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(1) Program Number (to be filled by SPLA) 360D-17.5.002

(2) Title of Program . . . . . Program CAPTURE -- FORTRAN IV Version

(3) System Type(s) (Machine). . . . . . CDC, IBM, Burroughs, Honeywell, Xerox, Univac, and DEC

(4) Search Key(s) . . . .

(5) Programming Systems/Languages . . FORTRAN IV with significant extensions from the ANSI standards marked by comment cards.

(6) Primary Subject Code . . . . 17.5 Biology

(7) Minimum System Requirements Approximately 200 K storage for IBM/360 if not overlaid, approximately 140 K storage if overlaid as described in the User's Manual

(8) New (N) or Revision (R) (if revision, show prior Program Number in Item 1) (N)

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(11) Author's Name and Address . . . . .

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(12) Direct Technical Inquiries to Name & Address (if different than Author)

(13) Submitter's Installation Membership Code . . . . .

(14) Abstract (should contain sufficient information for a reader to determine the value of the program). Listed on the reverse side of this form are subjects which may serve as a guide for a descriptive abstract.

SPLA 1001 Revised 11-76

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Abstract is attached.

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TITLE: USER's MANUAL FOR PROGRAM CAPTURE

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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 quite lengthy, and in most cases, nearly impossible without a computer. Therefore to provide methods of population estimation useful to the biologist, a comprehensive FORTRAN computer program has been written to complement the Wildlife Monograph. The input to the program has been written in a free-form and natural syle to provide ease of use by unsophisticated computer users. This manual describes the input options. No output is demonstrated in this manual because numerous examples are available in Otis et al. (1978). A copy of the Wildlife Monograph is available from The Wildlife Society, Suite S176, 3900 Wisconsin Avenue, N.W., Washington, D.C. 20016.

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 are 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. The variety of model estimators and the hypothesis tests of the validity of the models make up the TASKs available in the program. These are summarized in Table 1, and fully explained 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. Optional parameter specifications are in brackets, while mutually exclusive options are placed in braces with default value underscored.

$$\text{TASK READ CAPTURES} \left\{\begin{array}{l}\underline{\text{XY REDUCED}}\\ \text{XY COMPLETE}\\ \text{NON XY}\\ \text{X MATRIX}\end{array}\right\} \text{OCCASIONS= [FILE=] [CAPTURES=] [SUMMARY]}$$

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=]

$$\text{TASK POPULATION ESTIMATE} \left\{\begin{array}{l}\text{ALL}\\ \text{APPROPRIATE}\\ \text{NULL}\\ \text{JACKKNIFE}\\ \text{REMOVAL}\\ \text{DARROCH}\\ \text{ZIPPIN}\end{array}\right\} \text{[OCCASIONS=]}$$

Table 1a. Continued.

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

From 2 to 8 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. 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.'

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

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. An example is

TASK READ CAPTURES OCCASIONS=10 ,

which 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.

The 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 estimating density. Also, obviously, the captures must be read in before any of the TASKs requiring this data can be executed.

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

INPUT AND ERRORS LISTING .

Each input card is listed with

INPUT---

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

Errors are printed immediately after the input statement which caused an error to be detected. Often, however, an earlier statement may have actually caused the error, but it was undetected until the time of listing. The errors and warnings printed in the INPUT AND ERRORS LISTING generally only concern program input statement. Errors due to poor data (such as no recaptures) are printed in the output from the TASK.

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

SUCCESSFUL EXECUTION

This message indicates to the user that the program terminated normally. However, the message 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 are listed 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 which the user probably does not require. Hence file 7 should be a dummy print file. Capture data may be read from all but these files.

Comments

The user may punch comments on any of the input cards to the program in the space that remains after all of the necessary options and parameters have been set. One should not use any of the reserved words which specify information to the program because these may be picked up unintentionally as instructions. The reserved words are those listed in Table 1b.

Specific Format of Each Task

TITLE=

The TITLE= card can be thought of as a TASK card without the word TASK. Its purpose is to provide a title to be printed at the top of each page of output. The title on the output may be changed by placing a TITLE card directly prior to a TASK card.

The 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 one 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 the capture histories of each animal are coded on cards in one of the four allowable methods discussed below. If density estimates are required, the coordinates of each trap at which the animal was captured must be included, and hence the input slightly more complicated. The coordinates of the trap on the upper left corner of the grid should be (1,1). Note that coordinates of (0,0) are not permitted because zero values signify that the animal was not caught on this occasion. Two options are available for reading trap coordinates, XY COMPLETE and XY REDUCED. Option XY REDUCED is the default input format for the program, and therefore is generally the easiest to use. The general form of the XY REDUCED input on a card is *animal id, occasion 1, x-coordinate, y-coordinate, occasion 2, x-coordinate, y-coordinate, ...*

where *ocassion i* is the number of the trap 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 was caught. If an animal is caught only once, the *occasion, x-coordinate, y-coordinate* repetition is given only once, whereas for an animal caught three times, the repetition would be given three times. The remainder of the card is ignored after the first blank or zero set of coordinates and occasion number.

Note again that 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 (0,0) coordinates 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, an x and y coordinate is entered on the card only when the animal was captured, with each card representing a separate animal. When an animal is not captured on a particular occasion the columns are left blank. Hence for an animal only captured 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. All analyses can be computed except density estimates. 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 maximum number of occasions that an animal is captured is determined by the OCCASIONS= parameter, to be discussed later. The remainder of the card is ignored when the first blank or zero occasion is encountered.

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

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

The number of trapping occasions is determined by the OCCASIONS= parameter.

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

OCCASIONS= 7 .

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

The other two parameters which can be specified for this TASK concern the raw capture data input file. The raw data is assumed to be read from file 4 (logical unit 4) with the default format of (A3, 12(3F2.0)). This 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 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 only used 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, i.e.,

TASK READ CAPTURES OCCASIONS=10 SUMMARY .

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

Two additional cards may be included after the TASK READ CAPTURES card. The first to be discussed (they may be in either order) will be the FORMAT= card because it has been alluded to above. The FORMAT= card defines the format with which to read the captures. The format is put in quotes. An example is

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

This format corresponds to the default used in the program. Any of the ANSI FORTRAN IV format conventions may be used. The interpretation of the format will depend on which of the input options is being used. The animal identification must be in A format with the maximum number of columns allowed depending 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 with an 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. This parameter is used to specify 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 may specify general information about the run, whereas the three DATA= cards would specify information specific to the individual grids.

The above descriptions are abstract without examples so some specifics will now be discussed. First consider an example of the XY REDUCED option with all the defaults. The input is listed in Table 2. This listing 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 practice is not recommended. Multiple cards with the same animal identification will not cause problems--but the second card will override the first if there is a conflict.

In Table 3 a second example of the XY REDUCED option in given. Here all parameters are specified to illustrate input for which none of the defaults apply.

Table 2. Example of TASK READ CAPTURES with all the defaults 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. Example of TASK READ CAPTURES with XY REDUCED option set, 5 captures per card, with input from file 1. Note that the 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 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
```

In Table 4 an example of the XY COMPLETE option is provided. A non default 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.

In Table 5 an example of the NON XY option input is given. 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 ocassion 7.

In Table 6 and example of the X MATRIX option in given. The first four columns are the animal identification.

The TASK produces a small summary table of output on the INPUT AND ERRORS listing. The number of trapping occasions, the number of different animals captured, and the maximum x and y coordinates are printed. These values will help the user determine if the input was correctly coded because mispunched cards will often cause irregular x and y coordinates.

Table 4. Example of TASK READ CAPTURES with XY COMPLETE option set, and with 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)/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 non default 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 non default 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:

```
A00110110110
A00210110110
A00310000011
A00401100111
A00501000000
A00600010000
A00700010100
A00800000111
```

TASK CLOSURE TEST

This TASK determines whether the assumption of population closure can be made based on 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= are all the trapping occasions. As an example suppose that a grid was trapped for 12 days. Then when TASK CLOSURE TEST is run with the default value, OCCASIONS=1-12. Suppose, however, the biologist wants to look at the assumption of closure for only the first six days. Then the input would be TASK CLOSURE TEST OCCASIONS=1-6.. Note that no embedded blanks can appear around the equals, because a blank signifies the end of the specification. Note the OCCASIONS= parameter is used in TASK READ CAPTURES to specify the number of trapping occasions. It is a single valued parameter. In this TASK, and in the remainder of 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 values will be specified with no embedded blanks. Hyphens will indicate "thru" so that OCCASIONS=1-5 means the numbers 1, 2, 3, 4, 5. Slashes indicate "by", so that OCCASIONS=1-9/2 means the series 1, 3, 5, 7, 9, i.e., 1 through 9 by 2's. Commas can also be used to separate sequences of numbers, so that OCCASIONS=1-5,9-10,10 means the series 1, 2, 3, 4, 5, 9, 10, 12.

TASK MODEL SELECTION

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

TASK POPULATION ESTIMATE

Populations estimates are computed by this task for data read by TASK READ CAPTURES. The estimators desired are specified by five keywords: NULL, JACKKNIFE, DARROCH, REMOVAL and ZIPPIN. Any or all of these keywords may be specified. If all of these are desired, the keyword ALL may be used. Ususally the biologist is unsure of which estimator is appropriate until after he has seen the hypotheses testing output. To avoid multiple runs, the keyword APPROPRIATE may be used, and will then indicate to the program to calcualte the estimator selected in TASK MODEL SELECTION. Of course, the TASK MODEL SELECTION must have been run for the grid currently being analyzed. Also, other estimators may be specified along with APPROPRIATE, i.e.

TASK POPULATION ESTIMATE APPROPRIATE NULL .

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

The NULL estimator is that derived under Model M_o in Otis et al. (1978). It is described as null because none of the three 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 under Model M_{bh}. The ZIPPIN estimator is a special case of the REMOVAL estimator, and was derived under Model M_b in Otis et al. (1978).

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

TASK UNIFORM DENSITY TEST

This TASK tests the homogeneity of the distribution of captures over the grid read by TASK READ CAPTURES. A matrix of captures by trap station is printed to allow the user to see possible trends in density across 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 with the same usage and format described in 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.

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

Two parameters must also be specified on the TASK card. The first is TRAP INTERVAL= , which 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 to shorten the specification, INTERVAL=15. The default is INTERVAL=15.

The second parameter is used to convert from linear distance to area. It is UNITS CONVERSION= , or a shorter form CONVERSION= . For example if we assume 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, UNITS CONVERSION=43560 would be used, i.e., 43560 ft^2 = 1 acre. The default is CONVERSION=10000.

Grid definition cards follow the TASK card. Each card must specify values for two parameters: X= determines the range of x-coordinates for the grid, and similarly for Y= . There can be no embedded blanks in the specification. To illustrate the card

X=5-9 Y=3,8

specifies a 4 x 4 grid with lower left corner at (5,3). Note that either a hyphen or a comma may be used to separate the values. Labels for the grids punched on the card, such as INNER, MIDDLE, OUTER, etc., are useful to help with interpretation of the output and will not interfere with the parameter specification. An optional parameter on each grid card is the OCCASIONS= parameter, identical to the previous use in TASK CLOSURE TEST.

Up to eight grids may be specified. The order in which the grid cards appear is not important, although if they are ordered by increasing grid size the output is much 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 not consistent with this pattern if the grid cards are ordered.

The last card required is the

END OF GRID DEFINITIONS

card. This signifies the end of the input cards required by this TASK. In addition, two optional parameters may be specified on this card. These are DENSITY= and STRIP=, to be used to set the initial values for density and strip width needed to solve the density estimation problem. Either or both may be set. Initial values should probably be provided when the user has a good idea of 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.

An example of input for the TASK DENSITY ESTIMATE is given in Table 7. The grid is a 15 x 15 trap grid, with 30 feet 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, the units conversion is specified as 43560. All five population estimators are to be used. Three nested grids are used, with the largest grid being the total. Default values are to be 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 an option with five choices: NULL, JACKKNIFE, REMOVAL, DARROCH, and ZIPPIN. Only one of these key words 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. Note taht this TASK does not need to follow TASK READ CAPTURES because the capture data are not used. The user is assumed to have already summarized the statistic for the estimator desired.

Each estimator requires a different statistic and hence the input depends on the option specified. However common to all five options is identifying information which may be 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.

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
```

The minimal sufficient statistic for the NULL estimator is {n. , M_{t+1}} (notation from Otis et al. 1978). For this estimator only one special card is needed, with t, n., 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. and M_{t+1} on this card is important, although the indentifying 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, ..., f_t}. The value of t is given on the first card, with the f_j's on the second. Only values for f_j up to the last non-zero value need be punched as the program assumes any remaining undefined values are zero. This feature is illustrated in Table 7, where t is equal to 11, but only 9 f_j values are punched: f_{10} and f_{11} are assumed zero.

The minimal sufficient statistic for the REMOVAL estimator is {u_1, u_2, ..., 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, as they are assumed zero. Note that either commas or blanks were used to separate the u_j's in Table 8. The 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, ..., 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 ($j = 1, ..., t$) are punched on the second card. The program checks 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

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
```

density estimate. This method is much less desirable than computing density from the x and y coordinates because the covariance matrix used to weight the naive densities is a function of strip width. Hence 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 known, then 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 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 appears as

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(3,3) V(3,3)
⋮	⋮	⋮	⋮
Y_k,	a_k,	b_k,	V(k,1), V(k,2), ..., V(k,k)

An example is shown in Table 9.

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 (1977).'
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

The user can simulate a mark recapture experiment using this task. As described in Otis et al. (1978), simulation may be valuable in determining sample sizes needed, or determining what effect not meeting an assumption has on an estimator.

Tables 17 to 19 in Otis et al. (1978) were generated using TASK SIMULATE and provide the user with an idea of the output. This task requires a great deal of input. On the task card, four parameters may be set. First, the SEED= parameter sets the value of a random integer to be used as a starting value to generate random numbers between zero and one. Although this seed is usually 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 a maximum value of 1000 allowed. OCCASIONS= specifies the number of trapping occasions (default is 7, with maximum of 31). Also, a third limitation is that POPULATION times OCCASIONS must be less than 4000. REPLICATIONS= specifies the number of experiments (replications) to be simulated (default of 50, no maximum). The number of replications will determine the confidence that the user can have on the output, i.e., how precise the estimates are. These parameters may be specified in any order. In addition, a PRINT option sets a switch which causes the complete output for each experiment to be printed. Hence 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 may be printed when REPLICATIONS is large. PRINT should not be used for more than 10 replications. If PRINT is not specified, then only the table of summary statistics for the simulations will be printed. This table requires only one page of output--no matter how large REPLICATIONS is. However, the amount of time required will become larger as REPLICATIONS is increased. As a rule of thumb, 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 are available for this purpose. The HETEROGENEITY= card specifies a number of individuals followed by their probability of capture, followed by (optionally) a second number of individuals with their associated probability of capture, and so on. An example is

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

In this example, 50 animals have 0.5, 65 have 0.3, and 35 have 0.1 probability of capture. This specifies a total of 150 animals in the population, and this value must equal the value specified for POPULATION= on the task card. If only the above card is used to provide capture probabilities, then Model M_h experiment will be conducted. Note 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 POPULATIONS=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
```

then 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 had 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 two 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. As an 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 either have a recapture probability of (1.5)(0.4) = 0.6, or else (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.

Finally we will discuss an example 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 as 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 else (0.8)(0.5)(1.3) = 0.52

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

Specification 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.

Technical Details of Program

Run Costs

A typical run with the program is to read in a data matrix of 100 animals and 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. This run costs approximately $1.50 on the Utah State University Burroughs 6700, taking about 10 seconds of computer processor time.

Program Size

The program consists of a main routine and approximately 49 subroutines, depending upon what machine the program is being run and the intrinsic functions available. In addition, there are seven common blocks. Comment statements

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
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

are included to aid in following the program flow. The total code consists of approximately 6000 cards. Core 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

The dimensions on the program are presently 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

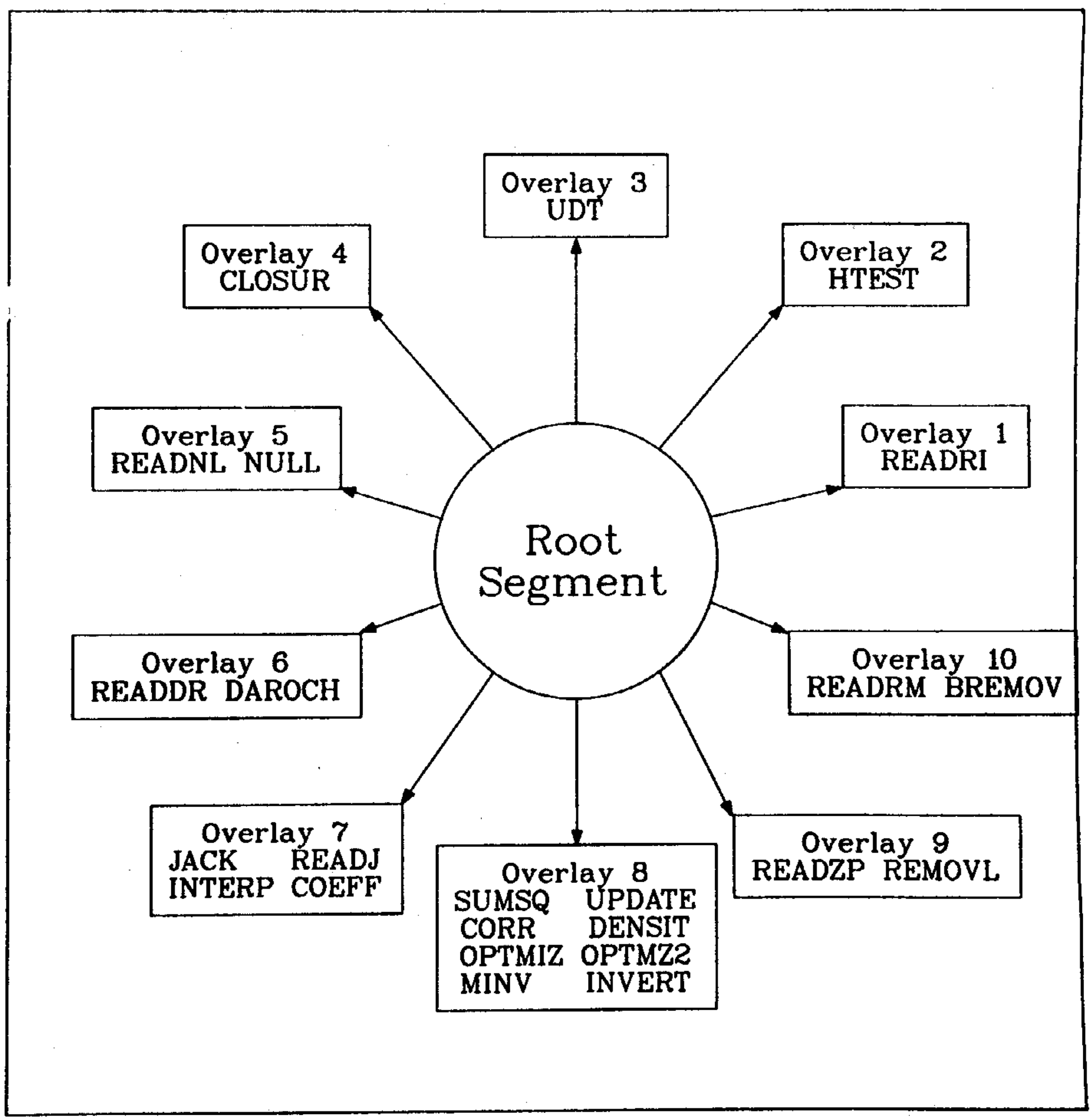
The program is written in ANSI FORTRAN IV with several small exceptions so that it will function on most brands of digital computers. FORTRAN statements known to cause problems with a particular FORTRAN compiler are marked with a comment statement. This feature is described in detail by comments in the program and will be useful for converting the program. The present version has been compiled and executed on Burroughs, CDC, and IMB machines. In addition, comment statements reflect changes required for Univac, Honeywell, Xerox, and DEC.

A magnetic tape with the FORTRAN code and 14 sets of example data are available from

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

at a cost of $____. 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.

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



Overlay 3
UDT
Overlay 4
CLOSUR
Overlay 2
HTEST
Overlay 5
READNL NULL
Overlay 1
READRI
Root
Segment
Overlay 6
READDR DAROCH
Overlay 10
READRM BREMOV
Overlay 7
JACK READJ
INTERP COEFF
Overlay 8
SUMSQ UPDATE
CORR DENSIT
OPTMIZ OPTMZ2
MINV INVERT
Overlay 9
READZP REMOVL

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