USER'S MANUAL FOR PROGRAM CAPTURE

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Introduction

The computations necessary to calculate many of the mark recapture population estimates described in Otis et al. (1978) are lengthy, and usually nearly impossible to perform without a computer. Therefore, to provide methods of population estimation useful to the biologist, a comprehensive FORTRAN computer program was written to complement the Wildlife Monograph (available from The Wildlife Society, Suite 611, 7101 Wisconsin Avenue, Washington, DC 20014). Input to the program was written in a free-form and natural style to provide ease of use by computer users. This manual describes the program input options. No output is demonstrated herein because numerous examples are given in Otis et al. (1978).

Overview of Program Input

The basic unit of the program is a TASK. The word TASK is a restricted word in the program input, and identifies that a particular set of computations or data input is requested. The computations necessary to calculate a population estimate based on a particular model are assumed to be a TASK. Input of the X_{ij} matrix of captures is also a TASK. Various model estimators and hypothesis tests of the validity of the models make up the TASKs available in the program. These are summarized in Table 1, and described in Section 3.0. Many of the TASKs require only one input card, for example

```
TASK MODEL SELECTION .
```

Table 1a. TASK cards available in program CAPTURE, and the parameters and options available for each card. Optional parameter specifications are in brackets; mutually exclusive options are in braces with the default value underscored.

TASK READ CAPTURES { XY REDUCED / XY COMPLETE / NON XY / X MATRIX } OCCASIONS= [FILE=] [CAPTURES=] [SUMMARY]

Optional additional input cards are

DATA='information on data'

FORMAT='format specified'

TASK CLOSURE TEST [OCCASIONS=]

TASK MODEL SELECTION [OCCASIONS=]

TASK UNIFORM DENSITY TEST [OCCASIONS=]

TASK POPULATION ESTIMATE { ALL / APPROPRIATE / NULL / JACKKNIFE / REMOVAL / DARROCH / ZIPPIN } [OCCASIONS=]

Table 1a. Continued.

TASK DENSITY ESTIMATE { ALL | APPROPRIATE | NULL | JACKKNIFE | REMOVAL | DARROCH | ZIPPIN } INTERVAL= CONVERSION=

From two to eight additional input cards define grids:

X= Y= [OCCASIONS=]
⋮ ⋮ ⋮
X= Y= [OCCASIONS=]

END OF GRID DEFINITIONS [DENSITY=] [STRIP=]

TASK READ POPULATION { NULL | JACKKNIFE | REMOVAL | DARROCH | ZIPPIN }

(Only one estimator may be selected, with no default value. Additional input card(s) are required to enter the number of trapping occasions, the minimal sufficient statistics for the estimator selected, and identifying information.)

TASK READ DENSITY { NULL | JACKKNIFE | REMOVAL | DARROCH | ZIPPIN }

Table 1a. Continued.

(Additional cards are required to enter the number of grids, k, the initial values for density and strip width, heading, and the naive densities Y(I), coefficients A(I) and B(I), and variance-covariance matrix VC(I,J) for I = 1,...,J, J = 1,...K)

TASK SIMULATE [SEED=] [POPULATION=] [OCCASIONS=] [REPLICATIONS=] [PRINT]

Up to four additional input cards define capture probability structure or provide identifying information.

HETEROGENEITY=

BEHAVIOR=

TIME=

DATA='identifying information about simulation.'

TITLE='a heading to be printed at the top of each page of output.'

A second example of a TASK card which requires only one input card, but on which additional key words may be specified to provide an option in the computations is

TASK POPULATION ESTIMATE JACKKNIFE .

This card specifies that a population estimate is desired, specifically the jackknife estimator appropriate for Model M_h. Other TASK cards require that parameters be specified on the card. For example,

TASK READ CAPTURES OCCASIONS=10 ,

indicates there were 10 trapping occasions for the data set to be read. The more complicated input requires additional cards after the TASK card. An example of such a procedure is TASK DENSITY ESTIMATE, which requires one card for each grid to specify the dimension and location of the grid.

TASKs may be performed in almost any order, although there is a logical order of determining which estimator is appropriate before estimating the population or density. Also, the captures must be input before any of the TASKs that require these data can be executed.

A listing at the beginning of the program output that is made of the input cards as they are read is entitled

INPUT AND ERRORS LISTING .

Each input card is listed with

INPUT---

in front to separate it from the errors and warnings that are also printed. Warnings provide the default values of parameters not specified on the preceding card, and when an option in taken by default. So long as the default values are satisfactory, the optional parameters need not be set.

Errors usually are printed immediately after the input statement that caused an error to be detected. However, if an earlier statement causes the error, often it is not detected until the time of listing. The errors and warnings printed in the INPUT AND ERRORS LISTING generally concern only program input statements. Errors resulting from poor data (such as no recaptures) are printed in the output from the TASK.

If the program terminates properly, that is, when the last card has been read from the instructions, the following message is printed

SUCCESSFUL EXECUTION

Although this message indicates the program terminated properly, it does not mean that all TASKs were executed. An error on the TASK card may have caused the TASK to be skipped.

Reserved Files

The program requires instructions from file 5. Input and errors are listed on file 8 and results, on file 6. File 21 is used as a work file and should be a magnetic tape or disk. File 7 is used for additional detailed output that the user probably does not require. Therefore, file 7 should be a dummy print file. Capture data may be read from all but these reserved files. File 4 is the default for capture data.

Comments

The user may punch comments on any of the input cards in the space that remains after the necessary options and parameters have been set. Do not use any of the reserved words given in Table 1b which specify information to the program because they may be unintentionally read as instructions.

TITLE=

The TITLE= card is the same as a TASK card, but without the word TASK. It provides a title to be printed at the top of each page of output. Title changes are made by placing a TITLE card directly before a TASK card.

Title information is specified by single quotes, for example

TITLE='PUT YOUR INFORMATION HERE' .

Note that there are no embedded blanks between the key word TITLE, the equal sign, and the first single quote. Blanks may appear between the two quotes, as needed. However, no single quotes are allowed in the information because the next quote encountered after TITLE=' is taken as the end of the title.

TASK READ CAPTURES

This task reads the raw data (the X_{ij} matrix) required to select a model, estimate population size, etc. The program assumes that the capture histories each animal are coded on cards in one of the four methods discussed below. If density estimates are required, you must include the coordinates of each trap at which the animal was captured (this complicates the input slightly). The coordinates of the trap on the upper left corner of the grid shoud be (1,1) Coordinates of (0,0) are not permitted because zero values signify that the animal was not captured on this occasion. The two options for reading trap coordinates are XY COMPLETE and XY REDUCED. Option XY REDUCED is the default input format for the program, and thus the easiest to use. The standard input of the XY REDUCED option is

animal id, occasion i, x-coordinate, y-coordinate, occasion i,

x-coordinate, y-coordinate, ...

where *ocassion i* is the number of the trapping occasion for which the animal was caught, and *x-coordinate* and *y-coordinate* are the Cartesian coordinates of the trap catching the animal. This input allows the user to specify information only when an animal is caught. If an animal is caught only once, the *occasion, x-coordinate, y-coordinate* repetition is given only once, whereas if an animal is caught three times, the repetition is given three times. The rest of the card is ignored after the first blank or zero set of coordinates and occasion number.

As stated earlier, the program assumes the upper left trap of the grid is numbered (1,1). Numbering systems where other corners are labeled (1,1) can be used, and will give correct estimates of population and density. However when the matrix of captures per trap station is printed, it will be transposed and/or reflected. The corner trap cannot be numbered (0,0) because zero values indicate the animal was not captured.

The XY COMPLETE option assumes the complete capture history of each animal is being read. The information appears in the form

animal id; x,y coordinates for occasion 1; x,y coordinates for occasion 2; ...; x,y coordinates for last occasion.

With this option, x,y coordinates are entered on the card only when the animal is captured, with each card representing a separate animal. When an animal is not captured on a particular occasion the columns are left blank. For an animal captured only once, most of the card would be blank. The number of pairs of x,y coordinates to be read is determined from the OCCASIONS= parameter, to be discussed later.

The third input option, NON XY, is used if the experiment is conducted without coordinates for the traps, or if trap coordinates are going to be ignored. With this option all but the density estimates can be computed. The general form of the input is

animal id, 1st capture occasion, 2nd capture occasion, 3rd capture occasion,...

where capture occasion specifies the number of the trapping occasion on which the animal was captured. The number of trapping occasions is determined by the OCCASIONS= parameter, to be discussed later. The rest of the card is ignored when the first blank or zero occasion is encountered.

The X MATRIX option assumes that the complete X_{ij} matrix is being read as described in Otis et al. (1978). The general form is

animal id, string of ones and zeros to signify capture history (1 = capture, 0 = no capture).

Three parameters can be specified on the TASK card. OCCASIONS= specifies the number of trapping occasions. For example, if the population was trapped for seven days, and the traps were checked daily the parameter would be set as

OCCASIONS= 7

Note that there are no embedded blanks, and cannot be, because the program is scanning for the end of specification, signified by the first blank. This is true for all paremeter specifications in the program. Remember that there can be no blanks between the key word, the equal sign, and value specification.

The other two parameters that can be specified for this TASK are in regard to the raw capture data input file. The raw data is assumed to be read from file 4 (logical unit 4) using the default format (A3, 12(3F2.0)), which means only one set of population data can be read per run (unless a multi-file data set is used). Hence with the FILE= parameter, files other than file 4 can be read, and hence multiple sets of data analyzed in one run. The examples provided with the program assume that a multi-file data set will be used with logical unit 4. Hence all the TASK READ CAPTURES have FYLE= rather than FILE= . The program does not recognize FYLE= and hence reads the input from file 4. For users without multi-file data set capability on their machine, the individual example decks must be correctly specified and the TASK READ CAPTURES cards changed to agree with the data decks.

The CAPTURES= parameter specifies the number of captures per card. The default value is the number of occasions specified if less than 12, or 12, which is consistent with the default format of up to 12 captures per animal on one card for the XY REDUCED option. The CAPTURES= parameter is used only for the XY REDUCED and NON XY options because the OCCASIONS parameter specifies the number of fields to read for the other options.

In addition, summary information about the distance moved between captures can be obtained by specifying the word SUMMARY in the task READ CAPTURES CARD. that is,

```
TASK READ CAPTURES OCCASIONS=10 SUMMARY  .
```

The program will then summarize the average and maximum distances that the animal moved between successive captures, and the average of the maximum distances moved for all animals by the frequency of capture. This information is used to check the reliability of the estimates of density, or as described in Otis et al. (1978), an estimate of density may be obtained based on distance moved.

Two optional cards may be included after the TASK READ CAPTURES card. The first is (they may be in either order) the FORMAT= card which defines the format with which to read the captures. The format is put in quotes, for example,

FORMAT=' (A3, 36 (F2.0))' .

This format corresponds to the default used in the program, although any of the ANSI FORTRAN IV format conventions may be used. Format interpretation will depend on the input option being used. Animal identification must be in A format, and the maximum number of columns allowed depends on the word size of the computer being used. For example, IBM and XEROX allow four characters per word, CDC allows ten, Burroughs, Univac, and Honeywell allow six, and DEC allows five. The x,y coordinates and the occasion number must be read in F format for all of the input options. For the X MATRIX option, the zeros and ones must be read in F format.

The second optional card is the DATA= parameter, which specifies information about the captures read in addition to that given on the TITLE= card. For example, if a set of three grids is to be run, the TITLE= card specifies general information about the run, whereas the three DATA= cards specify information specific to the individual grids.

Because the above descriptions are abstract without examples, we will now give some specifics. First consider an example of the XY REDUCED option with all the default values. The listing in Table 2 represents the simplest form of the TASK READ CAPTURES statement. The entries for each occasion an animal was captured need not be in chronological order, although this practic is not recommended. Multiple cards with the same animal identification will not cause problems--but the second card will over-ride the first if there is a conflict.

Table 2. Example of TASK READ CAPTURES with all the default values taken.

INSTRUCTIONS read from FILE 5 are:

```
TITLE='EXAMPLE INPUT FOR TABLE 2'
TASK READ CAPTURES  OCCASIONS=8
```

CAPTURES read from FILE 4 are:

```
A01 1 5 2 3 7 2 4 8 1 6 6 2 7 7 2
A02 1 4 3 3 6 2 4 6 2 6 3 4 7 1 4
A03 1 8 3 7 8 2 810 2
A04 2 9 2 3 9 2 6 9 2 7 8 3 8 9 3
A05 2 9 3
A06 4 8 9
A07 410 6 610 3
A08 610 6 710 7 810 6
```

Table 3 gives a second example of the XY REDUCED option in which all parameters are specified to illustrate input for which none of the default values apply.

Table 3. Example of TASK READ CAPTURES with XY REDUCED option set, five captures per card, with input from File 1. Animal identification appears in columns 73-76.

INSTRUCTIONS read from FILE 5 are:

```
TASK READ CAPTURES XY REDUCED   FILE=1  OCCASIONS=8  CAPTURES=5
DATA='EXAMPLE INPUT FOR TABLE 3'
FORMAT='(72X,A4,T1,5(F2.0,2F3.0))'
```

CAPTURES read from FILE 1 ar

CAPTURES read from FILE 1 are:

```
1  5  2 3  7  2 4  8  1 6  6  2 7  7  2                    A001
1  4  3 3  6  2 4  6  2 6  3  4 7  1  4                    A002
1  8  3 7  8  2 8 10  2                                    A003
2  9  2 3  9  2 6  9  2 7  8  3 8  9  3                    A004
2  9  3                                                    A005
4  8  9                                                    A006
4 10  6 6 10  3                                           A007
6 10  6 7 10  7 8 10  6                                   A008
```

Table 1b. Program CAPTURE reserved words and phrases.

TITLE	HETEROGENEITY
TASK	BEHAVIOR
READ CAPTURES	TIME
CLOSURE TEST	PRINT
MODEL SELECTION	SEED
UNIFORM DENSITY TEST	POPULATION
POPULATION ESTIMATE	REPLICATIONS
DENSITY ESTIMATE	X
READ POPULATION	Y
READ DENSITY	CONVERSION
SIMULATE	INTERVAL
XY REDUCED	END OF GRID DEFINITIONS
XY COMPLETE	DENSITY
NON XY	STRIP
X MATRIX	ALL
SUMMARY	APPROPRIATE
OCCASIONS	NULL
FILE	JACKKNIFE
CAPTURES	REMOVAL
DATA	DARROCH
FORMAT	ZIPPIN

Table 4 gives an example of the XY COMPLETE option. A nondefault format illustrates the use of two cards to record the coordinates for one animal. The default format cannot be used to read two cards as in the example.

Table 5 gives an example of the NON XY option input. Note that the animal identified as A01 was caught on occasions 1, 3, 4, and 6, and a later card also specifies it was caught on occasion 7.

Table 6 gives an example of the X MATRIX option. The first four columns are the animal identification.

TASK READ CAPTURES produces a summary table of output on the INPUT AND ERRORS listing. The listing gives the number of trapping occasions, number of different animals captures, and maximum x and y coordinates. These values will help the user to determine whether the input was coded correctly, because mispunched cards often cause irregular x,y coordinates.

Table 4. Example of TASK READ CAPTURES with XY COMPLETE option set and multiple cards per record. The default file of 4 is used.

INSTRUCTIONS read from FILE 5 are:

```
TASK READ CAPTURES XY COMPLETE  OCCASIONS=8
FORMAT='(A4,5(2F5.0)/4X,5(2F5.0))'
DATA='EXAMPLE INPUT FOR TABLE 4'
```

CAPTURES read from FILE 4 are:

```
A001   5   2                   7   2   8   1
A001   6   2   7   2
A002   4   3                   6   2   6   2
A002   3   4   1   4
A003   8   3
A003               8   2  10   2
A004               9   2   9   2
A004   9   2   8   3   9   3
A005               9   3
A005
A006                                       8   9
A006
A007                                      10   6
A007  10   3
A008
A008  10   6  10   7  10   6
```

Table 5. Example of TASK READ CAPTURES with the NON XY option set. A nondefault file of 3, and the default format are used.

INSTRUCTIONS read from FILE 5 are:

```
TASK READ CAPTURES  NON XY  OCCASIONS=8  FILE=3
DATA='EXAMPLE INPUT FOR TABLE 5'
```

CAPTURES read from FILE 3 are:

```
A01 1 3 4 6
A02 1 3 4 6 7
A03 1 7 8
A04 2 3 6 7 8
A05 2
A06 4
A07 4 6
A08 6 7 8
A01 7
```

Table 6. Example of TASK READ CAPTURES with the X MATRIX option set. A nondefault input of file 11 is used.

INSTRUCTIONS read from FILE 5 are:

```
TASK READ CAPTURES  X MATRIX  OCCASIONS=8  FILE=11
FORMAT='(A4,8F1.0)'
DATA='EXAMPLE INPUT FOR TABLE 6'
```

CAPTURES read from FILE 11 are:

```
A001101101 10
A002101101 10
A003100000 11
A004011001 11
A005010000 00
A006000100 00
A007000101 00
A008000001 11
```

TASK CLOSURE TEST

This TASK helps in determining whether the assumption of population closure can be made from the data read with TASK READ CAPTURES. The only parameter to be specified is OCCASIONS= . This determines which trapping occasions are to be used in the test for closure. The default value for OCCASIONS= is all the trapping occasions. For example, suppose that a grid was trapped for 12 days. When TASK CLOSURE TEST is run with the default value, OCCASIONS=1-12. However, if the biologist wants to look at the assumption of closure for only the first six days, the input would be TASK CLOSURE TEST OCCASIONS=1-6. Note that there are no embedded blanks around the equal sign, because a blank signifies the end of the specification. The OCCASIONS= parameter, a single-valued parameter, is used in TASK READ CAPTURES to specify the number of trapping occasions. In this TASK, and in the rest of the TASKs where OCCASIONS= will be used, it is a multiple-valued parameter used to specify the trapping occasions to be analyzed. Hence, a series of the values will be specified with no embedded blanks. Hyphens indicate "through" so that OCCASIONS=1-5 means the numbers 1, 2, 3, 4, and 5. Slashes indicate "by," so that OCCASIONS=1-9/2 means the series 1, 3, 5, 7, and 9, that is, 1 through 9 by 2's. Commas also may be used to separate sequences of numbers, so that OCCASIONS=1-5,9-10,12 means the series 1, 2, 3, 4, 5, 9, 10, and 12.

TASK MODEL SELECTION

This TASK computes the sequence of hypothesis tests described in Otis et al. (1978). It is used to determine which population estimator should be used. The data are those captures read by TASK READ CAPTURES. This TASK also has only one parameter, the OCCASIONS= parameter. The purpose and format for the parameter specification are identical to those described in the TASK CLOSURE TEST.

TASK POPULATION ESTIMATE

This TASK computes populations estimates for data read by TASK READ CAPTURES. The population estimators desired are specified by using any or all of the five key words: NULL, JACKKNIFE, DARROCH, REMOVAL, AND ZIPPIN. If all population estimators are desired, the key word ALL may be used. Usually the biologist is unsure of which estimator is appropriate until after he has reviewed the hypotheses testing output. To avoid multiple runs, the key word APPROPRIATE may be used to instruct the program to calculate the estimator selected in TASK MODEL SELECTION. However, the TASK MODEL SELECTION must have been run for the grid being analyzed. Other estimators may be specified with APPROPRIATE, that is,

TASK POPULATION ESTIMATE APPROPRIATE NULL .

If the NULL estimator is not selected as the appropriate one, two population estimates will be made.

The NULL estimator, derived from Model M_o in Otis et al. (1978), is described as null because none of the three possible sources of variability are assumed to be operating. The JACKKNIFE estimator is appropriate for Model M_h, where the probability of capture varies by animal. The DARROCH estimator is derived from Model M_t. The REMOVAL estimator is the generalized removal estimator derived from Model M_{bh}. The ZIPPIN estimator, a special case of the REMOVAL estimator, and is derived from Model M_b in Otis et al. (1978).

This TASK also has the OCCASIONS= parameter available. Use and format of this parameter are identical to that described for TASK CLOSURE TEST. The OCCASIONS= parameter in this TASK is used to look at changes in population during the trapping period.

TASK UNIFORM DENSITY TEST

This TASK tests the homogeneity of the distribution of captures from the grid read by TASK READ CAPTURES. A matrix of captures by trap station

is used to indicate possible trends in density within the grid. Also, the grid is collapsed by rows of traps and a chi-square test constructed, and then likewise by columns. This TASK also has the OCCASIONS= parameter. Its use and format are identifical to those described in the TASK CLOSURE TEST. The matrix output from this TASK is difficult to interpret if the upper left trap is not labeled (1,1). No output can be produced when the data are read with NON XY or X MATRIX formats.

TASK DENSITY ESTIMATE

This TASK computes an estimate of animal density based on the method presented in Otis et al. (1978). An option, several parameters, and additional specification cards are required.

The option determines the population estimator to be used to estimate the naive density of each grid. The five option key words are NULL, JACKKNIFE, DARROCH, REMOVAL, and ZIPPIN. If all population estimators are desired, the key word ALL may be used. If the estimator selected by TASK MODEL SELECTION is desired, the key word APPROPRIATE may be used.

Two parameters also must be specified on the TASK card. The first parameter, TRAP INTERVAL= , may be shortened to INTERVAL= . This parameter specifies the distance between traps for the grid. For example, if traps are set on a 15-m grid system, TRAP INTERVAL=15 would be used, or alternatively, the shorter form, INTERVAL=15, would be used. The default is INTERVAL=15.

The second parameter which converts from linear distance to area, is UNITS CONVERSION= , or a shorter form CONVERSION= . For example, if the linear distance between traps is measured in meters, then CONVERSION=1 results in animals/m^2, whereas CONVERSION=10000 results in animals/ha. To convert from feet to acres, UNTIS CONVERSION=43560 would be used, that is 43 560 ft^2 = 1 acre. The default is CONVERSION=10000. As a final example, if traps were

placed 100 ft apart, but density is to be in hectares, enter the interval in meters, INTERVAL=30.5, and use the default of CONVERSION=10000.

Grid definition cards follow the TASK card. Each grid card must specify values for two parameters: X= and Y= determine the range of x- and y- coordinates for the grid, respectively. There can be no embedded blanks in the specification. For example, a card with

X=5-9 Y=3,8

specifies a 4 by 4 grid with lower left corner at (5,3). Either a hyphen or comma may be used to separate the values. Labels for the grids punched on the card, such as INNER, MIDDLE, OUTER, etc., help to interpret the output and will not interfere with the parameter specification. Each grid card has the optional OCCASIONS= parameter, whose use and format are identical to those described in the TASK CLOSURE TEST.

Up to eight grid cards may be specified. The order in which they appear is not important, although if they are ordered by increasing grid size the output is easier to interpret. This is because the naive density estimates are expected to decrease with increasing grid size, and the user can easily note grids that are inconsistent with this pattern if the grid cards are ordered

The last card required is the

END OF GRID DEFINITIONS

card, which signifies the end of the input cards required by this TASK. In addition, two optional parameters, DENSITY= and STRIP=, may be set to obtain initial values for density and strip width needed to solve the density estimation problem. Initial values should be provided when the user can estimate the value, or when the program has not converged previously with default values. Default values are calculated from the data but will not always be close to the final values.

Table 7 gives an example of input for the TASK DENSITY ESTIMATE. The trap grid is 15 by 15, with 30 f between traps. Notice the word FEET is placed on the card as a comment, because it is not recognized by the program. To obtain density in acres, CONVERSION=43560 is specified. All five population estimators are to be used. Three nested grids are used, with the largest grid being the total. Default values are used for initial values of density and strip width.

TASK READ POPULATION

This TASK allows the user to enter only the number of trapping occasions and the minimal sufficient statistic for a population estimator. The estimator desired is specified by either: NULL, JACKKNIFE, REMOVAL, DARROCH, or ZIPPIN. Only one key word may be specified because the minimal sufficient statistic is different for each case. Following the TASK card additional cards are used to specify the input data. This TASK does not need to follow TASK READ CAPTURES because capture data are not used. It is assumed that the user has already summarized the statistics needed to compute the estimator desired.

Because each estimator requires a different statistic the input depends on the option specified. However, all five options may have identifying information specified anywhere on the first special input card by enclosing it in single quotes. No comments are allowed on these special input cards. The cards are free-form with values separated by either commas or blanks.

The minimal sufficient statistic for the NULL estimator is $\{n_{\cdot}, M_{t+1}\}$ (notation from Otis et al. 1978). For this estimator, only one special card is needed, with t, $n_{\cdot}$, M_{t+1}, and identifying information specified on it. The three values and the character string of information are punched free-form on the input card, with either blanks or commas separating them. The order of t, $n_{\cdot}$, and M_{t+1} on this card is important, although the

Table 7. Example input for TASK DENSITY ESTIMATE.

INSTRUCTIONS read from FILE 5 are:

```
TITLE='EXAMPLE INPUT FOR TABLE 7'
TASK DENSITY ESTIMATE  INTERVAL=30 FEET  CONVERSION=43560
INNER GRID  X=5-9   Y=5,9
MIDDLE GRID X=3,11 Y=3-11
TOTAL GRID  X=1,15 Y=1,15
END OF GRID DEFINITIONS
```

identifying information may appear anywhere on the card. An example of the NULL input as well as the other four estimators is given in Table 8.

The minimal sufficient statistic for the JACKKNIFE estimator is $\{f_1, f_2, \ldots, f_t\}$. The value of t is given on the first card, and the f_j's are given on the second card. Only values for f_j up to the last non zero value need be punched because the program assumes any remaining undefined values are zero. This feature is illustrated in Table 8, where t is equal to 11, but only nine f_j values are punched: f_{10} and f_{11} are assumed to be zero.

The minimal sufficient statistic for the REMOVAL estimator is $\{u_1, u_2, \ldots, u_t\}$. As with the f_j values for the JACKKNIFE option, zero values for the end of the u_j vector need not be punched, because they are assumed to be zero. Commas or blanks were used to separate the u_j's in Table 8. Input for the ZIPPIN option is identical to that of the REMOVAL option because ZIPPIN is just a special case of REMOVAL.

The minimal sufficient statistic for the DARROCH estimator is $\{M_{t+1}, n_1, n_2, \ldots, n_t\}$. The values for t and M_{t+1} are punched in that order on the first input card, and the values of n_j ($j = 1, \ldots, t$) are punched on the second card. The program verifies that the number of n_j values read is equal to t.

TASK READ DENSITY

This TASK allows the user to read the necessary data to compute a density estimate. This method is much less desirable than computing density from the x,y coordinates because the covariance matrix used for weighting the naive densities is a function of strip width. Hence, although the weighting matrix should be changed as strip width is changed, this is not possible with this procedure. However, if strip width is reasonably well

Table 8. Example input for TASK READ POPULATION showing all five options.

INSTRUCTIONS read from FILE 5 are:

```
TITLE='EXAMPLE INPUT FOR TABLE 8'
TASK READ POPULATION  NULL
  5, 224, 87, 'DATA FROM TABLE 4.1, PAGE 135, SEBER (1973).'
TASK READ POPULATION  JACKKNIFE
  11, 'DATA FROM TABLE 4.17, PAGE 173, SEBER (1973).'
  23  14  9  6  8  7  3  0  2
TASK READ POPULATION  REMOVAL
  10  'DATA FROM TABLE 4.9, PAGE 156, SEBER (1973).'
  10, 10, 8, 9, 7, 6, 5  4  7  5
TASK READ POPULATION  DARROCH
  5 87 'DATA FROM TABLE 4.1, PAGE 135, SEBER (1973).'
  32 54 37 60 41
TASK READ POPULATION  ZIPPIN
  10  'DATA FROM TABLE 4.9, PAGE 156, SEBER (1973).'
  10 10 8 9 7 6 5 4 7 5
```

known, the error will be small.

The TASK requires k + 1 special input cards. The first card defines k or the number of grids, the initial estimate of density, and the initial estimate of strip width. These cards must be presented in this order. Also, a string of identifying information enclosed in quotes may be included on this card.

The next k cards provide the data for each grid. The values in order (notation as in Otis et al. 1978) are the naive density (Y_i), a_i, b_i, and the i^{th} row of the variance-covariance matrix. Only the diagonal elements and the lower left off-diagonal elements are required because the matrix is symmetric. The input for this TASK is as follows. An example is shown in Table 9.

k,	D initial,	W initial,	'identifying information'
Y_1,	a_1,	b_1,	V(1,1)
Y_2,	a_2,	b_2,	V(2,1), V(2,2)
Y_3,	a_3,	b_3,	V(3,1), V(3,2) V(3,3)
⋮	⋮	⋮	⋮
Y_k,	a_k,	b_k,	V(k,1), V(k,2), ..., V(k,k)

Table 9. Example input for TASK READ DENSITY.

INSTRUCTIONS read from FILE 5 are:

```
TITLE='EXAMPLE INPUT FOR TABLE 9'
TASK READ DENSITY
 3  .619  533  'DATA FROM BURNHAM AND CUSHWA (IN PREP.).'
 3.3156  .004997  4.908E-6  .4002
 2.0448  .003333  2.178E-6  .1035  .0614
 1.2400  .001346  1.007E-6  .0284  .0168  .00749
```

TASK SIMULATE

This task is used to simulate a mark recapture experiment. As described in Otis et al. (1978), a simulation may be used to determine sample sizes needed, or the effect that not meeting an assumption has on an estimator.

Tables 17-19 in Otis et al. (1978) were generated using TASK SIMULATE and provide the user with an example of the output. This task requires much input. Four parameters may be set on the task card. First, the SEED= parameter provides a random integer used as a starting value to generate random numbers between zero and one. Although this seed usually is somewhat machine specific, a five or seven digit odd integer will usually suffice. The default value is 1234567. The system random number generator is used by the program, so the value of the seed will depend on the type of machine being used. Therefore the local documentation should be consulted to determine the choice of a seed. A second parameter, POPULATION= , specifies the size of population to be simulated. The default value is 400, with maximum value of 1000 allowed. OCCASIONS= specifies the number of trapping

ocassions (default value is 7, with a maximum of 31 allowed). A third limitation is that POPULATION times OCCASIONS must be less than 4000. REPLICATIONS= specifies the number of experiments (replications) to be simulated (default value of 50, no maximum). The number of replications will determine the user's confidence in the output, that is, how precise the estimates are. These parameters may be specified in any order.

In addition, a PRINT option sets a switch that results in a complete output for each experiment to be printed. If the user is interested in the MODEL SELECTION output, specifying PRINT will cause it to be printed. Beware, however, of the amount of output that will be printed when the number of REPLICATIONS is large. Do not use PRINT when more than 10 replications are specified. If PRINT is not specified, only the table of summary statistics for the simulations will be printed. This table requires only one page of output--no matter how large the number of REPLICATIONS is. However, more time will be required as the number of REPLICATIONS is increased. We suggest that approximately 100 replications would be expected to provide some useful information.

The most difficult part of the input to TASK SIMULATE is specifying the structure of the probability of captures for the population. Three additional cards may be used for this purpose. The HETEROGENEITY= card specifies a number of individuals and their probability of capture, followed by (optionally) a second number of individuals and their associated probability of capture, and so on. In the following example

```
TASK SIMULATE POPULATION=150 SEED=4119453 REPLICATIONS=50 OCCASIONS=10
HETEROGENEITY=50,0.5,65,0.3,35,0.1    ,
```

50 animals have 0.5, 65 have 0.3, and 35 have 0.1 probability of capture. This example specifies a total of 150 animals in the population; this value

must equal the value specified for POPULATION= on the task card. If only the above card is used to provide capture probabilities, a Model M_h experiment will be conducted. There are no embedded blanks in the HETEROGENEITY= card.

A Model M_{bh} experiment is indicated if a BEHAVIOR= card is included with a HETEROGENEITY= card. An example is

```
TASK SIMULATE SEED=4491935 POPULATION=200 OCCASIONS=10 REPLICATIONS=100
HETEROGENEITY=100,0.5,100,0.3
BEHAVIOR=200,1.5  .
```

In this example 100 animals have initial capture probability of 0.5, and 100 animals have initial capture probability of 0.3. However, recaptures are influenced by the values on the BEHAVIOR= card. In this example, all 200 animals will have an increased recapture probability of 1.5 times their initial capture probability. If the behavior card had been

```
BEHAVIOR=50,1.5,50,0.5,50,1.5,50,0.5    ,
```

one-half of each of the two groups of animals specified on the HETEROGENEITY= card would have increased recapture probabilities, and one-half would have decreased probabilities. As with the HETEROGENEITY= card, the total number of animals specified must equal the value specified on the TASK card, and no embedded blanks may occur.

A third card for specifying capture probabilities is the TIME= card. The format is different from the above cards however.

```
TASK SIMULATE SEED=2288319 OCCASIONS=5 POPULATION=500 REPLICATIONS=30
TIME=0.9,0.5,0.3,0.5,0.5
```

specifies that the capture probability on occasion 1 is 0.9, occasion 2 is 0.5, etc. This is a Model M_t experiment. The number of values specified must be equal to the number of occasions specified on the TASK card.

As with the HETEROGENEITY= and BEHAVIOR= cards, the TIME= card will interact with the others through a multiplication process. For example,

```
TASK SIMULATE POPULATION=200 OCCASIONS=4 REPLICATIONS=100
TIME=0.5,0.4,0.5,0.4
BEHAVIOR=100,1.5,100,0.75
```

results in an initial capture probability of 0.5 for all animals on trapping occasion 1. However on occasion 2, animals not yet captured will have a capture probability of 0.4. Those previously captured on occasion 1 will have a recapture probability of either (1.5)(0.4) = 0.6, or (0.75)(0.4) = 0.3, depending on whether the animal is among the first or second half of the 200 animals in the population. This process continues for the five trapping occasions, providing a Model M_{tb} experiment.

The last example we will discuss is one where all three types of cards are used to simulate a Model M_{tbh} experiment. The input is

```
TASK SIMULATE POPULATION=200 OCCASIONS=4 REPLICATIONS=50 SEED=459761
TIME=0.9,0.8,0.9,0.8
HETEROGENEITY=100,0.9,100,0.5
BEHAVIOR=50,0.75,50,1.3,50,0.75,50,1.3 .
```

The initial capture probability on occasion 1 is (0.9)(0.9) = 0.81 for the first 100 animals, and (0.9)(0.5) = 0.45 for the second 100 animals. The BEHAVIOR= card has no effect or capture probabilities on the first occasion because none of the animals are recaptures. However, on trapping occasion 2, the behavior structure is incorporated. If the animal is a recapture its probability will be either (0.8)(0.9)(0.75) = 0.54 or (0.8)(0.5)(1.3) = 0.52

depending on whether he is in the first or third group of animals, or in the second and fourth group of 50 animals, respectively. This process continues for the four occasions, and the results are given in Table 10.

Specifications for Model M_0 can be accomplished in two ways. Both of the following TASKS specify a constant probability of capture of 0.5 for the entire population

```
TASK SIMULATE SEED=45763 POPULATION=100 REPLICATIONS=25 OCCASIONS=5
HETEROGENEITY =100,0.5
TASK SIMULATE SEED =45763 POPULATION=100 REPLICATIONS=25 OCCASIONS=5
TIME=0.5,0.5,0.5,0.5,0.5  .
```

In addition to the four cards described above, a DATA= card can be used to specify identifying information about the simulation. The format is identical to that given in TASK READ CAPTURES. This card may appear anywhere among or after the three cards used to specify capture probabilities.

Typical Example

In Table 11 we have provided a typical example as a summary of the input to Program CAPTURE. The TITLE= card will label all the output from the run with the heading 'EXAMPLE INPUT FOR TABLE 10' . TASK READ CAPTURES reads the capture data in XY REDUCED format (default) from file 17. Traps were set for 10 occasions, and a summary of the distances moved between captures will be printed. The DATA= statement provides an additional heading on output related to this particular set of data.

The remaining 4 TASK cards request a test for closure, a model be selected, population estimates be made for the model selected as well as the generalized removal model, and a density estimate be made with the model selected. Note that all four tasks use only the last eight trapping occasions.

Table 10. Capture probabilities for each trapping occasion and capture or recapture status for the example input to TASK SIMULATE.

Animals	First Capture	Recapture
	Trapping Occasion 1	
1 - 50	(0.9)(0.9) = 0.81	-----
51 - 100	(0.9)(0.9) = 0.81	-----
101 - 150	(0.9)(0.5) = 0.45	-----
151 - 200	(0.9)(0.5) = 0.45	-----
	Trapping Occasion 2	
1 - 50	(0.8)(0.9) = 0.72	(0.8)(0.9)(0.75) = 0.54
51 - 100	(0.8)(0.9) = 0.72	(0.8)(0.9)(1.3) = 0.94
101 - 150	(0.8)(0.5) = 0.40	(0.8)(0.5)(0.75) = 0.30
151 - 200	(0.8)(0.5) = 0.40	(0.8)(0.5)(1.3) = 0.52
	Trapping Occasion 3	
1 - 50	(0.9)(0.9) = 0.81	(0.9)(0.9)(0.75) = 0.61
51 - 100	(0.9)(0.9) = 0.81	(0.9)(0.9)(1.3) = 1.05[1]
101 - 150	(0.9)(0.5) = 0.45	(0.9)(0.5)(0.85) = 0.34
151 - 200	(0.9)(0.5) = 0.45	(0.9)(0.5)(1.3) = 0.59
	Trapping Occasion 4	
1 - 50	(0.8)(0.9) = 0.72	(0.8)(0.9)(0.75) = 0.54
51 - 100	(0.8)(0.9) = 0.72	(0.8)(0.9)(1.3) = 0.94
101 - 150	(0.8)(0.5) = 0.40	(0.8)(0.5)(0.75) = 0.30
151 - 200	(0.8)(0.5) = 0.40	(0.8)(0.5)(1.3) = 0.52

[1] Program CAPTURE will reduce values greater than 1.0 a capture probability of 1.0.

Table 11. A typical set of input cards to Program CAPTURE.

```
TITLE='EXAMPLE INPUT FOR TABLE 11'
TASK READ CAPTURES   OCCASIONS=10 SUMMARY FILE=17
DATA='DATA FROM ERIC LARSEN, PEROMYSCUS MANICULATUS, PARACHUTE CREEK, COLORADO.'
TASK CLOSURE TEST   OCCASIONS=3-10
TASK MODEL SELECTION  OCCASIONS=3-10
TASK POPULATION ESTIMATE  APPROPRIATE  REMOVAL  OCCASIONS=3-10
TASK DENSITY ESTIMATE  APPROPRIATE  INTERVAL=15 CONVERSION=10000
INNER GRID  X=4-7  Y=4-7  OCCASIONS=3-10
MIDDLE INNER GRID  X=3-8  Y=3-8  OCCASIONS=3-10
MIDDLE OUTER GRID  X=4-9  Y=4-9  OCCASIONS=3-10
ENTIRE GRID   X=1-10  Y=1-10  OCCASIONS=3-10
END OF GRID DEFINITIONS.
```

Program Details

Run Costs

A typical run with the program is to read in a data matrix of 100 animals and to perform a sequence of tests and estimates. These are usually TASK CLOSURE TEST, TASK MODEL SELECTION, TASK UNIFORM DENSITY TEST, TASK POPULATION ESTIMATE ALL, and TASK DENSITY ESTIMATE with only one population estimator specified. The run costs approximately $1.50 on the Utah State University Burroughs 6700 and takes about 10 s of computer processor time.

Program Size

The program consists of a main routine and approximately 49 subroutines, depending upon the machine being used and the intrinsic functions available. In addition, there are seven common blocks. Comment statements are included to aid in following the program flow. The total code consists of approximately 6000 cards. Code requirements are approximately 190K for the code without an overlay structure on an IBM System/360. The overlay structure suggested in Fig. 1 will reduce storage requirements to approximately 130K.

Dimension Limitations

Program dimensions are now set to allow up to 2000 individual animals and 31 trapping occasions. In addition, the product of the number of animals and the number of trapping occasions must be less than 4000. This will allow, for example, 30 trapping occasions and 80 animals, or 120 animals and 20 trapping occasions. These values can be changed easily by changing DIMENSION statements in the program.

Availability

The program is written in ANSI FORTRAN IV with several small exceptions so that it will function on most brands of digital computers. FORTRAN statements known to cause problems with a particular FORTRAN compiler are marked with a comment statement. This feature, described in detail by comments in

the program, is useful for converting the program. The present version has been compiled and executed on Burroughs, CDC, and IBM machines. In addition, comment statements reflect changes required for Univac, Honeywell, Xerox, and DEC machines.

A magnetic tape with the IBM and CDC FORTRAN code and 12 sets of example data are available as program number 3600-17.5.002 from

SHARE Program Library Agency
P. O. Box 12076
Research Triangle Park, NC 27709

at a cost of $35 plus $5 for handling if not prepaid. Specifications for the tape (e.g., 7 or 9 track, 800 or 1600 bpi, etc.) and the brand of machine the program will be used on should be given when ordering the source code.

Literature Cited

Burnham, K. P. and C. T. Cushwa (in prep.). Robust estimation of population density from live trapping studies.

Otis, D. L., K. P. Burnham, G. C. White, and D. R. Anderson. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. No. 62:1-135.

Seber, G. A. F. 1973. Estimation of animal abundance and related parameters. Griffin, London. 506 p.

Figure 1. Suggested overlay structure to reduce program size by approximately 30 percent.