APPENDIX A
FORTRAN 77 USER'S MANUAL FOR PROGRAM CAPTURE

INTRODUCTION

The computations necessary to calculate many of the capture-recapture population estimates we have described are lengthy and essentially impossible to perform without a computer. Therefore, we have written a FORTRAN computer program to complement this primer. Input to the program was written in a free-form and natural style to provide ease of use by the computer users. The major program input options are described here, and a complete user's manual is provided in *White et al. (1978)* for earlier versions of CAPTURE. The material in this appendix is applicable to ANSI FORTRAN 77 versions of CAPTURE dated 1980 or later, and except for the file-naming conventions, everything in *White et al. (1978)* applies equally to ANSI FORTRAN 77 versions of CAPTURE. In addition, several modifications have increased the capabilities of the program. The main reason for changing the program was to provide greater portability between machines.

Overview of Program Input

The basic unit of the program is a TASK. TASK, a reserved word in the program input, specifies 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 available TASKs. TASKs are summarized in Table A.1a; reserved words and phrases for the CAPTURE program are listed in Table A.1b.

As a simple example of input to program CAPTURE, consider the job stream shown in Table A.2. This CAPTURE run would analyze the X_{ij} matrix shown in Table 3.1. The TITLE card specifies a title to be printed on each page of output. TASK READ CAPTURES specifies 6 columns in the X matrix, and the data make up an X_{ij} matrix of zeros and ones. The DATA statement specifies an identifier for the particular data set, also printed on each page of output for this data set. The FORMAT card specifies the X_{ij} matrix format on the file CAPTDT. In this case, the first three columns of the data set are the animal identification, read with the A3 format. Then three columns are skipped. The six columns of the X_{ij} matrix are read with the (3X, F1.0) specification, repeated six times. TASK MODEL SELECTION causes the model selection procedure to select the model best fitting this data set, and the TASK POPULATION ESTIMATE card produces a population estimate for the APPROPRIATE model as determined by the model selection procedure.

Many TASKs require only one input card, for example, the following.

TABLE A.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 if a default exists.

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'
READ INPUT DATA

TASK CLOSURE TEST [OCCASIONS=]
TASK MODEL SELECTION [OCCASIONS=]
TASK UNIFORM DENSITY TEST [OCCASIONS=]

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

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 SIMULATE [SEED=] [POPULATION=] [OCCASIONS=] [REPLICATIONS=] [PRINT] &
{ NULL / JACKKNIFE / REMOVAL / DARROCH / ZIPPIN } [MATRIX]

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 A.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
READ INPUT DATA	

TASK MODEL SELECTION

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

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 is TASK DENSITY ESTIMATE, which requires one card for each grid to specify the grid's dimensions and location.

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. The captures must be read in before any of the TASKs that require these data can be executed.

INPUT AND ERRORS LISTING

is a listing at the beginning of the program, made of the input cards as they are read. Each input card is

TABLE A.2. The input cards needed for program CAPTURE to analyze the X_{ij} matrix in Table 3.1. The data (X matrix) is located on file CAPTDT, while CAPTURE reads instructions from the file CAPTIN.

INSTRUCTIONS read from file CAPTIN

```
TITLE='ANALYSIS OF X MATRIX TAKEN FROM TABLE A.2'
TASK READ CAPTURES OCCASIONS=6 X MATRIX
DATA='X MATRIX FROM TABLE 3.1'
FORMAT='(A3,3X,6(3X,F1.0))'
TASK MODEL SELECTION
TASK POPULATION ESTIMATE APPROPRIATE
```

CAPTURES read from file CAPTDT

1	1	1	1	1	0	0
2	1	0	0	0	0	0
3	1	0	1	0	0	1
4	1	0	0	0	0	1
5	1	0	0	0	0	0
6	1	1	0	0	0	0
7	1	1	0	0	0	0
8	1	0	1	0	1	1
9	1	0	0	0	1	0
10	1	1	1	0	0	0
11	1	0	0	0	0	0
12	1	0	0	0	0	0
13	1	0	0	1	0	0
14	1	0	0	1	1	0
15	1	0	1	0	0	0
16	1	0	1	0	0	0
17	0	1	0	0	0	1
18	0	1	0	0	0	1
19	0	1	0	0	1	0
20	0	1	0	0	0	0
21	0	1	1	1	0	1
22	0	1	0	0	1	1
23	0	1	0	0	1	0
24	0	0	1	0	1	0
25	0	0	1	0	0	0
26	0	0	1	0	0	1
27	0	0	1	0	0	0
28	0	0	1	1	0	0
29	0	0	1	0	1	0
30	0	0	1	0	0	1
31	0	0	1	0	0	1
32	0	0	0	1	0	0
33	0	0	0	1	0	0
34	0	0	0	1	0	0
35	0	0	0	1	0	1
36	0	0	0	1	0	0
37	0	0	0	1	0	1
38	0	0	0	1	1	0
39	0	0	0	1	1	1
40	0	0	0	1	0	0
41	0	0	0	0	1	0
42	0	0	0	0	1	0
43	0	0	0	0	1	1
44	0	0	0	0	1	1
45	0	0	0	0	0	1
46	0	0	0	0	0	1
47	0	0	0	0	0	1

listed with

INPUT————

in front of the statement to separate it from the errors and warnings that also are printed. Warnings provide the default values of parameters not specified on the preceding card, and when an option is 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 caused the error, it may not be 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 that the program terminated properly, it does not mean that all TASKs were executed. An error on a TASK card may have caused that TASK to be skipped.

Reserved Files. The program requires that instructions be read from the file CAPTIN. The default data input file is assumed to be CAPTDT. Output is printed on the file CAPTLP.

These file conventions apply to versions of CAPTURE written in ANSI FORTRAN 77 and not to the older FORTRAN IV versions. If the version of CAPTURE available at your computer center is dated before 1980, see *White et al. (1978)* for a description of the files needed and used by CAPTURE.

Continuations. Any card may be continued by putting an ampersand (&) as the last nonblank character on the previous card. Up to two continuations may be used, for a total of 240 characters of input.

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. Any words but the reserved words given in Table A.1b may be used. The reserved words, which specify information to the program, should not be used because they may be unintentionally read as instructions.

Specific Task Formats

(1) 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 quotation marks as in the following example.

TITLE='PUT YOUR INFORMATION HERE'

Note that there are no embedded blanks between the key word TITLE, the equals 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.

(2) TASK READ CAPTURES

This task reads the raw data (the X_{ij} matrix) required to select a model, estimate population size, and so on. The program assumes that the capture histories of the animals 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, a process that complicates the input slightly. The coordinates of the trap on the upper left corner of the grid should 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 is easier to use than XY COMPLETE. The standard input of the XY REDUCED option is

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

where *occasion 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 in which the animal was caught. 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 or reflected (or both). 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 will 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 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 7 days and the traps were checked daily, the parameter would be set as follows.

OCCASIONS=7

Note that there can be no embedded blanks because the program is scanning for the end of specification, signified by the first blank. This limitation is true for all parameter specifications in the program. Remember that there can be no blanks between the key word, the equals sign, and value specification.

The other two parameters that can be specified for this TASK relate to the raw capture data input file. The raw data are assumed to be read from file CAPTDT, using the default format (A3, 12(3F2.0)), which means that only one set of population data can be read per run, unless a multifile data set is used. Hence, with the FILE='name' parameter, files other than file CAPTDT can be read, and multiple sets of data

can be analyzed in one run. The examples provided with the program assume that a multifile data set will be used with file CAPTDT. Note that if your version of CAPTURE is dated before 1980, a different file-handling system is used, and you must follow the instructions given in *White et al. (1978:11)*.

The CAPTURES= parameter specifies the number of captures per card. The default value is the number of occasions specified if the number is 12 or less, 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 on the TASK READ CAPTURES cards, as follows.

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

The program will 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.

Three optional cards may be included after the TASK READ CAPTURES card. The first is the FORMAT= card, which defines the format with which to read the captures. The format is put in quotes as in the following example.

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

This format corresponds to the default used in the program, although any of the ANSI FORTRAN 77 format conventions may be used. Format interpretation will depend on which input option is used. Animal identification must be in the A format, and the maximum number of columns allowed depends on the word size of the computer. For example, IBM, DEC-VAX, and Xerox computers allow 4 characters per word; Burroughs, Univac, and Honeywell computers allow 6; and CDC computers allow 10. The x,y coordinates and the occasion number must be read in F format for all 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. The order in which FORMAT= and DATA= cards appear is not crucial—either may precede the other.

The third optional card (and always the last) is READ INPUT DATA. Often the user does not want to have a separate data file for the X_{ij} matrix, but would prefer to read the captures from the input file CAPTIN. If the card READ INPUT DATA is encountered as the last card in the TASK READ CAPTURES input, the X_{ij} matrix cards are assumed to follow. Data will be read from file CAPTIN until a TASK or TITLE= card is encountered. This method of inputing data does not require that FILE= be specified. Note, however, that a program abort will occur if the first nondata card is not a TASK or TITLE= card.

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 A.3 represents the simplest form of the TASK READ CAPTURES statement. Although listing the entries for each occasion on which an animal was captured in chronological order is not mandatory, we suggest that you order them this way. Multiple cards with the same animal identification will not cause problems, but if there is a conflict, the second card will override the first.

Table A.4 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 A.3. Example of TASK READ CAPTURES with all the default values taken.

INSTRUCTIONS read from file CAPTIN

```
TITLE='EXAMPLE INPUT FOR TABLE A.3'
TASK READ CAPTURES OCCASIONS=8
```

CAPTURES read from file CAPTDT

```
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 A.4. Example of TASK READ CAPTURES with XY REDUCED option set, five captures per card, with input from file MATRIX. Animal identification appears in columns 73-76.

INSTRUCTIONS read from file CAPTIN

```
TASK READ CAPTURES XY REDUCED FILE='MATRIX' OCCASIONS=8 CAPTURES=5
DATA='EXAMPLE INPUT FOR TABLE A.4'
FORMAT='(72X,A4,T1,5(F2.0,2F3.0))'
```

CAPTURES read from file MATRIX

```
 1  5  2 3  7  1 4  8  1 6  6  2 7  7  1                A001
 1  4  3 3  6  2 4  6  2 6  3  4 7  1  1                A002
 1  8  3 7  8  1 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 A.5 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 A.6 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 specifies that it was also caught on occasion 7.

Table A.7 gives an example of 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 captured, and the 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 A.5. Example of TASK READ CAPTURES with XY COMPLETE option set and multiple cards per record. The captures are read from CAPTIN with the READ INPUT DATA card. The TASK CLOSURE TEST stops the reading of CAPTURES.

INSTRUCTIONS read from file CAPTIN

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

TABLE A.6. Example of TASK READ CAPTURES with the NON XY option set. A nondefault file of MYDATA and the default format are used.

INSTRUCTIONS read from file CAPTIN

```
TASK READ CAPTURES NON XY OCCASIONS=8 FILE='MYDATA'
DATA='EXAMPLE INPUT FOR TABLE A.6'
```

CAPTURES read from file MYDATA

```
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
```

(3) TASK CLOSURE TEST

The TASK CLOSURE TEST helps to determine 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 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 investigator wants to look at the assumption of closure for only the first 6 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 the TASK CLOSURE TEST and in the rest of the TASKs where OCCASIONS= will be used, a multiple-valued parameter is 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.

(4) TASK MODEL SELECTION

This TASK computes the sequence of hypothesis tests described in Chapter 3. It is used to determine which population estimator should be used. The data are those captures read by TASK READ

TABLE A.7. Example of TASK READ CAPTURES with the X MATRIX option set. The READ INPUT DATA card signifies to read all the cards up to the next TASK or TITLE = card.

```
INSTRUCTIONS read from file CAPTIN

TASK READ CAPTURES X MATRIX OCCASIONS=8
FORMAT='(A4,8F1.0)'
DATA='EXAMPLE INPUT FOR TABLE A.7'
READ INPUT DATA
A00110110110
A00210110110
A00310000011
A00401100111
A00501000000
A00600010000
A00700010100
A00800000111
TASK MODEL SELECTION
```

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.

(5) TASK POPULATION ESTIMATE

This TASK computes population 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, as shown below.

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 Chapter 3, is described as null because none of the three possible sources of variability is 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, is derived from Model M_b in Chapter 3.

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

(6) 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, a chi-square test is constructed, and the grid is then collapsed by columns. This TASK also has the OCCASIONS= parameter. Its use and format are identical 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.

(7) TASK DENSITY ESTIMATE

This TASK computes an estimate of animal density based on the method presented in Chapter 5. An option, several parameters, and additional specifications 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=. It specifies the distance between traps for the grid. For example, if traps are set on a 15-m grid system, TRAP INTERVAL=15 or 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, UNITS CONVERSION=43560 would be used; that is, 43 560 ft^2 = 1 A. The default is CONVERSION=10000. As a final example, if traps were placed 30.5 m (100 ft) apart, but density is to be in hectares, the interval is entered in meters, INTERVAL=30.5, and the default of CONVERSION=10000 is used.

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 5 by 6 grid with lower left corner at (5,3). Either a hyphen or comma (but not a blank) may be used to separate the values. Labels for the grids punched on the card, such as INNER, MIDDLE, OUTER, and so on, help to interpret the output and will not interfere with the parameter specification. Each grid card has the optional OCCASIONS= parameter, the use and format of which are identical to those described in the TASK CLOSURE TEST.

As many as 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. 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 by increasing size.

The last card required is the

END OF GRID DEFINITIONS

card, which specifies the end of the input cards required by this TASK. In addition, two optional parameters, DENSITY= and STRIP=, may be set to provide 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 with default values. Default values are calculated from the data, but will not always be close to the final values.

Table A.8 gives an example of input for the TASK DENSITY ESTIMATE. The trap grid is 15 by 15, with 30 ft 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 for initial values of density and strip width.

(8) TASK SIMULATE

This task is used to simulate a capture-recapture experiment. As described in Chapter 7, a simulation may be used to determine the sample sizes needed, or the effect that not meeting an assumption would have on an estimator.

Tables 17-19 in *Otis et al. (1978:60-62)*, generated by using TASK SIMULATE, provide the user with an example of the output. This task requires much input. Five 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 5- or 7-digit odd integer usually will 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. 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. The 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. The default value is 50, with 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.

TABLE A.8. Example input for TASK DENSITY ESTIMATE. TASK READ CAPTURES must have already been executed.

INSTRUCTIONS read from file CAPTIN

```
TITLE='EXAMPLE INPUT FOR TABLE A.8'
TASK DENSITY ESTIMATE INTERVAL=30 FEET CONVERSION=43560 ALL
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
```

In addition, a PRINT option sets a switch that results in a complete printed output for each experiment. 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 can be expected to provide some useful information. If PRINT is specified, the option X MATRIX may also be specified to have the X_{ij} matrix listed in the output.

The sixth option that may be set in the TASK SIMULATE card preselects one of the five estimators: NULL, JACKKNIFE, REMOVAL, DARROCH, and ZIPPIN. Only one estimator may be preselected. Normally, TASK SIMULATE selects the appropriate estimator based on the results of TASK MODEL SELECTION. By specifying one of the five estimators, the user is telling TASK SIMULATE not to use TASK MODEL SELECTION, but to go directly to the estimator specified to obtain an estimate. Should the user want to compare two estimators for the same sets of data, two TASK SIMULATE runs must be made, both with the same seed specified.

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, as in the following example.

```
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 first-capture probability of 0.5, and 100 animals have first-capture probability of 0.3. However, recaptures are influenced by the values on the BEHAVIOR= card. In this example, all 200 animals will have recapture probability of 1.5 times their first-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. The input

```
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, on occasion 2 is 0.5, and so on. 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 a first-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 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 is one in which all three types of cards are used to simulate a Model M_{tbh} experiment. The input

```
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
```

means that 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 on capture probabilities on the first occasion because none of the animals are recaptured. However, on 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 it is in the first or third group of 50 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 A.9.

Specifications for Model M_o can be accomplished in two ways. Both of the following TASKs specify a constant capture probability of 0.5 for the entire population and request that the NULL estimator be selected.

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

Other Tasks

Several other tasks listed in *White et al. (1978)* are not described in this Appendix. The FORTRAN 77 version of CAPTURE supports them, but we do not encourage their use.

TABLE A.9. 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	--
150-200	(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[a]
101-150	(0.9)(0.5)=0.45	(0.9)(0.5)(0.75)=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

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