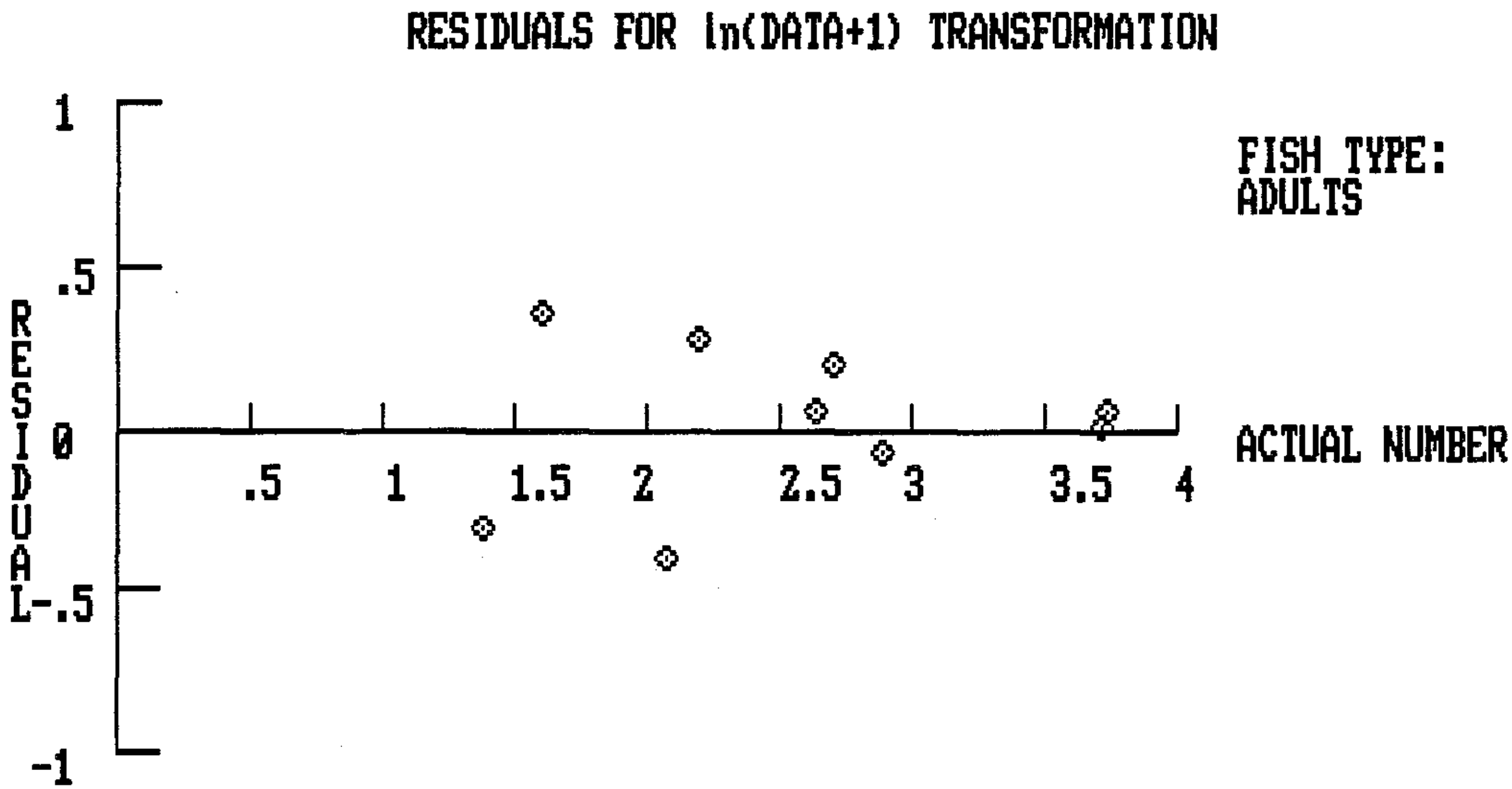

RESIDUALS FOR ln(DATA+1) TRANSFORMATION
1
.5
0
-.5
-1
RESIDUAL
.5
1
1.5
2
2.5
3
3.5
4
ACTUAL NUMBER
FISH TYPE:
ADULTS

Figure 12. Output graph from RESTIME program. Numbers of live tagged fish observed during visual surveys versus time (total tag curve).

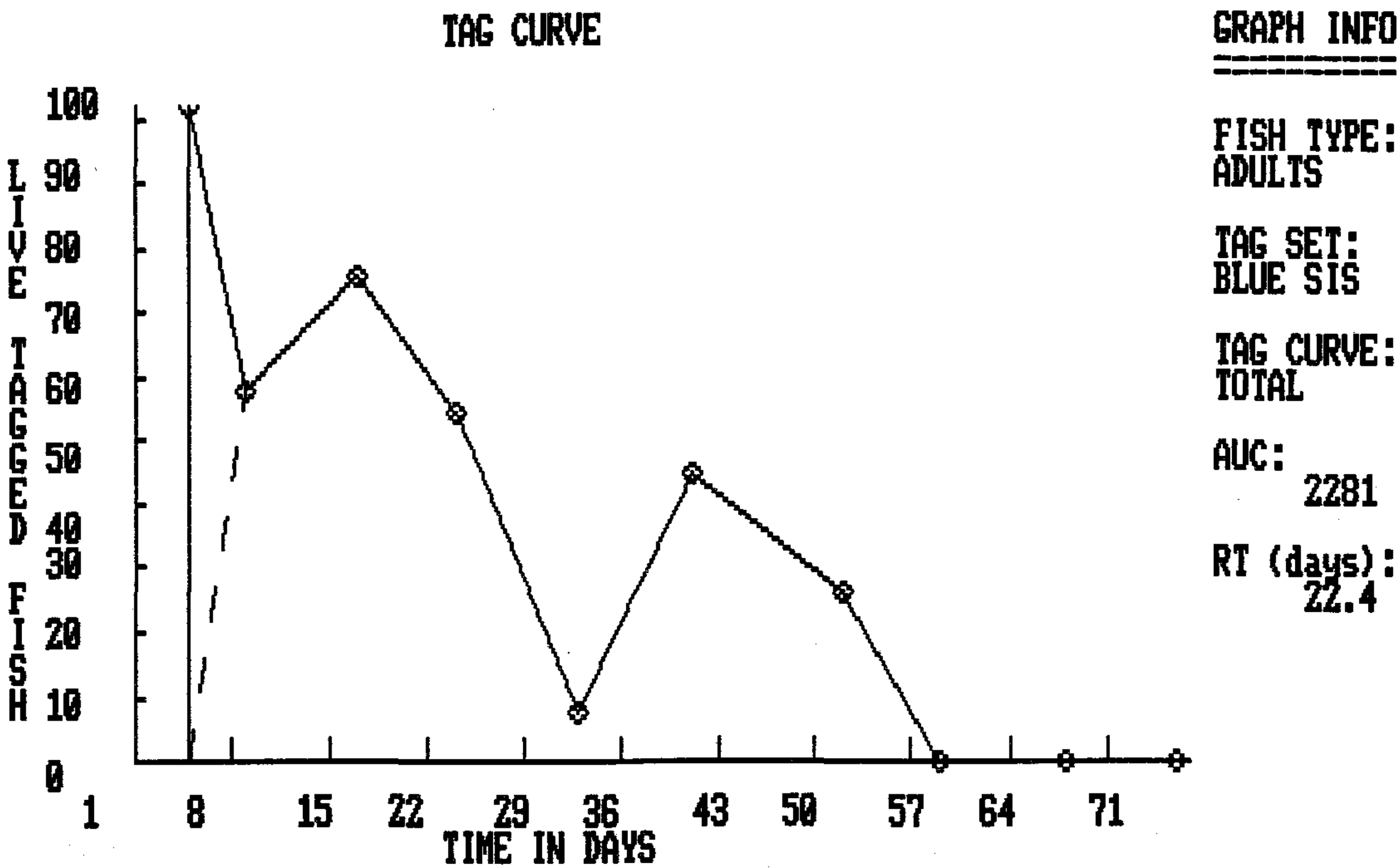

TAG CURVE
LIVE TAGGED FISH
100
90
80
70
60
50
40
30
20
10
0
1
8
15
22
29
36
43
50
57
64
71
TIME IN DAYS
GRAPH INFO
FISH TYPE:
ADULTS
TAG SET:
BLUE SIS
TAG CURVE:
TOTAL
AUC:
2281
RT (days):
22.4

Figure 13. Output graph from RESTIME program. Numbers of live tagged fish observed during visual surveys versus time (observed tag curve).

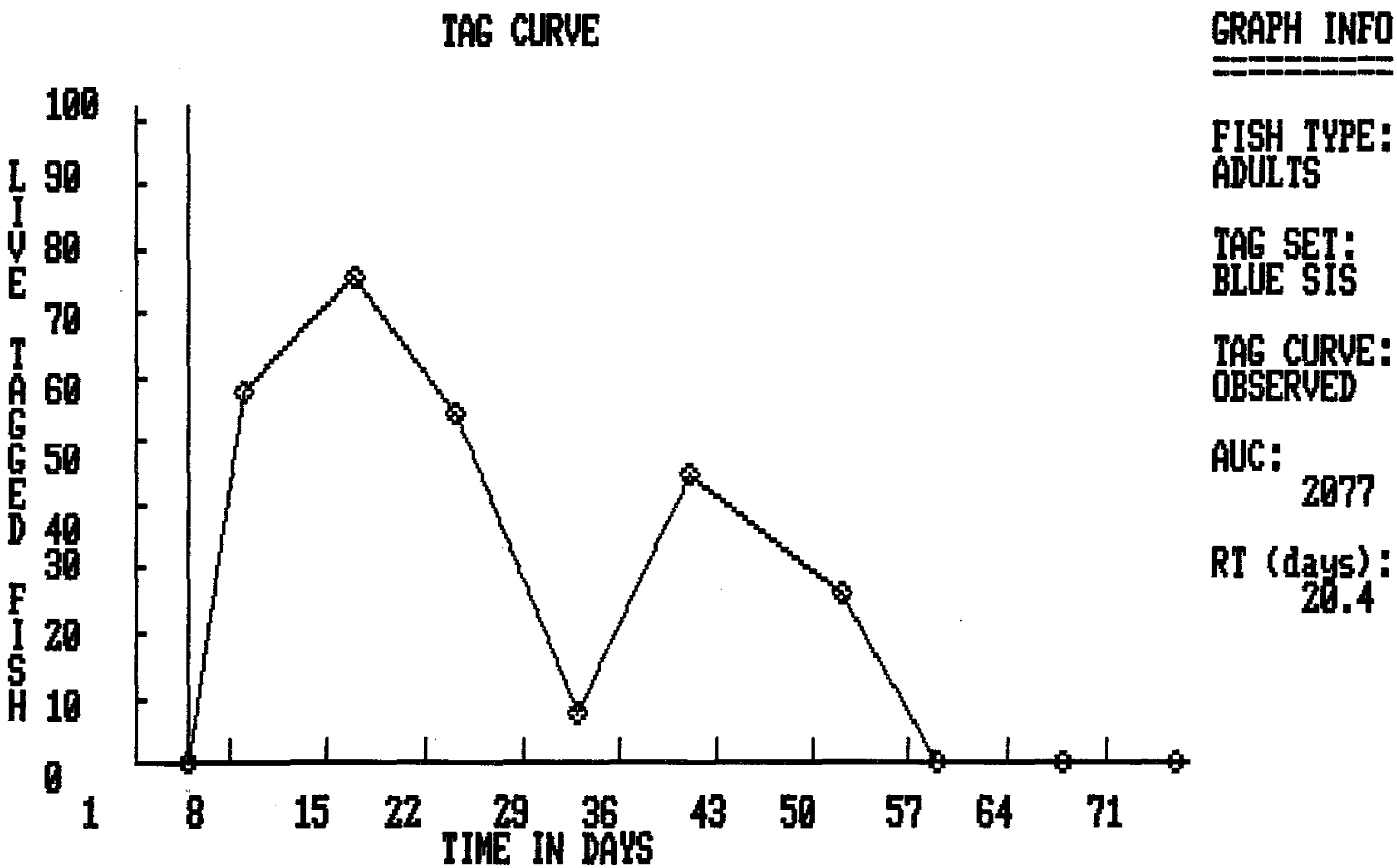

TAG CURVE
LIVE TAGGED FISH
100
90
80
70
60
50
40
30
20
10
0
1
8
15
22
29
36
43
50
57
64
71
TIME IN DAYS
GRAPH INFO
FISH TYPE:
ADULTS
TAG SET:
BLUE SIS
TAG CURVE:
OBSERVED
AUC:
2077
RT (days):
20.4

Figure 14. Output graph from AUC program. Numbers of live fish (SIS method, adults) versus time.

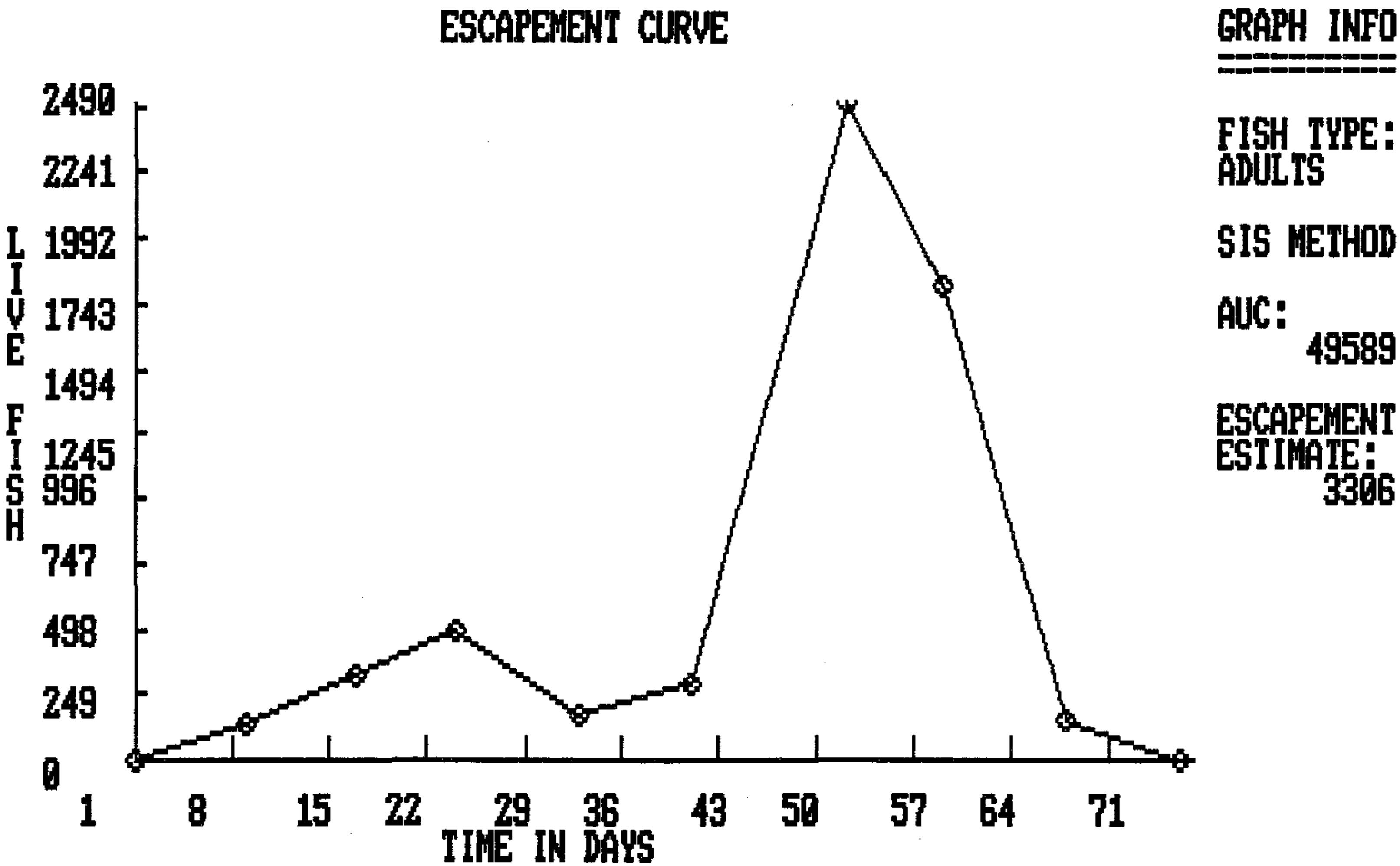

ESCAPEMENT CURVE
GRAPH INFO
FISH TYPE:
ADULTS
SIS METHOD
AUC:
49589
ESCAPEMENT
ESTIMATE:
3306
LIVE FISH
2490
2241
1992
1743
1494
1245
996
747
498
249
0
1
8
15
22
29
36
43
50
57
64
71
TIME IN DAYS

Figure 15. Output graph from AUC program. Numbers of live fish (SIS method, jacks) versus time.

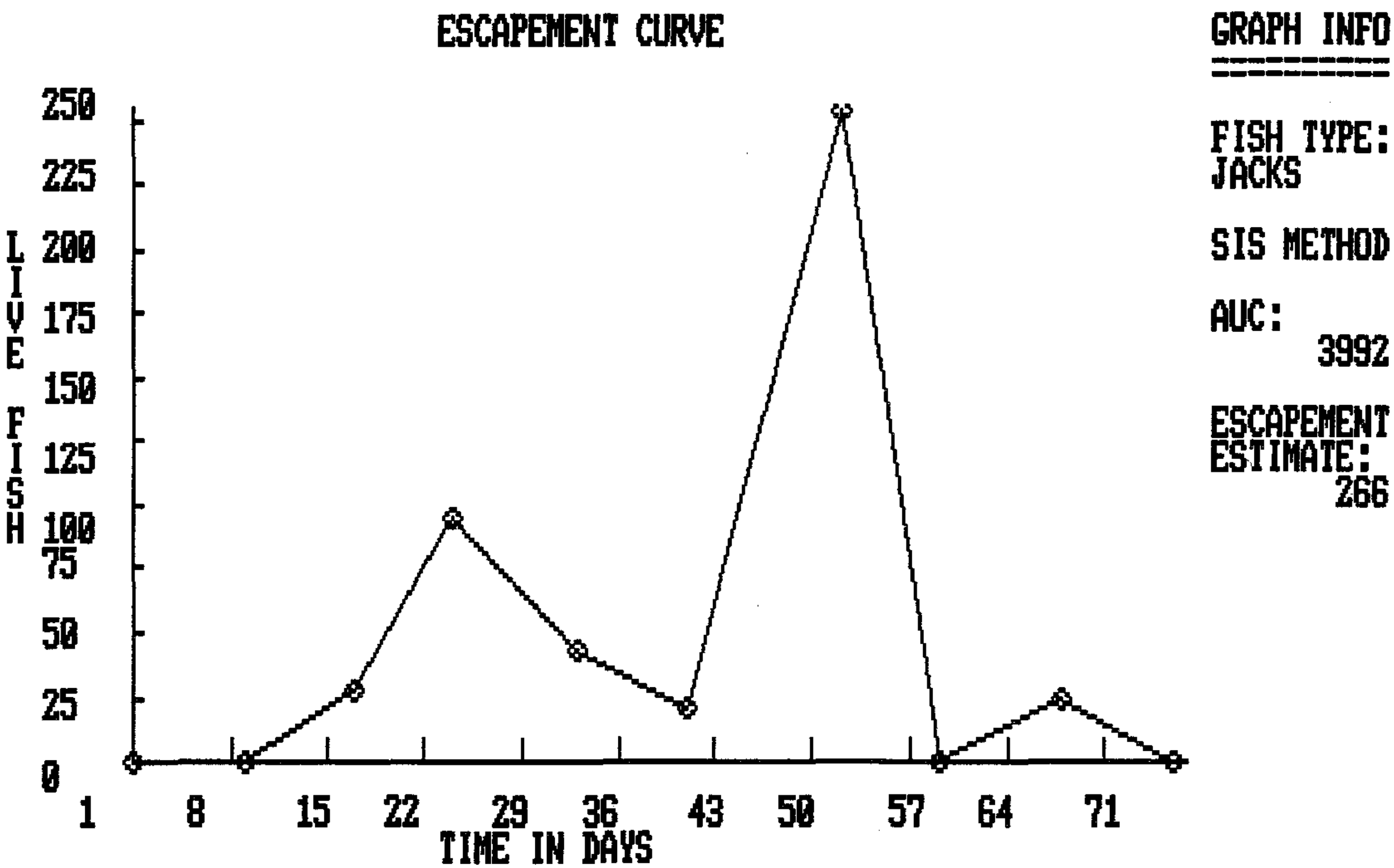

ESCAPEMENT CURVE
LIVE FISH
250
225
200
175
150
125
100
75
50
25
0
1
8
15
22
29
36
43
50
57
64
71
TIME IN DAYS
GRAPH INFO
FISH TYPE:
JACKS
SIS METHOD
AUC:
3992
ESCAPEMENT
ESTIMATE:
266

Figure 16. Output graph from AUC program. Numbers of live fish (SRS method, adults) versus time.

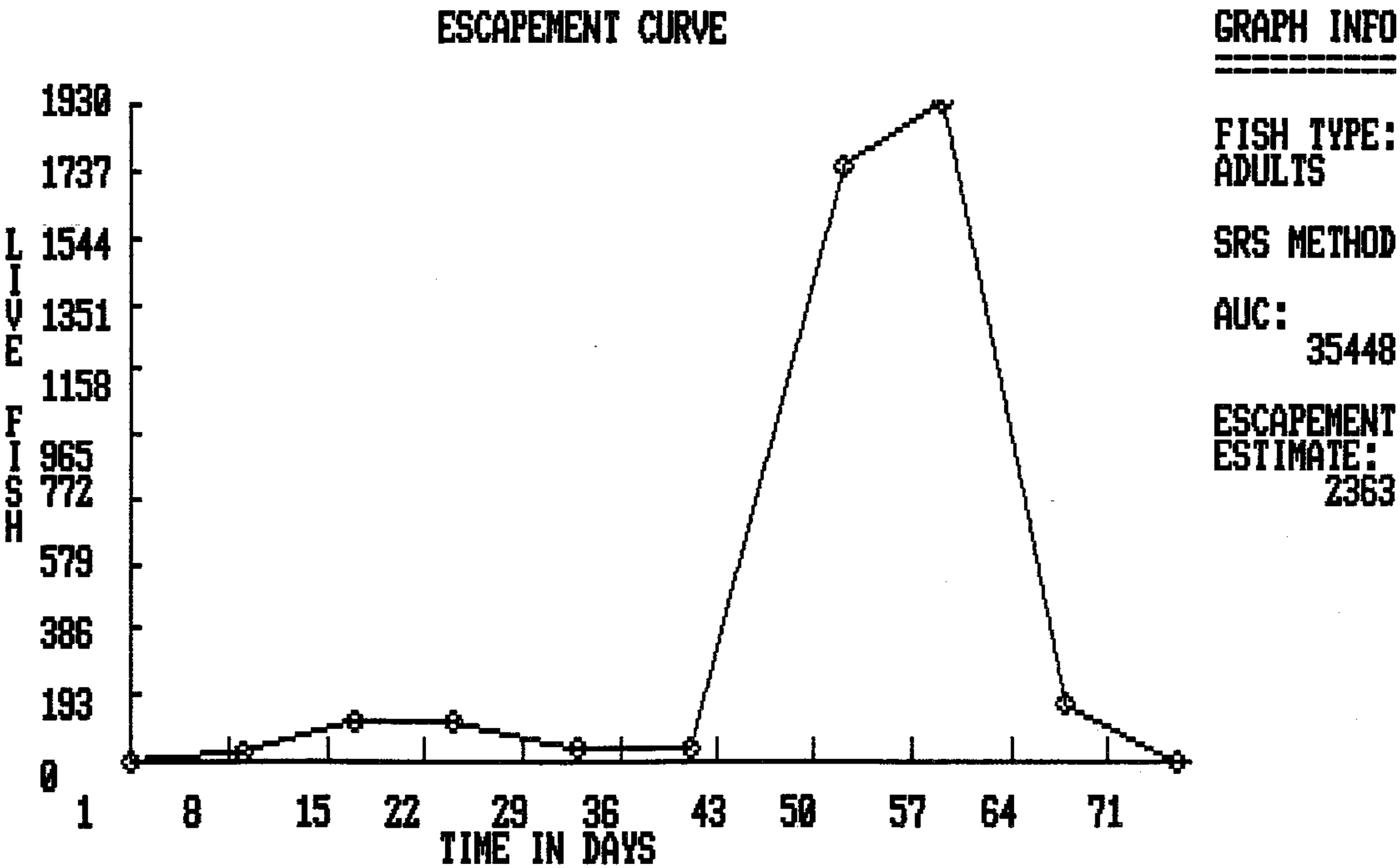
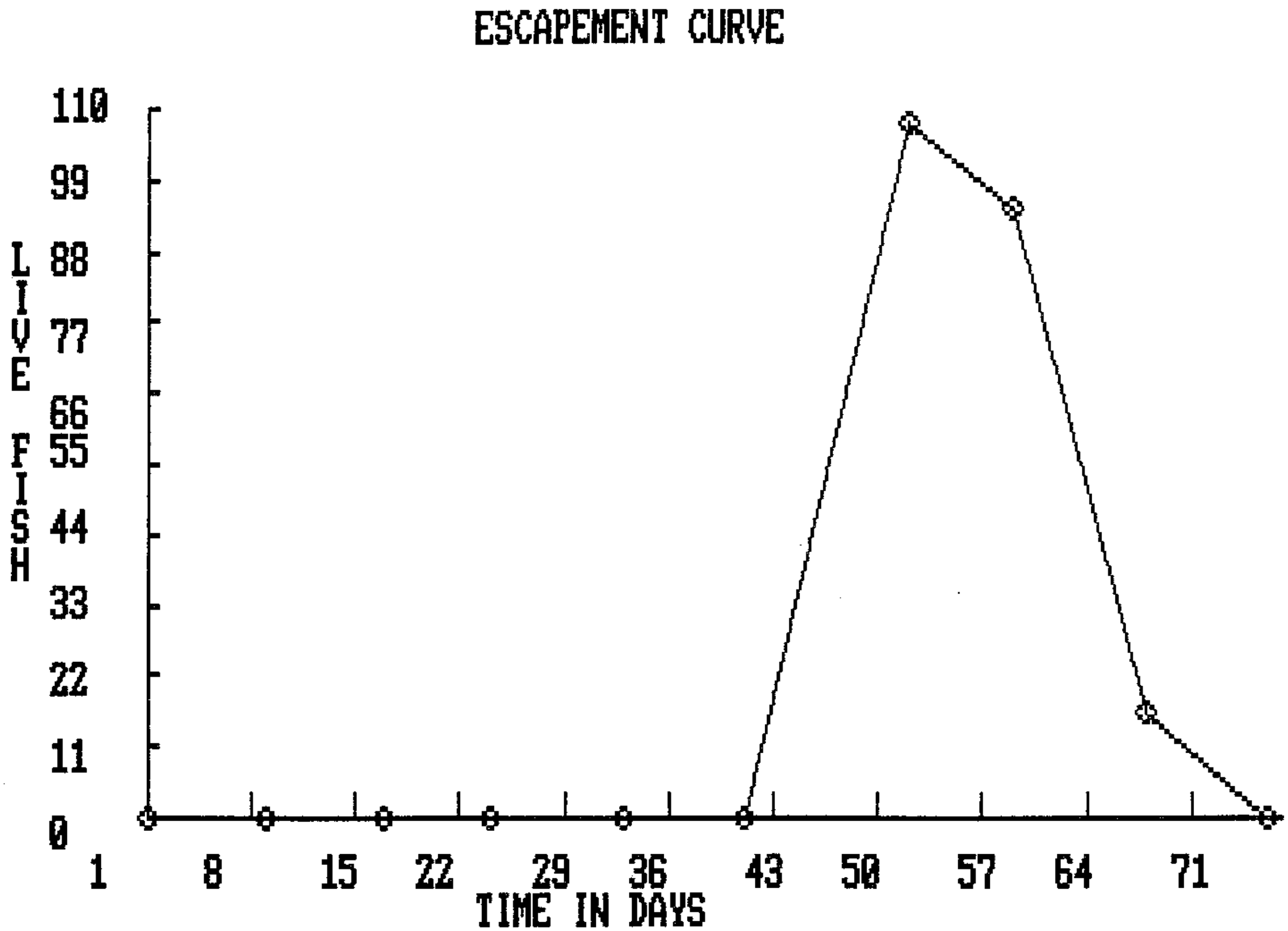

ESCAPEMENT CURVE
LIVE FISH
1930
1737
1544
1351
1158
965
772
579
386
193
0
1
8
15
22
29
36
43
50
57
64
71
TIME IN DAYS
GRAPH INFO
FISH TYPE:
ADULTS
SRS METHOD
AUC:
35448
ESCAPEMENT
ESTIMATE:
2363

Figure 17. Output graph from AUC program. Numbers of live fish (SRS method, jacks) versus time.



GRAPH INFO

FISH TYPE:
JACKS

SRS METHOD

AUC:
1863

ESCAPEMENT
ESTIMATE:
124

APPENDIX A - Obtaining Copies of This Report and/or the AUC Software Package

(1) A copy of this manual may be obtained by providing a brief note detailing your request and a self-addressed mail label.

(2) To obtain a copy of the AUC Software Package, you must provide a self-addressed mailer envelope for the single diskette we will send you. Indicate whether you prefer a 1.2Mb 5.25 inch floppy diskette, or a 1.44Mb 3.5 inch floppy diskette.

Send all requests to the first author:

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