

MSSURVIV User's Manual

James E. Hines
USGS, Patuxent Wildlife Research Center
12100 Beech Forest Rd
Laurel, MD 20708

email: jhines@usgs.gov

Introduction

Program MSSURVIV (Multi-State-SURVIVal analysis) computes parameter estimates of survival/transition and capture probability under the multistate models described in "Capture-recapture Studies for Multiple Strata including non-Markovian Transition Probabilities" (Brownie et. al., 1993). Actually, MSSURVIV is a specially modified version of Dr. G. White's program SURVIV (White, 1983) which incorporates the multistate models. With this program and it's companion program, CNVMEMOV, users are able to get parameter estimates for these complex models from capture-history data without having to specify the cell probabilities.

MSSURVIV is intended to be used in a situation where one is interested in not only survival and capture probabilities, but also transition probabilities (the probability of moving from one stratum to another). The strata may be defined as any discrete categories to which captured animals can be assigned at any given time. For example, strata may be based on such factors as capture location or individual variables such as breeding status or weight class. This situation may be thought of as a more general Jolly-Seber model where a matrix of survival/transition probabilities replaces a single survival rate and a vector of capture probabilities replaces a single capture probability. Output from MSSURVIV includes survival/movement probability estimates, capture probability estimates, goodness-of-fit tests, and likelihood-ratio tests. Estimates may be computed under the "Markovian" models or the "Non-Markovian/memory" models. The Markovian models assume that survival/transition probabilities of an animal depend on the stratum in which the animal is located at the beginning of the interval. The parameters under these models would be a matrix of survival/transition probabilities and a vector of capture probabilities for each time-period. Optionally, MSSURVIV may be instructed to decompose the combined survival/transition probabilities into separate survival and transition probabilities. Non-Markovian models assume that survival/transition probabilities for the interval (i , $i+1$) depend not only on stratum at time i , but also on stratum at $i-1$. These models produce much larger matrices of parameter estimates than Markovian models.

By default, three models are generated for either of these two model-sets. The three models are analogous to Models "D", "B", and "A" produced by program JOLLY for standard Jolly-Seber analysis (Pollock et. al., 1990). Model "D" computes estimates under the assumption that survival/transition probabilities and capture probabilities are constant over time. Model "B" assumes survival/transition probabilities are constant over time, but capture probabilities are time-dependent. Model "A" assumes both survival/transition and capture probabilities are time-dependent. If necessary, users may examine these models to generate statements for their own models.

The experimental situation to which this program applies is one in which animals are initially marked with a unique tag, and released. This process is repeated for each of the sampling periods. Information used to assign the animal to the proper stratum (eg. sex, weight, age, capture location, ...) is recorded for each capture of each animal. Using these data, the capture-history of each animal is generated consisting of codes indicating the status of the animal at each capture period. For example, if an animal were captured in stratum A in time-period 1, not captured in periods 2 and 3, and captured in stratum B in time-period 4, the capture history would be: "A 0 0 B". If the variable of interest is a

continuous variable, cutpoints must be defined to break it into discrete strata (eg., weight -> weight-class) before the capture-history records can be generated.

Input to MSSURVIV consists of statements which define the capture data and statements defining the selected model structure. The format of the input file is the same as for program SURVIV except that no cell probabilities need be given. The statements defining the data consist of the number of animals captured and released in each time-period and stratum, and the number next recaptured in each subsequent time-period and stratum. Statements which set parameters equal to other parameters define model structure.

Although MSSURVIV eliminates the need for specifying cell probabilities, the job of summarizing capture-history records and defining model structure can be very complicated and can lead to errors. Program CNVMEMOV was created to automate this process. CNVMEMOV reads as input the capture-history records and produces all of the statements necessary to run program MSSURVIV under the "Markovian" or "memory" model sets described above.

Using CNVMEMOV

To run CNVMEMOV, type CNVMEMOV at the DOS prompt and respond to the program prompts. When the program is run, the following should appear on the screen:

```
Program CNVMEMOV - Converts "Capture-history" data into
                    MSSURVIV input data
```

```
Date compiled: 1/23/98
```

```
Programmer: James E. Hines
            Biological Research Div., USGS
            11510 American Holly Dr. #201
            Patuxent Wildlife Research Center
            Laurel, MD. 20708-4017
            email: jim_hines%40usgs.gov
```

```
Version 2.0 - added capability for >2 age-classes
              added capability for >1 group
```

```
** Note: The order of age-classes in old version was
          ADULT followed by YOUNG. In this version
          the order must be from youngest to oldest.
** Also: The old version used "GROUP" as a synonym of
          "STRATA". (That was stupid!) In this version
          "STRATA" are the transitional states and
          "GROUPS" are the separate classification
          of animals to/from which animals cannot move.
          Examples of STRATA might be location,
          breeding-status, weight-class.
          Examples of GROUP might be sex, species.
```

After this informatory text is printed, CNVMEMOV attempts to open an output file called CNVMEMOV.OUT. This is the file which will contain the summarized data to be input to program MSSURVIV. If this file already exists (from a previous run) the program will ask if it is OK to overwrite this file. If "y" or "Y" is typed, CNVMEMOV will proceed. Any other response will abort the program.

```
*** Output file (CNVMEMOV.OUT) exists!, overwrite(Y/N)? Y
```

The next prompt is for the name of the input file containing the capture-history records. Respond with any legal filename, including drive and subdirectory if not in the current directory.

Enter the name of the file containing the capture-history records FILE:C:\MSSRV\SAMPLE.DAT

If the input file does not exist, CNVMEMOV will print an error message and abort. If it does exist, the first five lines of the file will be displayed on the screen. This helps the user find the column numbers needed for later prompts.

```
FILE:C:\MSSRV\SAMPLE.DAT
      1      2      3      4      5      6      7
....5....0....5....0....5....0....5....0....5....0....5....0
A000 491
A00A 15
A00B 12
A00C 11
A0A0 37
.....
```

The next prompt is for the number of strata and time-periods. The program requires that you enter two numbers separated by a comma, e.g.,

```
Enter the number of strata, time-periods, age-classes and groups:
STRATA,TIME-PERIODS,AGE-CLASSES,GROUPS(eg 3,7,1,1):3,4,1,1
```

In this example, there are 4 capture periods, 3 strata (designated A, B, and C), 1 age-class and 1 group. The next prompt is for the codes representing each stratum. These are the codes which represent each of the strata of capture in the capture-history records. Any character other than the ones in this list indicate that the animal was not captured in a time-period. Selected strata may be omitted from an analysis by not including them in the this list. Any single character may be used to represent each of the strata, e.g.,

```
Enter the codes representing each strata:
(If upper case in input file, type upper case here.)
STRATA CODES(no quotes or spaces- eg 123):ABC
```

CNVMEMOV will distinguish between lower and upper case characters for these codes, so it is imperative that these codes match the codes in the data file. If "abc" were entered instead of "ABC", none of the captures would be used.

The next prompt asks for the column numbers containing stratum codes for each time period. The first five lines of data have been listed previously to help locate the column numbers, e.g.,

```
If strata codes are in consecutive columns, enter the
column number of the first strata code,
Or enter 0 if they are not sequential
FIRST COLUMN OF STRATA CODES:1
```

The next prompt asks for the column number containing the fate on last capture. If the data set contains a field indicating whether animals were released or not released (e.g., dead in trap), the column number of this field would be entered here. If there is no such field in the data, enter 0 and it will be assumed that all animals were released on last capture. Any non-blank character in this column indicates that the animals were not released on last capture.

```
Enter column number containing fate on last capture, or
0 if all captured animals were always released.
Note: Any non-blank character in this column is
interpreted as indicating that the animal was
not released
FATE COLUMN:0
```

If more than one group was specified in the earlier prompt, the next prompt would ask for the column number containing the group of the animals. If the data set contains a field indicating a group the

animals belong to, (e.g. sex, size), the column number of this field would be entered here. As with the strata codes, upper/lower case is significant here.

Enter the column number containing the GROUP code,
GROUP COLUMN:
Enter groupe-codes
(eg. MF for male, female)
GROUP-CODES:

The next prompt is for the starting column of a frequency variable. If the capture-histories are summarized, the data will contain a frequency variable for each capture-history and the starting column is entered here. If the data are not summarized (i.e., one record per animal), enter 0 for the starting column, e.g.,

Enter starting column of cap-history frequency, or
0 if capture-histories are not summarized.
STARTING COLUMN:6

If a number greater than zero is entered for the frequency starting column, CNVMEMOV will prompt for the ending column of the frequency variable.

The next prompt is for the selection of model sets to be run with MSSURVIV. One or both of the model sets may be chosen, e.g.,

Enter 1 for the "MEMORY-MOVEMENT model set
2 for the "MOVEMENT-ONLY model set
3 for both model sets
4 for the "MOVEMENT-ONLY model set w/ S-M parameterization
MODEL SETS (1,2,3, or 4):4

In some cases, it is desirable to compute estimates in terms of separate survival rate and movement probabilities rather than with transition probabilities that include both survival and movement. If we assume survival from time i to $i+1$ does not depend on stratum in time-period $i+1$, then we can rewrite Φ_i^{rs} as $\Phi_i^{rs} = S_i^r \Psi_i^{rs}$, where Ψ_i^{rs} is the conditional probability that an animal in stratum r at time i is in stratum s at time $i+1$, given that the animal is alive at $i+1$. The sum of the survival/transition probabilities is equal to the survival rate (i.e., $\sum_s \Phi_i^{rs} = S_i^r$, where Φ_i^{rs} is the probability that an animal alive in stratum r at period i is alive and in stratum s at period $i+1$, and S_i^r is the probability that an animal in stratum r at time i is alive at period $i+1$.) In a k -stratum experiment, we can compute a survival rate and k movement probabilities for each stratum and time-interval from the k transition probabilities, Φ_i^{rs} . This computation may be done from the output for the movement-only model set, however the computation of variances would be very difficult. MSSURVIV can be instructed to treat survival rate and movement probabilities as separate parameters instead of combined transition probabilities in order to produce the desired estimates and variances. I have called this the "S-M parameterization" for the estimation of separate survival and movement parameters.

If the "MOVEMENT-ONLY model set with S-M parameterization" is chosen, CNVMEMOV will prompt for a stratum number. This number controls which movement probability is replaced by the survival probability in the output parameters. For the S-M parameterization, the $k \times k$ survival/movement estimates for each time-period will be changed to N survival estimates and $k \times (k-1)$ movement estimates. Since the sum of the movement probabilities for any cohort must equal 1.0, one of the movement parameters is not needed (i.e., it is obtained as 1 minus the sum of the others). Any of the k movement parameters may be omitted, however, the optimization routine in MSSURVIV works better if the parameters are not close to 0.0 or 1.0. For this reason, the best movement parameter to omit is the one closest to 0.0 or 1.0.

For the S-M parameterization, one of the 3 movement parameters must be replaced by the survival parameter. Choose 0 to replace the diagonal parameter (probability of returning to a stratum), or the index of one of the 3 strata.
Stratum (0 or 1-3)?3

By choosing 3, CNVMEMOV will produce the statements to cause MSSURVIV to use the "S-M parameterization" of the movement-only model set. Instead of a 3x3 matrix of survival/movement probability estimates, MSSURVIV will compute 3 survival rate estimates and 6 movement probabilities for each time period. The 9 parameters for time i are:

- S_i^A : probability of surviving from i to i+1 for animals captured in stratum A in time i,
- Ψ_i^{AA} : probability of remaining in stratum A at times i and i+1,
- Ψ_i^{AB} : probability of moving from stratum A in time i to stratum B in time i+1,
- S_i^B : probability of surviving from i to i+1 for animals captured in stratum B in time i,
- Ψ_i^{BA} : probability of moving from stratum B at time i to stratum A at time i+1,
- Ψ_i^{BB} : probability of remaining in stratum B at times i and i+1,
- S_i^C : probability of surviving from i to i+1 for animals captured in stratum C in time i,
- Ψ_i^{CA} : probability of moving from stratum C at time i to stratum A at time i+1,
- Ψ_i^{CB} : probability of moving from stratum C at time i to stratum B at time i+1.

The probability of moving from any stratum, X, to stratum C must be computed by subtracting the sum of Ψ_i^{XA} and Ψ_i^{XB} from 1.0.

The next prompt is for a title to appear on the output. Any string of characters (not including quotes) is acceptable as long as the length is less than 256, e.g.,

Enter a title to appear on the MSSURVIV output
TITLE(no quotes):MSSURVIV SAMPLE DATA (SAMPLE.DAT)

CNVMEMOV will output the number of records read and the total number of transitions. The total number of transitions can be used to determine if some of the strata need to be combined to help with convergence problems (See section on sparse data).

Here is the file created by CNVMEMOV which can be input to MSSURVIV:

```
PROC TITLE 'expected value data w/ 2 groups';
PROC MODEL NPAR=0036 ADDCELL NAGE=1 NYRS=04 STRATA=2 NGROUPS=2
  PHIMISS=2;
COHORT=1000;236;;102;;76;;79;;22;;42;;
COHORT=1001;0;;338;;0;;156;;0;;64;;
COHORT=1236;267;;114;;77;;80;;
COHORT=1440;0;;444;;0;;183;;
COHORT=1343;260;;111;;
COHORT=1793;0;;495;;
COHORT=1000;62;;41;;11;;18;;2;;7;;
COHORT=1001;0;;105;;0;;29;;0;;8;;
COHORT=1062;74;;50;;14;;23;;
COHORT=1146;0;;135;;0;;40;;
COHORT=1085;83;;56;;
COHORT=1232;0;;158;;
LABELS;
S(001)=MOV(01,A,M) AA ;
S(002)=SRV(01,A,M) A ;
```

```

S(003)=MOV(01,A,M) BA ;
S(004)=SRV(01,A,M) B ;
S(005)=MOV(02,A,M) AA ;
S(006)=SRV(02,A,M) A ;
S(007)=MOV(02,A,M) BA ;
S(008)=SRV(02,A,M) B ;
S(009)=MOV(03,A,M) AA ;
S(010)=SRV(03,A,M) A ;
S(011)=MOV(03,A,M) BA ;
S(012)=SRV(03,A,M) B ;
S(013)=p(02,A,M) A ;
S(014)=p(02,A,M) B ;
S(015)=p(03,A,M) A ;
S(016)=p(03,A,M) B ;
S(017)=p(04,A,M) A ;
S(018)=p(04,A,M) B ;
S(019)=MOV(01,A,F) AA ;
S(020)=SRV(01,A,F) A ;
S(021)=MOV(01,A,F) BA ;
S(022)=SRV(01,A,F) B ;
S(023)=MOV(02,A,F) AA ;
S(024)=SRV(02,A,F) A ;
S(025)=MOV(02,A,F) BA ;
S(026)=SRV(02,A,F) B ;
S(027)=MOV(03,A,F) AA ;
S(028)=SRV(03,A,F) A ;
S(029)=MOV(03,A,F) BA ;
S(030)=SRV(03,A,F) B ;
S(031)=p(02,A,F) A ;
S(032)=p(02,A,F) B ;
S(033)=p(03,A,F) A ;
S(034)=p(03,A,F) B ;
S(035)=p(04,A,F) A ;
S(036)=p(04,A,F) B ;
PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_D;
INITIAL; ALL= 0.500;
CONSTRAINTS;
S(005)=S(001) /* MOV(02,A,M) AA=MOV(01,A,M) AA */;
S(006)=S(002) /* SRV(02,A,M) A =SRV(01,A,M) A */;
S(007)=S(003) /* MOV(02,A,M) BA=MOV(01,A,M) BA */;
S(008)=S(004) /* SRV(02,A,M) B =SRV(01,A,M) B */;
S(009)=S(001) /* MOV(03,A,M) AA=MOV(01,A,M) AA */;
S(010)=S(002) /* SRV(03,A,M) A =SRV(01,A,M) A */;
S(011)=S(003) /* MOV(03,A,M) BA=MOV(01,A,M) BA */;
S(012)=S(004) /* SRV(03,A,M) B =SRV(01,A,M) B */;
S(015)=S(013) /* p(03,A,M) A =p(02,A,M) A */;
S(016)=S(014) /* p(03,A,M) B =p(02,A,M) B */;
S(017)=S(013) /* p(04,A,M) A =p(02,A,M) A */;
S(018)=S(014) /* p(04,A,M) B =p(02,A,M) B */;
S(023)=S(019) /* MOV(02,A,F) AA=MOV(01,A,F) AA */;
S(024)=S(020) /* SRV(02,A,F) A =SRV(01,A,F) A */;
S(025)=S(021) /* MOV(02,A,F) BA=MOV(01,A,F) BA */;
S(026)=S(022) /* SRV(02,A,F) B =SRV(01,A,F) B */;
S(027)=S(019) /* MOV(03,A,F) AA=MOV(01,A,F) AA */;
S(028)=S(020) /* SRV(03,A,F) A =SRV(01,A,F) A */;
S(029)=S(021) /* MOV(03,A,F) BA=MOV(01,A,F) BA */;
S(030)=S(022) /* SRV(03,A,F) B =SRV(01,A,F) B */;
S(033)=S(031) /* p(03,A,F) A =p(02,A,F) A */;
S(034)=S(032) /* p(03,A,F) B =p(02,A,F) B */;
S(035)=S(031) /* p(04,A,F) A =p(02,A,F) A */;
S(036)=S(032) /* p(04,A,F) B =p(02,A,F) B */;
PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_B;
INITIAL; RETAIN=MODL_D; CONSTRAINTS;
S(005)=S(001) /* MOV(02,A,M) AA=MOV(01,A,M) AA */;
S(006)=S(002) /* SRV(02,A,M) A =SRV(01,A,M) A */;

```

```

S(007)=S(003) /* MOV(02,A,M) BA=MOV(01,A,M) BA */;
S(008)=S(004) /* SRV(02,A,M) B =SRV(01,A,M) B */;
S(009)=S(001) /* MOV(03,A,M) AA=MOV(01,A,M) AA */;
S(010)=S(002) /* SRV(03,A,M) A =SRV(01,A,M) A */;
S(011)=S(003) /* MOV(03,A,M) BA=MOV(01,A,M) BA */;
S(012)=S(004) /* SRV(03,A,M) B =SRV(01,A,M) B */;
S(023)=S(019) /* MOV(02,A,F) AA=MOV(01,A,F) AA */;
S(024)=S(020) /* SRV(02,A,F) A =SRV(01,A,F) A */;
S(025)=S(021) /* MOV(02,A,F) BA=MOV(01,A,F) BA */;
S(026)=S(022) /* SRV(02,A,F) B =SRV(01,A,F) B */;
S(027)=S(019) /* MOV(03,A,F) AA=MOV(01,A,F) AA */;
S(028)=S(020) /* SRV(03,A,F) A =SRV(01,A,F) A */;
S(029)=S(021) /* MOV(03,A,F) BA=MOV(01,A,F) BA */;
S(030)=S(022) /* SRV(03,A,F) B =SRV(01,A,F) B */;
PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_A;
INITIAL; RETAIN=MODL_B; CONSTRAINTS;
S(017)=1.0 /* p(04,A,M) A */;
S(018)=1.0 /* p(04,A,M) B */;
S(035)=1.0 /* p(04,A,F) A */;
S(036)=1.0 /* p(04,A,F) B */;
PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=1GRP_A;
INITIAL; RETAIN=MODL_A; CONSTRAINTS;
S(019)=S(001) /* MOV(01,A,F) AA=MOV(01,A,M) AA */;
S(020)=S(002) /* SRV(01,A,F) A =SRV(01,A,M) A */;
S(021)=S(003) /* MOV(01,A,F) BA=MOV(01,A,M) BA */;
S(022)=S(004) /* SRV(01,A,F) B =SRV(01,A,M) B */;
S(023)=S(005) /* MOV(02,A,F) AA=MOV(02,A,M) AA */;
S(024)=S(006) /* SRV(02,A,F) A =SRV(02,A,M) A */;
S(025)=S(007) /* MOV(02,A,F) BA=MOV(02,A,M) BA */;
S(026)=S(008) /* SRV(02,A,F) B =SRV(02,A,M) B */;
S(027)=S(009) /* MOV(03,A,F) AA=MOV(03,A,M) AA */;
S(028)=S(010) /* SRV(03,A,F) A =SRV(03,A,M) A */;
S(029)=S(011) /* MOV(03,A,F) BA=MOV(03,A,M) BA */;
S(030)=S(012) /* SRV(03,A,F) B =SRV(03,A,M) B */;
S(031)=S(013) /* p(02,A,F) A =p(02,A,M) A */;
S(032)=S(014) /* p(02,A,F) B =p(02,A,M) B */;
S(033)=S(015) /* p(03,A,F) A =p(03,A,M) A */;
S(034)=S(016) /* p(03,A,F) B =p(03,A,M) B */;
S(017)=1.0 /* p(04,A,M) A */;
S(035)=1.0 /* p(04,A,F) A */;
S(018)=1.0 /* p(04,A,M) B */;
S(036)=1.0 /* p(04,A,F) B */;
PROC TEST; PROC STOP;

```

The output file, CNVMEMOV.OUT, contains a title statement, statements to define the input data, label definitions, statements to describe models, a test statement and a stop statement. The title statement is used to identify the data used in the analysis.

The model definition statements start with "PROC MODEL NPAR=0036 ADDCELL NAGE=1 NYRS=04 STRATA=2 NGROUPS=2 PHIMISS=2;" and end with "COHORT=1232;0;;158;; ". The "NPAR=36" indicates the maximum number of parameters (estimated or fixed) in any of the following models. In this example there are 4 (2x2) transition probability parameters for each of the 3 intervals (4 sample periods), giving 12 parameters per group. There are 2 capture probabilities for each period (not including the first) giving 6 parameters per group. So, the total number of parameters is 12x2+6x2=36. The NAGE, NYRS, STRATA, and NGROUPS keywords indicate the respective values for each, and PHIMISS indicates which of the transitions is to be computed by subtraction. In this case, PHIMISS=2 indicates that transitions to the 2nd strata are to be computed as 1 - the probability of moving to the first strata.

The rest of the model definition statements contains the summary data in a form which could be thought of as a generalized "Leslie Method-B Table" or "m-array" where each 2x2 matrix is treated as

one element in the m-array. Each of the records starts with "COHORT=x" where x is the number of animals released in a stratum and year. The numbers that follow indicate the number of recaptures in succeeding periods and strata. Figure 1 shows the structure of the m-array for these data.

Figure 1.

R_1	$M_{1,2}$	$M_{1,3}$	$M_{1,4}$
R_2		$M_{2,3}$	$M_{2,4}$
R_3			$M_{3,4}$

$$R_i = (R_i^1 \ R_i^2)$$

$$(M_i^{1,1} \ M_i^{1,2})$$

$$M_i = (M_i^{2,1} \ M_i^{2,2})$$

where R_i^r =number released in time i, stratum r, and $M_{i,j}^{rs}$ =number captured in time j in stratum s, last captured in time i in stratum r.

From the output file, the numbers of animals released in time period 1 are: 1000 from stratum 1 and 1001 from stratum 2. The matrix of recaptures in time period 2 of animals captured in time period 1 is:

$$M_{1,2} = \begin{bmatrix} 236 & 102 \\ 0 & 338 \end{bmatrix}$$

Of the 676 animals captured in time period 2 which were also captured in time period 1, 236 animal started in stratum 1 and stayed in stratum 1, 102 animals started in 1 and moved to 2. (Row indicates stratum of previous capture. Column indicates stratum of capture.) 0 animals moved from 2 to 1 and 338 moved from 2 to 2.

The next 2 columns of rows 1-2 in the data are the matrix of transitions of animals captured in time period 3 that were last captured in time period 1 (not captured in time period 2). The last 2 columns in the first 2 rows form the matrix of transitions of animals captured in time period 4 which were last captured in time period 1 (not captured in time periods 2 or 3).

Following the data are the labels for each of the parameters. Internally, the parameters are called "S(1), S(2), ... S(NPAR)". The labels relate these internal parameters to meaningful labels for these models. If the "Movement-only" model was chosen, the transition probabilities are labeled "PHI" followed by the time period in parenthesis and the transition. So, "PHI(01) AB" is the probability of survival from time period one to time period two and moving from stratum "A" to stratum "B". If the "Memory-movement" models were chosen, there will be three strata following the time period for each "PHI" since transition in time period i depends on stratum of capture in time period i-1 as well as in time period i. If the S-M parameterization is chosen, the survival parameter (SRV) will be followed by time period, age, and group in parenthesis, followed the stratum of capture in time period i. The movement parameters (MOV) will be followed by the time period, age, and group in parenthesis, then stratum in time period i and stratum in period i+1.

In all models, capture-probability parameters are labeled "p" and are followed by time period of capture, age, and group in parentheses, and stratum of capture.

After the label definitions come the model definitions for each model. Each model starts with a "PROC ESTIMATE" statement. Options on the "PROC ESTIMATE" statement include "NOVAR" which inhibits printing of the variance-covariance matrix, the number of significant digits, "NSIG" (i.e., number of digits following the decimal point which do not change at the end of the iterative process), the

maximum number of function evaluations, "MAXFN", and the name of the model. If the variance-covariance matrix of parameter estimates is desired, delete the string "NOVAR" using a text editor.

CNVMEMOV produces the model definitions from most restrictive (model "D") to most general (model "A"). The reason for this is that the most restrictive model has the fewest estimable parameters and converges more easily. Final estimates from this model can then be input as starting values to more general models. MSSURVIV requires starting values for all models and CNVMEMOV sets all parameters to 1/(# of strata) for the first model to ensure that the estimates of transition probability are less than or equal to 1.0. (INITIAL; ALL=0.333;).

The statements following the "CONSTRAINTS" statement describe each model in terms of the most general model. In model "D", the survival and movement probabilities are assumed to be constant across time, so the survival and movement probabilities for time period two and three are set equal to the survival and movement probabilities for time period one. The capture probabilities are also assumed constant over time, so the capture probabilities for time periods 3 and 4 are set equal to the capture probabilities for time period 2. These equalities must be specified in terms of parameter number which can be obtained from the labels section. In the example, the first constraint is "S(005)=S(001);". A comment appears immediately after the constraint which indicates which parameters are constrained.

The sequence of statements starting with "PROC ESTIMATE ... NAME=MODL_B" cause MSSURVIV to produce estimates under the model with time-specific capture probabilities and constant survival and movement probabilities. The initial values are set equal to the final values obtained for model "D" (INITIAL; RETAIN=MODL_D;), and the constraints on the survival and movement probability parameters are the same as for model "D". Since capture probabilities may vary with time, there are no constraints on the capture probability parameters.

Statements for model "A" follow model "B". Model "A" assumes time-specific survival and movement probabilities and time-specific capture probabilities. Since there is no information on animals after the last time period, the last survival and movement probabilities and last capture probabilities cannot be separately estimated under model "A". For this reason, the last capture probability parameters have to be constrained to a constant. This causes the last survival/movement probability estimates to be the product of survival and movement and capture-probability for this model.

If more than one group is to be analyzed, CNVMEMOV produces one other model which is equivalent to model A except that the parameters are constrained equal across groups.

The "PROC TEST;" statement causes MSSURVIV to print tables of statistics used for comparison of the models. "PROC STOP;" causes MSSURVIV to stop execution even if more statements follow. MSSURVIV

MSSURVIV prompts for one line of input to specify the name of the input and output files and command line options. When the program is run, the following prompt appears:

```
Enter command line parameters [i=in_file] [l=out_file]
[lines=n] [compile run] [noecho]:
```

At this prompt, any or all of the items enclosed in brackets may be specified. If "i=in_file" is specified, the input will be read from the file "in_file". Usually, this is the file created by CNVMEMOV and is called CNVMEMOV.OUT unless it has been renamed. A full pathname may be used to indicate a different directory. If this item is omitted, MSSURVIV expects the input from the keyboard. (Cntrl-Break will abort the program).

If "l=out_file" is specified, output from MSSURVIV will be directed to the file "out_file". The default output file is the CRT screen. To direct output directly to the printer, use "l=lpt1".

If "lines=n" is included, MSSURVIV will print a header and the title in the output file after every n lines. The default value for n is 9999.

The "noecho" option causes MSSURVIV to suppress printing of the input data. This option is useful when there are several runs of models on the same data and you would like to conserve paper, but at least one run should contain a listing of the data to check for "typos".

To run the sample data file with MSSURVIV, enter the following at the above prompt:

```
i=cnvmemov.out l=sample.out
```

The output produced by MSSURVIV contains a listing of the input data, estimates of the parameters under each model, a goodness-of-fit test for each model, an AIC statistic for each model, and between model tests. The following output was created using MSSURVIV on the sample data file listed previously:

```
MSSURVIV - Survival Rate Estimation with User Specified Cell Probabilities
28-Jan-98      11:20:03      Ver 2.0      01/01/98      Page 001
```

```
INPUT --- PROC TITLE 'SADF';
```

```
      CPU time in seconds for last procedure was      0.00
```

```
INPUT --- PROC MODEL NPAR=0036 ADDCELL NAGE=1 NYRS=04 STRATA=2
```

```
INPUT --- NGROUPS=2 PHIMISS=2;
```

```
INPUT ---      COHORT=1000; 236;;102;;76;;79;;22;;42;;
```

```
INPUT ---      COHORT=1001; 0;;338;;0;;156;;0;;64;;
```

```
INPUT ---      COHORT=1236; 267;;114;;77;;80;;
```

```
INPUT ---      COHORT=1440; 0;;444;;0;;183;;
```

```
INPUT ---      COHORT=1343; 260;;111;;
```

```
INPUT ---      COHORT=1793; 0;;495;;
```

```
INPUT ---      COHORT=1000; 62;;41;;11;;18;;2;;7;;
```

```
INPUT ---      COHORT=1001; 0;;105;;0;;29;;0;;8;;
```

```
INPUT ---      COHORT=1062; 74;;50;;14;;23;;
```

```
INPUT ---      COHORT=1146; 0;;135;;0;;40;;
```

```
INPUT ---      COHORT=1085; 83;;56;;
```

```
INPUT ---      COHORT=1232; 0;;158;;
```

```
INPUT --- PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_D;
```

```
      Number of parameters in model = 36
```

```
      Number of parameters set equal = 24
```

```
      Number of parameters fixed      = 0
```

```
      Number of parameters estimated = 12
```

```
Final function value 11038.617      (Error Return = 130)
```

```
Number of significant digits      5
```

```
Number of function evaluations      834
```

```
* * WARNING * *      Rounding errors became dominant before parameters estimated
```

```
* * WARNING * *      to NSIG digits for Model MODL_D
```

```
* * WARNING * *      Check to be sure the parameters are identifiable,
```

```
* * WARNING * *      but the problem may just be ill-conditioned.
```

```
Cohort Cell Observed Expected Chi-square Note
```

1	1	236.	213.083	2.465	0 < P < 1
1	2	102.	91.077	1.310	0 < P < 1
1	3	76.	70.554	0.420	0 < P < 1
1	4	79.	73.626	0.392	0 < P < 1
1	5	22.	23.361	0.079	0 < P < 1
1	6	42.	45.126	0.217	0 < P < 1
1	7	443.	483.173	3.340	0 < P < 1
1 Cohort	df= 6			8.223	P = 0.2222
2	2	338.	301.610	4.391	0 < P < 1
2	4	156.	143.954	1.008	0 < P < 1
2	6	64.	68.707	0.322	0 < P < 1
2	7	443.	486.730	3.929	0 < P < 1
2 Cohort	df= 3			9.650	P = 0.0218
3	1	267.	263.370	0.050	0 < P < 1
3	2	114.	112.571	0.018	0 < P < 1
3	3	77.	87.205	1.194	0 < P < 1
3	4	80.	91.002	1.330	0 < P < 1
3	5	698.	681.852	0.382	0 < P < 1
3 Cohort	df= 4			2.975	P = 0.5620
4	2	444.	433.884	0.236	0 < P < 1
4	4	183.	207.086	2.801	0 < P < 1
4	5	813.	799.030	0.244	0 < P < 1
4 Cohort	df= 2			3.282	P = 0.1938
5	1	260.	286.170	2.393	0 < P < 1
5	2	111.	122.316	1.047	0 < P < 1
5	3	972.	934.514	1.504	0 < P < 1
5 Cohort	df= 2			4.944	P = 0.0844
6	2	495.	540.246	3.789	0 < P < 1
6	3	1298.	1252.754	1.634	0 < P < 1
6 Cohort	df= 1			5.424	P = 0.0199
7	1	62.	69.693	0.849	0 < P < 1
7	2	41.	46.448	0.639	0 < P < 1
7	3	11.	11.855	0.062	0 < P < 1
7	4	18.	20.221	0.244	0 < P < 1
7	5	2.	2.017	0.000	0 < P < 1
7	6	7.	6.708	0.013	0 < P < 1
7	7	859.	843.057	0.301	0 < P < 1
7 Cohort	df= 6			2.108	P = 0.9095
8	2	105.	118.159	1.466	0 < P < 1
8	4	29.	31.341	0.175	0 < P < 1
8	6	8.	8.313	0.012	0 < P < 1
8	7	859.	843.186	0.297	0 < P < 1
8 Cohort	df= 3			1.949	P = 0.5831
9	1	74.	74.014	0.000	0 < P < 1
9	2	50.	49.328	0.009	0 < P < 1
9	3	14.	12.590	0.158	0 < P < 1
9	4	23.	21.475	0.108	0 < P < 1
9	5	901.	904.592	0.014	0 < P < 1
9 Cohort	df= 4			0.290	P = 0.9905
10	2	135.	135.275	0.001	0 < P < 1
10	4	40.	35.881	0.473	0 < P < 1
10	5	971.	974.843	0.015	0 < P < 1
10 Cohort	df= 2			0.488	P = 0.7833
11	1	83.	75.617	0.721	0 < P < 1
11	2	56.	50.396	0.623	0 < P < 1
11	3	946.	958.987	0.176	0 < P < 1
11 Cohort	df= 2			1.520	P = 0.4677
12	2	158.	145.427	1.087	0 < P < 1
12	3	1074.	1086.573	0.145	0 < P < 1
12 Cohort	df= 1			1.233	P = 0.2669

@@ 2 130 0 36 42.4007 24 42.0848 -126.955 277.910
G Total (Degrees of freedom = 36) 42.401
Pr(Larger Chi-square) = 0.2144

With pooling, Degrees of freedom = 24 Pearson Chi-square = 42.085
 Pr(Larger Chi-square) = 0.0126

Log-likelihood = -126.95523 Akaike Information Criterion = 277.91045

PARAMETER		ESTIMATES FOR MODEL MODL_D			
				95% Confidence Interval	
I	Parameter	S(I)	Standard Error	Lower	Upper
1	1 MOV(01,A,M) AA	0.698096	0.148408E-01	0.669008	0.727184
2	2 SRV(01,A,M) A	0.779541	0.176877E-01	0.744873	0.814209
3	3 MOV(01,A,M) BA	0.223989E-15	0.331077E-09	-.648912E-09	0.648912E-09
4	4 SRV(01,A,M) B	0.778593	0.165709E-01	0.746114	0.811071
5	1 MOV(02,A,M) AA	0.698096	0.148408E-01	0.669008	0.727184
6	2 SRV(02,A,M) A	0.779541	0.176877E-01	0.744873	0.814209
7	3 MOV(02,A,M) BA	0.223989E-15	0.331077E-09	-.648912E-09	0.648912E-09
8	4 SRV(02,A,M) B	0.778593	0.165709E-01	0.746114	0.811071
9	1 MOV(03,A,M) AA	0.698096	0.148408E-01	0.669008	0.727184
10	2 SRV(03,A,M) A	0.779541	0.176877E-01	0.744873	0.814209
11	3 MOV(03,A,M) BA	0.223989E-15	0.331077E-09	-.648912E-09	0.648912E-09
12	4 SRV(03,A,M) B	0.778593	0.165709E-01	0.746114	0.811071
13	5 p(02,A,M) A	0.391556	0.196561E-01	0.353030	0.430082
14	6 p(02,A,M) B	0.386991	0.134749E-01	0.360580	0.413402
15	5 p(03,A,M) A	0.391556	0.196561E-01	0.353030	0.430082
16	6 p(03,A,M) B	0.386991	0.134749E-01	0.360580	0.413402
17	5 p(04,A,M) A	0.391556	0.196561E-01	0.353030	0.430082
18	6 p(04,A,M) B	0.386991	0.134749E-01	0.360580	0.413402
19	7 MOV(01,A,F) AA	0.613898	0.419646E-01	0.531647	0.696148
20	8 SRV(01,A,F) A	0.390622	0.272521E-01	0.337207	0.444036
21	9 MOV(01,A,F) BA	0.357247E-11	0.848155E-07	-.166235E-06	0.166242E-06
22	10 SRV(01,A,F) B	0.383289	0.248185E-01	0.334644	0.431933
23	7 MOV(02,A,F) AA	0.613898	0.419646E-01	0.531647	0.696148
24	8 SRV(02,A,F) A	0.390622	0.272521E-01	0.337207	0.444036
25	9 MOV(02,A,F) BA	0.357247E-11	0.848155E-07	-.166235E-06	0.166242E-06
26	10 SRV(02,A,F) B	0.383289	0.248185E-01	0.334644	0.431933
27	7 MOV(03,A,F) AA	0.613898	0.419646E-01	0.531647	0.696148
28	8 SRV(03,A,F) A	0.390622	0.272521E-01	0.337207	0.444036
29	9 MOV(03,A,F) BA	0.357247E-11	0.848155E-07	-.166235E-06	0.166242E-06
30	10 SRV(03,A,F) B	0.383289	0.248185E-01	0.334644	0.431933
31	11 p(02,A,F) A	0.290629	0.408893E-01	0.210486	0.370772
32	12 p(02,A,F) B	0.307970	0.265552E-01	0.255922	0.360018
33	11 p(03,A,F) A	0.290629	0.408893E-01	0.210486	0.370772
34	12 p(03,A,F) B	0.307970	0.265552E-01	0.255922	0.360018
35	11 p(04,A,F) A	0.290629	0.408893E-01	0.210486	0.370772
36	12 p(04,A,F) B	0.307970	0.265552E-01	0.255922	0.360018

CPU time in seconds for last procedure was 1.56

INPUT --- PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_B;

Number of parameters in model = 36

Number of parameters set equal = 16

Number of parameters fixed = 0

Number of parameters estimated = 20

Final function value 11019.531 (Error Return = 130)

Number of significant digits 3

Number of function evaluations 1147

* * WARNING * * Rounding errors became dominant before parameters estimated

* * WARNING * * to NSIG digits for Model MODL_B

* * WARNING * * Check to be sure the parameters are identifiable,

* * WARNING * * but the problem may just be ill-conditioned.

Cohort	Cell	Observed	Expected	Chi-square	Note

1	1	236.	235.015	0.004	0 < P < 1
1	2	102.	101.021	0.009	0 < P < 1
1	3	76.	72.577	0.161	0 < P < 1
1	4	79.	75.912	0.126	0 < P < 1
1	5	22.	21.873	0.001	0 < P < 1
1	6	42.	41.662	0.003	0 < P < 1
1	7	443.	451.940	0.177	0 < P < 1
1 Cohort	df= 6			0.481	P = 0.9981
2	2	338.	336.898	0.004	0 < P < 1
2	4	156.	149.009	0.328	0 < P < 1
2	6	64.	63.507	0.004	0 < P < 1
2	7	443.	451.586	0.163	0 < P < 1
2 Cohort	df= 3			0.499	P = 0.9192
3	1	267.	270.924	0.057	0 < P < 1
3	2	114.	116.580	0.057	0 < P < 1
3	3	77.	81.651	0.265	0 < P < 1
3	4	80.	84.436	0.233	0 < P < 1
3	5	698.	682.409	0.356	0 < P < 1
3 Cohort	df= 4			0.968	P = 0.9146
4	2	444.	452.505	0.160	0 < P < 1
4	4	183.	192.855	0.504	0 < P < 1
4	5	813.	794.640	0.424	0 < P < 1
4 Cohort	df= 2			1.088	P = 0.5805
5	1	260.	255.726	0.071	0 < P < 1
5	2	111.	108.837	0.043	0 < P < 1
5	3	972.	978.437	0.042	0 < P < 1
5 Cohort	df= 2			0.157	P = 0.9246
6	2	495.	484.098	0.246	0 < P < 1
6	3	1298.	1308.902	0.091	0 < P < 1
6 Cohort	df= 1			0.336	P = 0.5620
7	1	62.	62.242	0.001	0 < P < 1
7	2	41.	41.537	0.007	0 < P < 1
7	3	11.	11.494	0.021	0 < P < 1
7	4	18.	19.590	0.129	0 < P < 1
7	5	2.	2.058	0.002	0 < P < 1
7	6	7.	6.882	0.002	0 < P < 1
7	7	859.	856.196	0.009	0 < P < 1
7 Cohort	df= 6			0.171	P = 0.9999
8	2	105.	105.229	0.000	0 < P < 1
8	4	29.	30.287	0.055	0 < P < 1
8	6	8.	8.518	0.032	0 < P < 1
8	7	859.	856.965	0.005	0 < P < 1
8 Cohort	df= 3			0.092	P = 0.9928
9	1	74.	73.260	0.007	0 < P < 1
9	2	50.	48.660	0.037	0 < P < 1
9	3	14.	13.116	0.060	0 < P < 1
9	4	23.	22.435	0.014	0 < P < 1
9	5	901.	904.530	0.014	0 < P < 1
9 Cohort	df= 4			0.132	P = 0.9979
10	2	135.	132.891	0.033	0 < P < 1
10	4	40.	37.375	0.184	0 < P < 1
10	5	971.	975.734	0.023	0 < P < 1
10 Cohort	df= 2			0.241	P = 0.8866
11	1	83.	83.808	0.008	0 < P < 1
11	2	56.	55.908	0.000	0 < P < 1
11	3	946.	945.284	0.001	0 < P < 1

11 Cohort df= 2 0.008 P = 0.9958
 12 2 158. 160.665 0.044 0 < P < 1
 12 3 1074. 1071.335 0.007 0 < P < 1
 12 Cohort df= 1 0.051 P = 0.8216

@@ 3 130 0 28 4.22760 16 4.22315 -107.869 255.737
 G Total (Degrees of freedom = 28) 4.228
 Pr(Larger Chi-square) = 1.0000
 With pooling, Degrees of freedom = 16 Pearson Chi-square = 4.223
 Pr(Larger Chi-square) = 0.9985

Log-likelihood = -107.86867 Akaike Information Criterion = 255.73734

PARAMETER ESTIMATES FOR MODEL MODL_B

I	Parameter	S(I)	Standard Error	95% Confidence Interval	
				Lower	Upper
1	1 MOV(01,A,M) AA	0.699495	0.156129E-01	0.668893	0.730096
2	2 SRV(01,A,M) A	0.809333	0.194461E-01	0.771219	0.847447
3	3 MOV(01,A,M) BA	0.153274E-12	0.875236E-08	-.171545E-07	0.171548E-07
4	4 SRV(01,A,M) B	0.810277	0.186997E-01	0.773626	0.846929
5	1 MOV(02,A,M) AA	0.699495	0.156129E-01	0.668893	0.730096
6	2 SRV(02,A,M) A	0.809333	0.194461E-01	0.771219	0.847447
7	3 MOV(02,A,M) BA	0.153274E-12	0.875236E-08	-.171545E-07	0.171548E-07
8	4 SRV(02,A,M) B	0.810277	0.186997E-01	0.773626	0.846929
9	1 MOV(03,A,M) AA	0.699495	0.156129E-01	0.668893	0.730096
10	2 SRV(03,A,M) A	0.809333	0.194461E-01	0.771219	0.847447
11	3 MOV(03,A,M) BA	0.153274E-12	0.875236E-08	-.171545E-07	0.171548E-07
12	4 SRV(03,A,M) B	0.810277	0.186997E-01	0.773626	0.846929
13	5 p(02,A,M) A	0.415130	0.255054E-01	0.365139	0.465121
14	6 p(02,A,M) B	0.415366	0.181679E-01	0.379757	0.450975
15	7 p(03,A,M) A	0.387183	0.243717E-01	0.339415	0.434952
16	8 p(03,A,M) B	0.387817	0.163238E-01	0.355823	0.419812
17	9 p(04,A,M) A	0.336347	0.247926E-01	0.287753	0.384940
18	10 p(04,A,M) B	0.333211	0.163182E-01	0.301228	0.365195
19	11 MOV(01,A,F) AA	0.612762	0.430408E-01	0.528403	0.697122
20	12 SRV(01,A,F) A	0.373504	0.269556E-01	0.320671	0.426337
21	13 MOV(01,A,F) BA	0.795825E-12	0.398934E-07	-.781903E-07	0.781919E-07
22	14 SRV(01,A,F) B	0.366048	0.250264E-01	0.316996	0.415099
23	11 MOV(02,A,F) AA	0.612762	0.430408E-01	0.528403	0.697122
24	12 SRV(02,A,F) A	0.373504	0.269556E-01	0.320671	0.426337
25	13 MOV(02,A,F) BA	0.795825E-12	0.398934E-07	-.781903E-07	0.781919E-07
26	14 SRV(02,A,F) B	0.366048	0.250264E-01	0.316996	0.415099
27	11 MOV(03,A,F) AA	0.612762	0.430408E-01	0.528403	0.697122
28	12 SRV(03,A,F) A	0.373504	0.269556E-01	0.320671	0.426337
29	13 MOV(03,A,F) BA	0.795825E-12	0.398934E-07	-.781903E-07	0.781919E-07
30	14 SRV(03,A,F) B	0.366048	0.250264E-01	0.316996	0.415099
31	15 p(02,A,F) A	0.271953	0.438024E-01	0.186101	0.357806
32	16 p(02,A,F) B	0.287187	0.286197E-01	0.231093	0.343282
33	17 p(03,A,F) A	0.301408	0.495588E-01	0.204273	0.398543
34	18 p(03,A,F) B	0.316791	0.315622E-01	0.254929	0.378653
35	19 p(04,A,F) A	0.337494	0.593484E-01	0.221171	0.453817
36	20 p(04,A,F) B	0.356265	0.389534E-01	0.279916	0.432613

CPU time in seconds for last procedure was 2.22

INPUT --- PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_A;

Number of parameters in model = 36

Number of parameters set equal = 0

Number of parameters fixed = 4

Number of parameters estimated = 32

Final function value 11017.458 (Error Return = 130)

Number of significant digits 5

Number of function evaluations 2182

* * WARNING * * Rounding errors became dominant before parameters estimated
 * * WARNING * * to NSIG digits for Model MODL_A
 * * WARNING * * Check to be sure the parameters are identifiable,
 * * WARNING * * but the problem may just be ill-conditioned.

Cohort	Cell	Observed	Expected	Chi-square	Note
1	1	236.	236.000	0.000	0 < P < 1
1	2	102.	101.823	0.000	0 < P < 1
1	3	76.	75.943	0.000	0 < P < 1
1	4	79.	79.281	0.001	0 < P < 1
1	5	22.	21.929	0.000	0 < P < 1
1	6	42.	42.024	0.000	0 < P < 1
1	7	443.	443.000	0.000	0 < P < 1
1 Cohort	df= 6			0.002	P = 1.0000
2	2	338.	338.177	0.000	0 < P < 1
2	4	156.	155.691	0.001	0 < P < 1
2	6	64.	64.131	0.000	0 < P < 1
2	7	443.	443.000	0.000	0 < P < 1
2 Cohort	df= 3			0.001	P = 1.0000
3	1	267.	267.057	0.000	0 < P < 1
3	2	114.	113.949	0.000	0 < P < 1
3	3	77.	77.116	0.000	0 < P < 1
3	4	80.	79.878	0.000	0 < P < 1
3	5	698.	698.000	0.000	0 < P < 1
3 Cohort	df= 4			0.000	P = 1.0000
4	2	444.	444.079	0.000	0 < P < 1
4	4	183.	182.921	0.000	0 < P < 1
4	5	813.	813.000	0.000	0 < P < 1
4 Cohort	df= 2			0.000	P = 1.0000
5	1	260.	259.955	0.000	0 < P < 1
5	2	111.	111.045	0.000	0 < P < 1
5	3	972.	972.000	0.000	0 < P < 1
5 Cohort	df= 2			0.000	P = 1.0000
6	2	495.	495.000	0.000	0 < P < 1
6	3	1298.	1298.000	0.000	0 < P < 1
6 Cohort	df= 1			0.000	P = 1.0000
7	1	62.	62.000	0.000	0 < P < 1
7	2	41.	40.877	0.000	0 < P < 1
7	3	11.	10.940	0.000	0 < P < 1
7	4	18.	18.418	0.010	0 < P < 1
7	5	2.	2.033	0.001	0 < P < 1
7	6	7.	6.731	0.011	0 < P < 1
7	7	859.	859.000	0.000	0 < P < 1
7 Cohort	df= 6			0.021	P = 1.0000
8	2	105.	105.123	0.000	0 < P < 1
8	4	29.	28.555	0.007	0 < P < 1
8	6	8.	8.322	0.012	0 < P < 1
8	7	859.	859.000	0.000	0 < P < 1
8 Cohort	df= 3			0.019	P = 0.9993
9	1	74.	74.060	0.000	0 < P < 1
9	2	50.	49.516	0.005	0 < P < 1
9	3	14.	13.764	0.004	0 < P < 1
9	4	23.	23.660	0.018	0 < P < 1
9	5	901.	901.000	0.000	0 < P < 1

9 Cohort	df=	4		0.027	P = 0.9999
10	2	135.	135.510	0.002	0 < P < 1
10	4	40.	39.490	0.007	0 < P < 1
10	5	971.	971.000	0.000	0 < P < 1
10 Cohort	df=	2		0.008	P = 0.9958
11	1	83.	83.203	0.000	0 < P < 1
11	2	56.	55.797	0.001	0 < P < 1
11	3	946.	946.000	0.000	0 < P < 1
11 Cohort	df=	2		0.001	P = 0.9994
12	2	158.	158.000	0.000	0 < P < 1
12	3	1074.	1074.000	0.000	0 < P < 1
12 Cohort	df=	1		0.000	P = 1.0000

@@ 4 130 0 16 0.811741E-01 4 0.810022E-01 -105.795 275.591
 G Total (Degrees of freedom = 16) 0.081
 Pr(Larger Chi-square) = 1.0000
 With pooling, Degrees of freedom = 4 Pearson Chi-square = 0.081
 Pr(Larger Chi-square) = 0.9992

Log-likelihood = -105.79546 Akaike Information Criterion = 275.59091

PARAMETER ESTIMATES FOR MODEL MODL_A

I	Parameter	S(I)	Standard Error	95% Confidence Interval	
				Lower	Upper
1	1 MOV(01,A,M) AA	0.698291	0.272011E-01	0.644977	0.751605
2	2 SRV(01,A,M) A	0.841311	0.301219E-01	0.782272	0.900350
3	3 MOV(01,A,M) BA	0.791250E-13	0.152194E-07	-.298299E-07	0.298300E-07
4	4 SRV(01,A,M) B	0.842191	0.313906E-01	0.780665	0.903717
5	5 MOV(02,A,M) AA	0.700908	0.263021E-01	0.649355	0.752460
6	6 SRV(02,A,M) A	0.768141	0.344931E-01	0.700534	0.835747
7	7 MOV(02,A,M) BA	0.161038E-11	0.505247E-07	-.990267E-07	0.990300E-07
8	8 SRV(02,A,M) B	0.768514	0.332930E-01	0.703260	0.833769
9	9 MOV(03,A,M) AA	0.700688	0.224495E-01	0.656687	0.744689
10	10 SRV(03,A,M) A	0.276247	0.122013E-01	0.252333	0.300162
11	11 MOV(03,A,M) BA	0.267271E-11	0.639044E-07	-.125250E-06	0.125255E-06
12	12 SRV(03,A,M) B	0.276074	0.105577E-01	0.255381	0.296767
13	13 p(02,A,M) A	0.401716	0.288422E-01	0.345185	0.458247
14	14 p(02,A,M) B	0.401144	0.206752E-01	0.360620	0.441667
15	15 p(03,A,M) A	0.401314	0.289046E-01	0.344661	0.457967
16	16 p(03,A,M) B	0.401278	0.190077E-01	0.364023	0.438533
17	-33 p(04,A,M) A	1.00000	0.000000E+00	1.00000	1.00000
18	-34 p(04,A,M) B	1.00000	0.000000E+00	1.00000	1.00000
19	19 MOV(01,A,F) AA	0.618899	0.707288E-01	0.480270	0.757527
20	20 SRV(01,A,F) A	0.353662	0.409073E-01	0.273484	0.433841
21	21 MOV(01,A,F) BA	0.181829E-15	0.134831E-08	-.264270E-08	0.264270E-08
22	22 SRV(01,A,F) B	0.346269	0.414183E-01	0.265089	0.427449
23	23 MOV(02,A,F) AA	0.610099	0.647022E-01	0.483283	0.736916
24	24 SRV(02,A,F) A	0.391317	0.437016E-01	0.305662	0.476972
25	25 MOV(02,A,F) BA	0.883231E-15	0.231888E-08	-.454501E-08	0.454501E-08
26	26 SRV(02,A,F) B	0.386940	0.429353E-01	0.302787	0.471094
27	27 MOV(03,A,F) AA	0.598583	0.402479E-01	0.519697	0.677469
28	28 SRV(03,A,F) A	0.128111	0.101463E-01	0.108224	0.147997
29	29 MOV(03,A,F) BA	0.658437E-15	0.190194E-08	-.372781E-08	0.372781E-08
30	30 SRV(03,A,F) B	0.128247	0.952609E-02	0.109576	0.146918
31	31 p(02,A,F) A	0.283259	0.590986E-01	0.167425	0.399092
32	32 p(02,A,F) B	0.303285	0.399842E-01	0.224915	0.381654
33	17 p(03,A,F) A	0.292098	0.563421E-01	0.181667	0.402528
34	18 p(03,A,F) B	0.305592	0.351321E-01	0.236733	0.374451
35	-35 p(04,A,F) A	1.00000	0.000000E+00	1.00000	1.00000
36	-36 p(04,A,F) B	1.00000	0.000000E+00	1.00000	1.00000

CPU time in seconds for last procedure was 4.20

INPUT --- PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=1GRP_A;

Number of parameters in model = 36

Number of parameters set equal = 16

Number of parameters fixed = 4

Number of parameters estimated = 16

Final function value 11767.052 (Error Return = 130)

Number of significant digits 5

Number of function evaluations 946

* * WARNING * * Rounding errors became dominant before parameters estimated

* * WARNING * * to NSIG digits for Model 1GRP_A

* * WARNING * * Check to be sure the parameters are identifiable,

* * WARNING * * but the problem may just be ill-conditioned.

Cohort	Cell	Observed	Expected	Chi-square	Note

1	1	236.	149.000	50.799	0 < P < 1
1	2	102.	70.658	13.902	0 < P < 1
1	3	76.	43.346	24.599	0 < P < 1
1	4	79.	49.802	17.119	0 < P < 1
1	5	22.	11.529	9.510	0 < P < 1
1	6	42.	24.665	12.183	0 < P < 1
1	7	443.	651.000	66.458	0 < P < 1
1 Cohort	df= 6			194.570	P = 0.0000
2	2	338.	222.342	60.164	0 < P < 1
2	4	156.	92.258	44.041	0 < P < 1
2	6	64.	35.401	23.104	0 < P < 1
2	7	443.	651.000	66.458	0 < P < 1
2 Cohort	df= 3			193.766	P = 0.0000
3	1	267.	183.576	37.912	0 < P < 1
3	2	114.	86.748	8.561	0 < P < 1
3	3	77.	48.826	16.257	0 < P < 1
3	4	80.	56.814	9.462	0 < P < 1
3	5	698.	860.037	30.529	0 < P < 1
3 Cohort	df= 4			102.721	P = 0.0000
4	2	444.	322.746	45.554	0 < P < 1
4	4	183.	123.843	28.258	0 < P < 1
4	5	813.	993.411	32.764	0 < P < 1
4 Cohort	df= 2			106.576	P = 0.0000
5	1	260.	190.367	25.470	0 < P < 1
5	2	111.	91.729	4.048	0 < P < 1
5	3	972.	1060.904	7.450	0 < P < 1
5 Cohort	df= 2			36.969	P = 0.0000
6	2	495.	387.051	30.107	0 < P < 1
6	3	1298.	1405.949	8.288	0 < P < 1
6 Cohort	df= 1			38.396	P = 0.0000
7	1	62.	149.000	50.799	0 < P < 1
7	2	41.	70.658	12.449	0 < P < 1
7	3	11.	43.346	24.137	0 < P < 1
7	4	18.	49.802	20.307	0 < P < 1
7	5	2.	11.529	7.876	0 < P < 1
7	6	7.	24.665	12.652	0 < P < 1
7	7	859.	651.000	66.458	0 < P < 1
7 Cohort	df= 6			194.678	P = 0.0000
8	2	105.	222.342	61.927	0 < P < 1
8	4	29.	92.258	43.373	0 < P < 1

8	6	8.	35.401	21.209	0 < P < 1
8	7	859.	651.000	66.458	0 < P < 1
8 Cohort	df=	3		192.967	P = 0.0000
9	1	74.	157.732	44.449	0 < P < 1
9	2	50.	74.536	8.077	0 < P < 1
9	3	14.	41.953	18.625	0 < P < 1
9	4	23.	48.816	13.652	0 < P < 1
9	5	901.	738.963	35.531	0 < P < 1
9 Cohort	df=	4		120.334	P = 0.0000
10	2	135.	256.852	57.807	0 < P < 1
10	4	40.	98.559	34.793	0 < P < 1
10	5	971.	790.589	41.169	0 < P < 1
10 Cohort	df=	2		133.769	P = 0.0000
11	1	83.	153.796	32.589	0 < P < 1
11	2	56.	74.107	4.424	0 < P < 1
11	3	946.	857.096	9.222	0 < P < 1
11 Cohort	df=	2		46.235	P = 0.0000
12	2	158.	265.949	43.817	0 < P < 1
12	3	1074.	966.051	12.063	0 < P < 1
12 Cohort	df=	1		55.879	P = 0.0000

@@ 5 130 0 32 1499.27 20 1416.86 -855.390 1742.78
 G Total (Degrees of freedom = 32) 1499.270
 Pr(Larger Chi-square) = 0.0000
 With pooling, Degrees of freedom = 20 Pearson Chi-square = 1416.861
 Pr(Larger Chi-square) = 0.0000

Log-likelihood = -855.38982 Akaike Information Criterion = 1742.7796

PARAMETER ESTIMATES FOR MODEL 1GRP_A

I	Parameter	S(I)	Standard Error	95% Confidence Interval	
				Lower	Upper
1	1 MOV(01,A,M) AA	0.686338	0.259820E-01	0.635413	0.737262
2	2 SRV(01,A,M) A	0.642315	0.258643E-01	0.591621	0.693009
3	3 MOV(01,A,M) BA	0.424835E-17	0.995660E-10	-.195149E-09	0.195149E-09
4	4 SRV(01,A,M) B	0.633335	0.262895E-01	0.581808	0.684862
5	5 MOV(02,A,M) AA	0.686668	0.248164E-01	0.638027	0.735308
6	6 SRV(02,A,M) A	0.622153	0.280548E-01	0.567166	0.677141
7	7 MOV(02,A,M) BA	0.308311E-12	0.204126E-07	-.400083E-07	0.400089E-07
8	8 SRV(02,A,M) B	0.622532	0.269198E-01	0.569769	0.675295
9	9 MOV(03,A,M) AA	0.674830	0.196852E-01	0.636247	0.713413
10	10 SRV(03,A,M) A	0.210049	0.826678E-02	0.193847	0.226252
11	11 MOV(03,A,M) BA	0.133071E-10	0.118946E-06	-.233120E-06	0.233147E-06
12	12 SRV(03,A,M) B	0.215868	0.748042E-02	0.201206	0.230529
13	13 p(02,A,M) A	0.337987	0.248288E-01	0.289323	0.386652
14	14 p(02,A,M) B	0.350714	0.179123E-01	0.315606	0.385822
15	15 p(03,A,M) A	0.347658	0.249419E-01	0.298772	0.396544
16	16 p(03,A,M) B	0.360028	0.165166E-01	0.327656	0.392401
17	-33 p(04,A,M) A	1.00000	0.000000E+00	1.00000	1.00000
18	-34 p(04,A,M) B	1.00000	0.000000E+00	1.00000	1.00000
19	1 MOV(01,A,F) AA	0.686338	0.259820E-01	0.635413	0.737262
20	2 SRV(01,A,F) A	0.642315	0.258643E-01	0.591621	0.693009
21	3 MOV(01,A,F) BA	0.424835E-17	0.995660E-10	-.195149E-09	0.195149E-09
22	4 SRV(01,A,F) B	0.633335	0.262895E-01	0.581808	0.684862
23	5 MOV(02,A,F) AA	0.686668	0.248164E-01	0.638027	0.735308
24	6 SRV(02,A,F) A	0.622153	0.280548E-01	0.567166	0.677141
25	7 MOV(02,A,F) BA	0.308311E-12	0.204126E-07	-.400083E-07	0.400089E-07
26	8 SRV(02,A,F) B	0.622532	0.269198E-01	0.569769	0.675295
27	9 MOV(03,A,F) AA	0.674830	0.196852E-01	0.636247	0.713413
28	10 SRV(03,A,F) A	0.210049	0.826678E-02	0.193847	0.226252
29	11 MOV(03,A,F) BA	0.133071E-10	0.118946E-06	-.233120E-06	0.233147E-06
30	12 SRV(03,A,F) B	0.215868	0.748042E-02	0.201206	0.230529
31	13 p(02,A,F) A	0.337987	0.248288E-01	0.289323	0.386652

32	14	p(02,A,F) B	0.350714	0.179123E-01	0.315606	0.385822
33	15	p(03,A,F) A	0.347658	0.249419E-01	0.298772	0.396544
34	16	p(03,A,F) B	0.360028	0.165166E-01	0.327656	0.392401
35	-35	p(04,A,F) A	1.00000	0.000000E+00	1.00000	1.00000
36	-36	p(04,A,F) B	1.00000	0.000000E+00	1.00000	1.00000

CPU time in seconds for last procedure was 1.77

INPUT --- PROC TEST;

Submodel	Name	Log-likelihood	NDF	Akaike Inf. Criter.	G-O-F
3	MODL_B	-107.869	28	255.73734	1.0000
1	ULTRA1/*	-105.812	22	263.62421	1.0000
4	MODL_A	-105.795	16	275.59091	1.0000
2	MODL_D	-126.955	36	277.91045	0.0000
5	1GRP_A	-855.390	32	1742.7796	0.0000

Likelihood Ratio Tests Between Models

General Submodel	Reduced Submodel	Chi-square	Degrees Freedom	Pr(Larger Chi-square)
ULTRA1/*	MODL_B	4.113	6	0.6614
MODL_A	MODL_B	4.146	12	0.9806
MODL_B	MODL_D	38.173	8	0.0000
MODL_B	1GRP_A	1495.042	4	0.0000
MODL_A	ULTRA1/*	0.033	6	1.0000
ULTRA1/*	MODL_D	42.286	14	0.0001
ULTRA1/*	1GRP_A	1499.155	10	0.0000
MODL_A	MODL_D	42.320	20	0.0025
MODL_A	1GRP_A	1499.189	16	0.0000
1GRP_A	MODL_D	0.000	4	1.0000

* * WARNING * * Sequence of models reinitialized to zero.

CPU time in seconds for last procedure was 0.00

INPUT --- PROC STOP;

CPU time in minutes for this job was 0.30

E X E C U T I O N S U C C E S S F U L

User-defined models

After running CNVMEMOV, other models may be added to the ones produced by default. To add new models, edit the CNVMEMOV output file, CNVMEMOV.OUT with a text editor. If a word-processor (eg. Word, Word Perfect, WordPro,...) is used, the file must be saved in ASCII or DOS text format.

Each model must begin with a **PROC ESTIMATE'** statement. This is followed by **INITIAL'**, and **CONSTRAINTS'** statements. The statements following the **CONSTRAINTS'** statement define how the parameters are related to each other. The best procedure for designing a model is to copy the statements from a previous model and modify the copy. For example, to build a model where survival/movement is time-specific and capture-probabilities are constant over time, you could copy the statements from model **D'** and delete the statements which constrain survival/transition parameters.

The following rules must be followed when constraining parameters:

- 1) Parameters can be constrained to be less than, greater than, or equal to constant values. (Eg. $S(10)=1$; $S(11)<0.5$; $S(12)>0.1$;) 2) Parameters can not be constrained to be less than or greater than other parameters. (Eg. $S(10)>S(11)$ - invalid) 3) Parameters can not be constrained to be equal to a previously constrained parameter. (Eg. $S(5)=S(1)$; $S(10)=S(5)$; - invalid $S(5)=S(1)$; $S(10)=S(1)$; - valid)

```

PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=MODL_C;
INITIAL; ALL= 0.500;
CONSTRAINTS;
S(015)=S(013) /* p(03,A,M) A =p(02,A,M) A */;
S(016)=S(014) /* p(03,A,M) B =p(02,A,M) B */;
S(017)=S(013) /* p(04,A,M) A =p(02,A,M) A */;
S(018)=S(014) /* p(04,A,M) B =p(02,A,M) B */;
S(033)=S(031) /* p(03,A,F) A =p(02,A,F) A */;
S(034)=S(032) /* p(03,A,F) B =p(02,A,F) B */;
S(035)=S(031) /* p(04,A,F) A =p(02,A,F) A */;
S(036)=S(032) /* p(04,A,F) B =p(02,A,F) B */;

```

External Covariates and additive models

To define models with external covariates a few new statements are needed. The list of parameters can be mapped to a new set of parameters using the **PIM'** and **DESMAT'** statements. The **PIM'** (Parameter Information Matrix) statement is used to map the actual parameters to unique transformed parameters. The unique transformed parameters are multiplied by the design matrix to give the value for the actual parameter. For example, to model survival and transition probabilities and capture probabilities as constant over time (as in model D), the PIM would be:

```

PIM;
1 2 3 4 1 2 3 4 1 2 3 4 5 6 5 6 5 6 7 8 9 10 7 8 9 10 7 8 9 10 11 12 11 12 11 12;

```

These 2 statements cause parameters 1,5,9 {mov(*,a,m) AA} to be mapped to a new parameter 1. This parameter would be the probability of moving from strata A to A for the first group(m) for any of the time-periods. Similarly, parameters 2,6,10 would be mapped to a new parameter 2. Using these two statements gives the same results as using the constraints in model D.

Although this statement could be used to generate models, the intended purpose of the PIM statement is to help generate additive or covariate models. Additive models are models where one parameter is defined in terms of other parameter(s) plus fixed values. Covariate models are models where parameters are defined as a function of some external variable (eg. Rainfall, temperature). For example, if we wanted to define a model where survival for groups M and F are related to an external covariate (temperature), the PIM would be:

```

PIM;
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
24 25 26 27 28 29 30 31 32 33 34 35 36;

```

In this example, each parameter is mapped to a transformed parameter. The transformed parameters are computed by multiplying the design matrix by the estimable parameters. The default design matrix is the identity matrix (zeros except on the diagonal; ones on the diagonal). This matrix would yield no transformation of the parameters. The transformation of parameters is achieved by matrix multiplication of the design matrix and the parameter vector. Here is an example where there are 4 parameters(p1-p4) , and the last two are equal to the first two plus a constant (t3)

```

[P1] = [1 0 0] [ ] , [T1]
[P2] = [0 1 0] [T1] , [T2]
[P3] = [1 0 1] [T2] , [T1+T3]
[P4] = [0 1 1] [T3] , [T2+T3]

```

In the previous example, the design matrix contains only ones and zeros. To specify that the parameters are to be a function of an external variable, the external variable can be inserted into a column of the design matrix. In the following example, only one parameter will be estimated, t1, and the actual parameters, p1-p4 will be computed using t1 and the covariates (.44 .48 .41 .52).

$$\begin{aligned} [P_1] &= [.44] & , & [.44T_1] \\ [P_2] &= [.48] & [T_1] & , [.48T_1] \\ [P_3] &= [.41] & , & [.41T_1] \\ [P_4] &= [.52] & , & [.52T_1] \end{aligned}$$

Here is the input for generating a model where survival for the 2 groups are a function of an external variable and capture and movement probabilities vary over time and group:

[illegible]

```

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;.15;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;.15;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;.10;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0;.10;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0;
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0;
INITIAL; ALL= 0.500;

```

First, notice the comment in the PROC ESTIMATE which is enclosed by /* and */. Since the parameters are transformed, new definitions of the transformed parameters would be helpful in reading the output (LABELS;). The PIM statement specifies that all 36 parameters are unique. The DESMAT statement declares the size of the matrix to be 36 rows by 26 columns. Each row of the design matrix corresponds to one of the 36 original parameters, and each column corresponds to one of the 26 transformed parameters.

To make defining the design matrix easier, you only need specify parts of the matrix which are different from the identity matrix. For clarity, the entire matrix is listed here, but it is possible to only specify a subset of the matrix using the SUBMAT statement. The 4 numbers of the SUBMAT statement specify the starting row and column followed by the ending row and column of values which follow.

The output produced by MSSURVIV for the previous model is:

```

INPUT --- PROC ESTIMATE NOVAR NSIG=6 MAXFN=64000 NAME=ULTRA1/* SRV(M)
INPUT --- = F(A1,X), SRV(F)=F(A2,X) */;
      Number of parameters in model   =   36

      Number of parameters set equal   =    0

      Number of parameters fixed       =    0

      Number of parameters estimated   =   26

      Final function value  11017.474      (Error Return = 130)

      Number of significant digits      5

      Number of function evaluations   2514

* *  WARNING  * *  Rounding errors became dominant before parameters estimated
* *  WARNING  * *  to NSIG digits for Model ULTRA1/*
* *  WARNING  * *  Check to be sure the parameters are identifiable,
* *  WARNING  * *  but the problem may just be ill-conditioned.

```

Cohort	Cell	Observed	Expected	Chi-square	Note
1	1	236.	236.034	0.000	0 < P < 1
1	2	102.	101.866	0.000	0 < P < 1
1	3	76.	76.062	0.000	0 < P < 1
1	4	79.	79.362	0.002	0 < P < 1
1	5	22.	21.968	0.000	0 < P < 1

1	6	42.	42.052	0.000	0 < P < 1
1	7	443.	442.656	0.000	0 < P < 1
1 Cohort	df=	6		0.002	P = 1.0000
2	2	338.	338.131	0.000	0 < P < 1
2	4	156.	155.669	0.001	0 < P < 1
2	6	64.	64.076	0.000	0 < P < 1
2	7	443.	443.124	0.000	0 < P < 1
2 Cohort	df=	3		0.001	P = 1.0000
3	1	267.	266.950	0.000	0 < P < 1
3	2	114.	113.940	0.000	0 < P < 1
3	3	77.	77.098	0.000	0 < P < 1
3	4	80.	79.839	0.000	0 < P < 1
3	5	698.	698.173	0.000	0 < P < 1
3 Cohort	df=	4		0.001	P = 1.0000
4	2	444.	443.987	0.000	0 < P < 1
4	4	183.	182.751	0.000	0 < P < 1
4	5	813.	813.262	0.000	0 < P < 1
4 Cohort	df=	2		0.000	P = 0.9998
5	1	260.	259.938	0.000	0 < P < 1
5	2	111.	111.056	0.000	0 < P < 1
5	3	972.	972.006	0.000	0 < P < 1
5 Cohort	df=	2		0.000	P = 1.0000
6	2	495.	495.210	0.000	0 < P < 1
6	3	1298.	1297.790	0.000	0 < P < 1
6 Cohort	df=	1		0.000	P = 0.9911
7	1	62.	61.866	0.000	0 < P < 1
7	2	41.	40.652	0.003	0 < P < 1
7	3	11.	10.654	0.011	0 < P < 1
7	4	18.	18.216	0.003	0 < P < 1
7	5	2.	1.956	0.001	0 < P < 1
7	6	7.	6.662	0.017	0 < P < 1
7	7	859.	859.994	0.001	0 < P < 1
7 Cohort	df=	5		0.035	P = 1.0000
8	2	105.	105.438	0.002	0 < P < 1
8	4	29.	28.856	0.001	0 < P < 1
8	6	8.	8.481	0.027	0 < P < 1
8	7	859.	858.225	0.001	0 < P < 1
8 Cohort	df=	3		0.031	P = 0.9986
9	1	74.	74.262	0.001	0 < P < 1
9	2	50.	49.421	0.007	0 < P < 1
9	3	14.	13.630	0.010	0 < P < 1
9	4	23.	23.646	0.018	0 < P < 1
9	5	901.	901.040	0.000	0 < P < 1
9 Cohort	df=	4		0.035	P = 0.9998
10	2	135.	135.649	0.003	0 < P < 1
10	4	40.	39.868	0.000	0 < P < 1
10	5	971.	970.483	0.000	0 < P < 1
10 Cohort	df=	2		0.004	P = 0.9981
11	1	83.	83.399	0.002	0 < P < 1
11	2	56.	55.807	0.001	0 < P < 1
11	3	946.	945.794	0.000	0 < P < 1
11 Cohort	df=	2		0.003	P = 0.9987
12	2	158.	157.567	0.001	0 < P < 1
12	3	1074.	1074.433	0.000	0 < P < 1
12 Cohort	df=	1		0.001	P = 0.9705

@@ 1 130 0 22 0.114473 9 0.113113 -105.812 263.624

G Total (Degrees of freedom = 22)

0.114

Pr(Larger Chi-square) = 1.0000

With pooling, Degrees of freedom = 9 Pearson Chi-square = 0.113

Pr(Larger Chi-square) = 1.0000

Log-likelihood = -105.81211

Akaike Information Criterion = 263.62421

itrans,nyrs= 2 4

SURVIVAL/MOVEMENT & CAPTURE PROB. ESTIMATES

1	MOV(01,A,M) AA	0.698437
2	SRV(01,A,M) A	0.842177
3	MOV(01,A,M) BA	0.565833E-12
4	SRV(01,A,M) B	0.842177
5	MOV(02,A,M) AA	0.701015
6	SRV(02,A,M) A	0.767827
7	MOV(02,A,M) BA	0.103410E-10
8	SRV(02,A,M) B	0.767827
9	MOV(03,A,M) AA	0.700596
10	SRV(03,A,M) A	0.689415
11	MOV(03,A,M) BA	0.861494E-15
12	SRV(03,A,M) B	0.689415
13	p(02,A,M) A	0.401277
14	p(02,A,M) B	0.401096
15	p(03,A,M) A	0.401256
16	p(03,A,M) B	0.401554
17	p(04,A,M) A	0.400724
18	p(04,A,M) B	0.400616
19	MOV(01,A,F) AA	0.614067
20	SRV(01,A,F) A	0.348870
21	MOV(01,A,F) BA	0.548536E-45
22	SRV(01,A,F) B	0.348870
23	MOV(02,A,F) AA	0.606850
24	SRV(02,A,F) A	0.390379
25	MOV(02,A,F) BA	0.521048E-29
26	SRV(02,A,F) B	0.390379
27	MOV(03,A,F) AA	0.597835
28	SRV(03,A,F) A	0.426255
29	MOV(03,A,F) BA	0.422671E-11
30	SRV(03,A,F) B	0.426255
31	p(02,A,F) A	0.288786
32	p(02,A,F) B	0.301926
33	p(03,A,F) A	0.295174
34	p(03,A,F) B	0.303211
35	p(04,A,F) A	0.301634
36	p(04,A,F) B	0.300044

UNTRANSFORMED ESTIMATES FOR MODEL ULTRA1/*

I	Parameter	S(I)	Standard Error	95% Confidence Interval	
				Lower	Upper
1	1 MOV(01,A,M) AA	0.839867	0.528164E-01	0.736346	0.943387
2	2 MOV(01,A,M) BA	-20.0000	0.427416E-01	-20.0838	-19.9162
3	3 MOV(02,A,M) AA	0.852135	0.472473E-01	0.759530	0.944739
4	4 MOV(02,A,M) BA	-20.0000	0.349412E-01	-20.0685	-19.9315
5	5 MOV(03,A,M) AA	0.850136	0.522983E-01	0.747631	0.952640
6	6 MOV(03,A,M) BA	-20.0000	0.354779E-01	-20.0695	-19.9305
7	7 p(02,A,M) A	-1.400146	0.361840E-01	-.471066	-.329225
8	8 p(02,A,M) B	-.400902	0.330581E-01	-.465696	-.336109
9	9 p(03,A,M) A	-.400235	0.325735E-01	-.464080	-.336391
10	10 p(03,A,M) B	-.398993	0.290952E-01	-.456019	-.341966
11	11 p(04,A,M) A	-.402450	0.505944E-01	-.501615	-.303285
12	12 p(04,A,M) B	-.402898	0.476067E-01	-.496207	-.309589
13	13 MOV(01,A,F) AA	0.464440	0.240815	-.755734E-02	0.936438
14	14 MOV(01,A,F) BA	-20.0000	0.178446	-20.3498	-19.6502
15	15 MOV(02,A,F) AA	0.434089	0.193629	0.545757E-01	0.813603
16	16 MOV(02,A,F) BA	-20.0000	0.132460	-20.2596	-19.7404
17	17 MOV(03,A,F) AA	0.396454	0.192605	0.189479E-01	0.773960
18	18 MOV(03,A,F) BA	-20.0000	0.114655	-20.2247	-19.7753
19	19 p(02,A,F) A	-.901288	0.113968	-1.12467	-.677910
20	20 p(02,A,F) B	-.838141	0.973045E-01	-1.02886	-.647424
21	21 p(03,A,F) A	-.870388	0.902454E-01	-1.04727	-.693507
22	22 p(03,A,F) B	-.832054	0.737722E-01	-.976647	-.687460

23	23	p(04,A,F) A	-.839531	0.818452E-01	-.999948	-.679114
24	24	p(04,A,F) B	-.847088	0.587391E-01	-.962217	-.731959
25	25	A1	7.97388	1.13913	5.74118	10.2066
26	26	A2	-2.97148	0.408431	-3.77200	-2.17095

PARAMETER ESTIMATES FOR MODEL ULTRA1/*

I	Parameter		S(I)	Standard Error	95% Confidence Interval	
					Lower	Upper
1	1	MOV(01,A,M) AA	0.698437	0.111245E-01	0.676633	0.720241
2	2	SRV(01,A,M) A	0.842177	0.317975E-01	0.779854	0.904500
3	3	MOV(01,A,M) BA	0.206115E-08	0.881853E-10	0.188831E-08	0.223400E-08
4	4	SRV(01,A,M) B	0.842177	0.317975E-01	0.779854	0.904500
5	5	MOV(02,A,M) AA	0.701015	0.990287E-02	0.681605	0.720424
6	6	SRV(02,A,M) A	0.767827	0.304617E-01	0.708122	0.827532
7	7	MOV(02,A,M) BA	0.206115E-08	0.720913E-10	0.191985E-08	0.220245E-08
8	8	SRV(02,A,M) B	0.767827	0.304617E-01	0.708122	0.827532
9	9	MOV(03,A,M) AA	0.700596	0.109703E-01	0.679094	0.722097
10	10	SRV(03,A,M) A	0.689415	0.243917E-01	0.641608	0.737223
11	11	MOV(03,A,M) BA	0.206115E-08	0.731985E-10	0.191768E-08	0.220462E-08
12	12	SRV(03,A,M) B	0.689415	0.243917E-01	0.641608	0.737223
13	13	p(02,A,M) A	0.401277	0.869338E-02	0.384238	0.418316
14	14	p(02,A,M) B	0.401096	0.794117E-02	0.385531	0.416660
15	15	p(03,A,M) A	0.401256	0.782581E-02	0.385917	0.416594
16	16	p(03,A,M) B	0.401554	0.699185E-02	0.387850	0.415258
17	17	p(04,A,M) A	0.400724	0.121500E-01	0.376910	0.424538
18	18	p(04,A,M) B	0.400616	0.114315E-01	0.378210	0.423022
19	19	MOV(01,A,F) AA	0.614067	0.570708E-01	0.502208	0.725926
20	20	SRV(01,A,F) A	0.348870	0.194838E-01	0.310682	0.387058
21	21	MOV(01,A,F) BA	0.206115E-08	0.368173E-09	0.133953E-08	0.278277E-08
22	22	SRV(01,A,F) B	0.348870	0.194838E-01	0.310682	0.387058
23	23	MOV(02,A,F) AA	0.606850	0.461969E-01	0.516304	0.697396
24	24	SRV(02,A,F) A	0.390379	0.145800E-01	0.361802	0.418955
25	25	MOV(02,A,F) BA	0.206115E-08	0.273294E-09	0.152550E-08	0.259681E-08
26	26	SRV(02,A,F) B	0.390379	0.145800E-01	0.361802	0.418955
27	27	MOV(03,A,F) AA	0.597835	0.463079E-01	0.507072	0.688599
28	28	SRV(03,A,F) A	0.426255	0.998868E-02	0.406677	0.445833
29	29	MOV(03,A,F) BA	0.206115E-08	0.236557E-09	0.159750E-08	0.252481E-08
30	30	SRV(03,A,F) B	0.426255	0.998868E-02	0.406677	0.445833
31	31	p(02,A,F) A	0.288786	0.234082E-01	0.242906	0.334666
32	32	p(02,A,F) B	0.301926	0.205089E-01	0.261729	0.342124
33	33	p(03,A,F) A	0.295174	0.187755E-01	0.258374	0.331974
34	34	p(03,A,F) B	0.303211	0.155864E-01	0.272662	0.333760
35	35	p(04,A,F) A	0.301634	0.172410E-01	0.267841	0.335426
36	36	p(04,A,F) B	0.300044	0.123364E-01	0.275865	0.324224

CPU time in seconds for last procedure was 8.38

Hardware Considerations

Two versions of MSSURVIV are available for PC's. A small version which will work on older PC's running DOS without Extended memory or a math coprocessor is set up to handle up to 25 cohorts, 20 classes and 50 parameters. See appendix A to determine the possible combinations of strata and sample periods for these limits.

A larger version, compiled with a "DOS extender", requires a 386/387 or 486 PC, 640Kb RAM, and at least 10Mb of free hard disk space (although MSSURVIV will run faster with more RAM). The maximum number of cohorts, classes and parameters for this version are: 64, 64, and 250, respectively.

The source code for MSSURVIV has been successfully compiled and run on a Prime minicomputer running PrimeOS, and two different unix workstations.

The program has also been compiled for Windows and OS/2. The limitations for the Windows version are the same as the DOS extender version.

Software Installation

To install MSSURVIV on a PC simply make a sub-directory to contain the programs and copy the files from the floppy disk. The disk contains the executable program file, so no compilation is necessary unless you wish to alter the dimensions. Here are the commands to install the MSSURVIV programs onto the hard disk of a PC:

```
c:> mkdir mssrv
c:> cd mssrv
c:> xcopy a:*. * /s
```

To install MSSURVIV on other computers, a FORTRAN compiler will be required. The files must first be transferred to disk on the computer, then compiled and linked into an executable program file. A "make" file is included which will create the executable program file from the source files if the target computer has the make utility (as most Unix systems do). If the target computer doesn't have a make utility, a "batch" file is included to compile all of the routines. Most likely, the make file or batch file will have to be edited to reflect the names of the compiler and linker on the target system.

Literature Cited

Brownie, C., J.E. Hines, J.D. Nichols, K.H. Pollock, and J.B. Hestbeck. 1993. Capture-recapture studies for multiple strata including non-Markovian transition probabilities. *Biometrics* 49:1173-1187.

Pollock, K.H., J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. *Wildlife Monographs* 107. 97pp.

White, G.C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. *The Journal of Wildlife Management* 47:716-728. Appendix A: Maximum number of cohorts/classes/parameters for "Movement-only" and "Memory-Movement" models.

"Movement-only" models

SAMPLE PERIODS	STRATA					
	1	2	3	4	5	6
3	2/ 2/ 4	4/ 4/ 12	6/ 6/ 24	8/ 8/ 40	10/10/ 60	12/ 12/ 84
4	3/ 3/ 6	6/ 6/ 18	9/ 9/ 36	12/12/ 60	15/15/ 90	18/ 18/126
5	4/ 4/ 8	8/ 8/ 24	12/12/ 48	16/16/ 80	20/20/120	24/ 24/168
6	5/ 5/10	10/10/ 30	15/15/ 60	20/20/100	25/25/150	30/ 30/210
7	6/ 6/12	12/12/ 36	18/18/ 72	24/24/120	30/30/180	36/ 36/252
8	7/ 7/14	14/14/ 42	21/21/ 84	28/28/140	35/35/210	42/ 42/294
9	8/ 8/16	16/16/ 48	24/24/ 96	32/32/160	40/40/240	48/ 48/336
10	9/ 9/18	18/18/ 54	27/27/108	36/36/180	45/45/270	54/ 54/378
11	10/10/20	20/20/ 60	30/30/120	40/40/200	50/50/300	60/ 60/420
12	11/11/22	22/22/ 66	33/33/132	44/44/220	55/55/330	66/ 66/462
13	12/12/24	24/24/ 72	36/36/144	48/48/240	60/60/360	72/ 72/504
14	13/13/26	26/26/ 78	39/39/156	52/52/260	65/65/390	78/ 78/546
15	14/14/28	28/28/ 84	42/42/168	56/56/280	70/70/420	84/ 84/588
16	15/15/30	30/30/ 90	45/45/180	60/60/300	75/75/450	90/ 90/630
17	16/16/32	32/32/ 96	48/48/192	64/64/320	80/80/480	96/ 96/672
18	17/17/34	34/34/102	51/51/204	68/68/340	85/85/510	102/102/714
19	18/18/36	36/36/108	54/54/216	72/72/360	90/90/540	108/108/756
20	19/19/38	38/38/114	57/57/228	76/76/380	95/95/570	114/114/798

"Memory-Movement" models

SAMPLE PERIODS	STRATA					
	1	2	3	4	5	6
3	1/ 1/ 2	4/ 2/ 10	9/ 3/ 30	16/ 4/ 68	25/ 5/ 130	36/ 6/ 222
4	2/ 2/ 4	8/ 4/ 20	18/ 6/ 60	32/ 8/ 136	50/10/ 260	72/ 12/ 444
5	3/ 3/ 6	12/ 6/ 30	27/ 9/ 90	48/12/ 204	75/15/ 390	108/ 18/ 666
6	4/ 4/ 8	16/ 8/ 40	36/12/120	64/16/ 272	100/20/ 520	144/ 24/ 888
7	5/ 5/10	20/10/ 50	45/15/150	80/20/ 340	125/25/ 650	180/ 30/1,110
8	6/ 6/12	24/12/ 60	54/18/180	96/24/ 408	150/30/ 780	216/ 36/1,332
9	7/ 7/14	28/14/ 70	63/21/210	112/28/ 476	175/35/ 910	252/ 42/1,554
10	8/ 8/16	32/16/ 80	72/24/240	128/32/ 544	200/40/1,040	288/ 48/1,776
11	9/ 9/18	36/18/ 90	81/27/270	144/36/ 612	225/45/1,170	324/ 54/1,998
12	10/10/20	40/20/100	90/30/300	160/40/ 680	250/50/1,300	360/ 60/2,220
13	11/11/22	44/22/110	99/33/330	176/44/ 748	275/55/1,430	396/ 66/2,442
14	12/12/24	48/24/120	108/36/360	192/48/ 816	300/60/1,560	432/ 72/2,664
15	13/13/26	52/26/130	117/39/390	208/52/ 884	325/65/1,690	468/ 78/2,886
16	14/14/28	56/28/140	126/42/420	224/56/ 952	350/70/1,820	504/ 84/3,108
17	15/15/30	60/30/150	135/45/450	240/60/1,020	375/75/1,950	540/ 90/3,330
18	16/16/32	64/32/160	144/48/480	256/64/1,088	400/80/2,080	576/ 96/3,552
19	17/17/34	68/34/170	153/51/510	272/68/1,156	425/85/2,210	612/102/3,774
20	18/18/36	72/36/180	162/54/540	288/72/1,224	450/90/2,340	648/108/3,996