Chapter 6. Comprehensive Computer Programs

The calculation of the various point estimates and their associated standard errors and covariances and tests of hypotheses is a laborious task, even for small sets of banding and recovery data. The computational requirements are large when the Maximum Likelihood equations must be solved numerically (i.e., Models 2, 3, H_{01} and H_{02}). Rounding errors can become significant and mathematical errors are nearly unavoidable if the calculations are performed by hand. To alleviate these problems, we developed two comprehensive computer programs to allow estimation and testing to be done inexpensively, accurately, and quickly. In addition, White (1983) developed program SURVIV and Conroy and Williams (1985) developed program MULT. These are extremely powerful computer programs allowing the more sophisticated user to make ML estimates and efficient tests based on more complex models. Use of the output from these programs allows the biologist to concentrate on the interpretation of the results, rather than on the tedious and often complex calculations involved.

The first program, ESTIMATE, computes estimates and test statistics for adult banding data – where parameters can be assumed to be independent of age. Point estimates of the parameters and their sampling variances and various test statistics under Models 0, 1, 2, and 3 are computed by this program.

The second program, BROWNIE, permits estimation under the various age-specific models: H_{01}, H_{02}, H_1, H_2, H_3, H_4, H_5, and H_6. Goodness of fit tests and tests between these models are also computed by BROWNIE. In addition, a chi-square test for differences between adult male and female recovery and survival rates (Section 5.1) is provided as an option.

Programs SURVIV and MULT are very general in that the user can specify the expectation of each R_{ij} cell in terms of the unknown parameters to be estimated. Arbitrary subsets of parameters can be set equal, given an *a priori* value, or constrained to a fixed or variable range. In addition, structural relations can be specified among parameters or even between parameters and auxillary variables. Advanced hypothesis testing is possible through likelihood ratio tests. Unequal intervals between times of banding can be treated, including the models given in Chapter 7. Program SURVIV allows Monte Carlo studies to be easily performed.

All four computer programs are now written in FORTRAN 77 and are designed to be run on nearly any modern computer. ESTIMATE and BROWNIE require a machine with 256k bytes of memory and a FORTRAN 77 compiler, while SURVIV and MULT require 512 k bytes of memory and a hard disk. All mainframe computers satisfy these requirements. Within the past year or two, many desktop microcomputers have achieved these capabilities (e.g., the IBM PC class and various compatible machines).

Most users will employ programs ESTIMATE and BROWNIE for the analysis of band recovery data. These programs are easy to use on a large mainframe computer. We have provided standard input formats (Figs. 6.1 and 6.2 for ESTIMATE and Figs. 6.3 and 6.4 for BROWNIE). The standard (data entry) format and appropriate instructions appear back-to-back on forms which are available. Typical data sets would be coded onto the form and entered as 5 to 25 lines for adult data, 8 to 46 lines for models H_{01}-H_3 which treat adult and young data, and 11 to 68 lines for models H_4-H_6 which treat the three-age-class case. The examples used in Chapter 2-5 were derived by the two programs. Versions of ESTIMATE and BROWNIE are available to be run interactively via a remote terminal system as part of a mainframe computer or on a desktop microcomputer. Conceptually, the information required is the same (i.e., Figs. 6.1-6.4), however, the programs ask the user for the information, accepts the data from the terminal keyboard, and then provides the analysis on a video (CRT) screen or as printed output.

Programs ESTIMATE and BROWNIE for large mainframe computers are available on 9-track, 800-BPI magnetic tapes from the Chief, EDP Section, Office of Migratory Bird Management, Patuxent Wildlife Research Center, Laurel, Maryland 20708. Generally, tapes will be loaned to the individual requesting the programs. The user will be asked to copy the tape and return the original tape so it can be loaned to others. The tape will be sent on a loan basis without charge; the user must pay only the cost of returning the tape. Data entry forms are also available upon request. Hundreds of copies of these two programs have been distributed over the past seven years. Users may wish to check nearby universities or state conservation agency offices to see if these software packages can be obtained locally.

Copies of programs SURVIV and MULT can be obtained from the original authors (see Appendix C where the papers by White (1983) and Conroy and Williams (1985) are reprinted). These are large, complex programs with many advanced features. The user must be fully acquainted with the contents of this *Handbook* or seek the help of a statistician before contemplating the use of these programs.

When using a mainframe computer, the user is usually most concerned with costs, while time is more of concern to users of microcomputers. Here we will attempt to provide some orders of magnitude for these resource requirements. The cost of compiling ESTIMATE or BROWNIE on a mainframe computer may be in the $10-15 range, depending on the user's computer facility. The cost of running a fairly large data set, say $k = \ell = 12$, is often in the

$1-2 range, again depending on the computer used and local billing rates. The cost per data set often drops substantially if several data sets are submitted as a single computer run. Programs SURVIV and MULT may cost $10-20 to compile, but run costs may be significantly higher for large data sets and complex models. We have seen a single large data set cost $40 using program SURVIV when the model is very complex. Still, these costs are negligible compared to the initial cost of obtaining the basic data in the field.

The widespread availability of microcomputers now allows many biologists the opportunity to use ESTIMATE and BROWNIE on an interactive basis. The following information will provide some run times for data sets in this *Handbook*, using an IBM PC/AT with a 80287 coprocessor (data were previously stored on a hard disk).

Program	Date Set	Page	Time (seconds)
ESTIMATE	Male Wood Ducks	21	14
	Male Mallards	25	23
	Male Mallards	45	23
BROWNIE	Young and Adult Mallards	58	18
	Synthetic	118	28
	Male and Female Mallards	146	10

These times are negligible, but do not include time required for the entry of the data (N_i and R_{ij}). A user with reasonable familiarity with a desktop computer might be able to fully analyze a typical data set in 10-20 minutes. This would include providing the answers to queries for information during an interactive session, waiting perhaps 30-200 seconds, and printing the results.

We have consulted with literally hundreds of biologists concerning the analysis of their data over the past seven years. We are willing to try to continue this service as it has provided us with impressions on how this series of models is supported by real data and showed some extensions that were needed.

Figure 6.1 Coding instructions for adult recovery data.

Instructions for Program Estimate

This form is to be used in conjunction with the FORTRAN IV computer program to estimate time-specific survival and recovery rates from banding and recovery data (see Anderson, Kimball & Fiehrer. 1974. J. Wildl. Manage. 38(2):369-370). The information on this coding form is to be punched onto a standard 80-column card. Each line represents one card. All numbers must be integers (no decimal points) and must be in the right-most columns in each field.

The first line (card) is used to identify the data set: e.g.,"PINK-FOOTED GOOSE DATA (FROM BOYD. 1956. J. ANIMAL ECOL.)." This is a Header Card and will identify the information on the computer output.

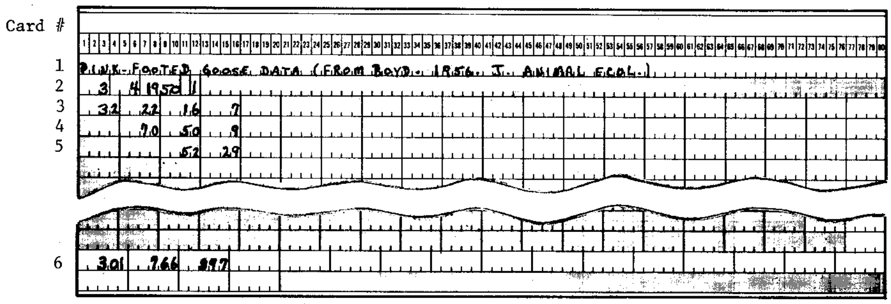
The second line (card) is a Parameter Card and contains four fields:

1. The number of years of banding must appear in columns 1-3 (maximum is 20).
2. The number of years of recovery must appear in columns 4-6 (maximum is 20).
3. The first year of the banding study must appear in columns 7-10, (e.g., 1950).
4. Column 12 must contain the number 1.

The next lines (group of cards) is for the array of recovery information. There must be a minimum of 2 years of recovery information and a maximum of 20. Each field is 4 columns wide. The number of these cards should agree with the number punched in columns 1-3 of the Parameter Card. This group of cards is termed Recovery Cards.

The final line (2 lines if more than 16 years of banding are involved) is for the number of birds banded each year. Each field is 5 columns wide. The number of birds banded the first year must appear in columns 1-5, the number banded the second year must appear in columns 6-10, etc.

An example follows:



In this example, birds were banded in 3 years and recoveries were recorded in 4 years. Banding began in 1950 when 301 birds were banded; 32 recoveries were reported in 1950 from the cohort banded in 1950. During 1952, 16 recoveries were reported from the cohort banded in 1950, 50 recoveries were reported from the cohort banded in 1951, and 52 recoveries were reported from the cohort banded in 1952. 897 birds were banded during the final year of the experiment (1952). This data set would be punched onto 6 cards. Other data sets could follow. This example data set is discussed and analyzed by Seber (1970. Biometrika).

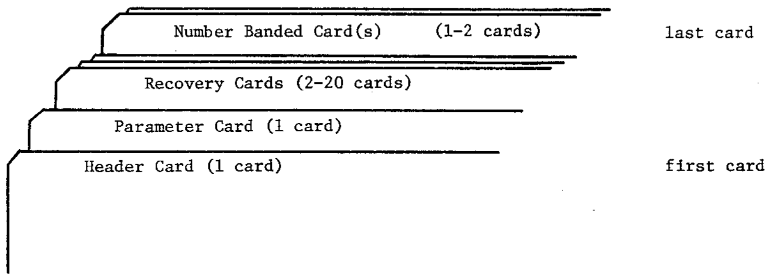


Figure 6.2 General coding form for adult recovery data.

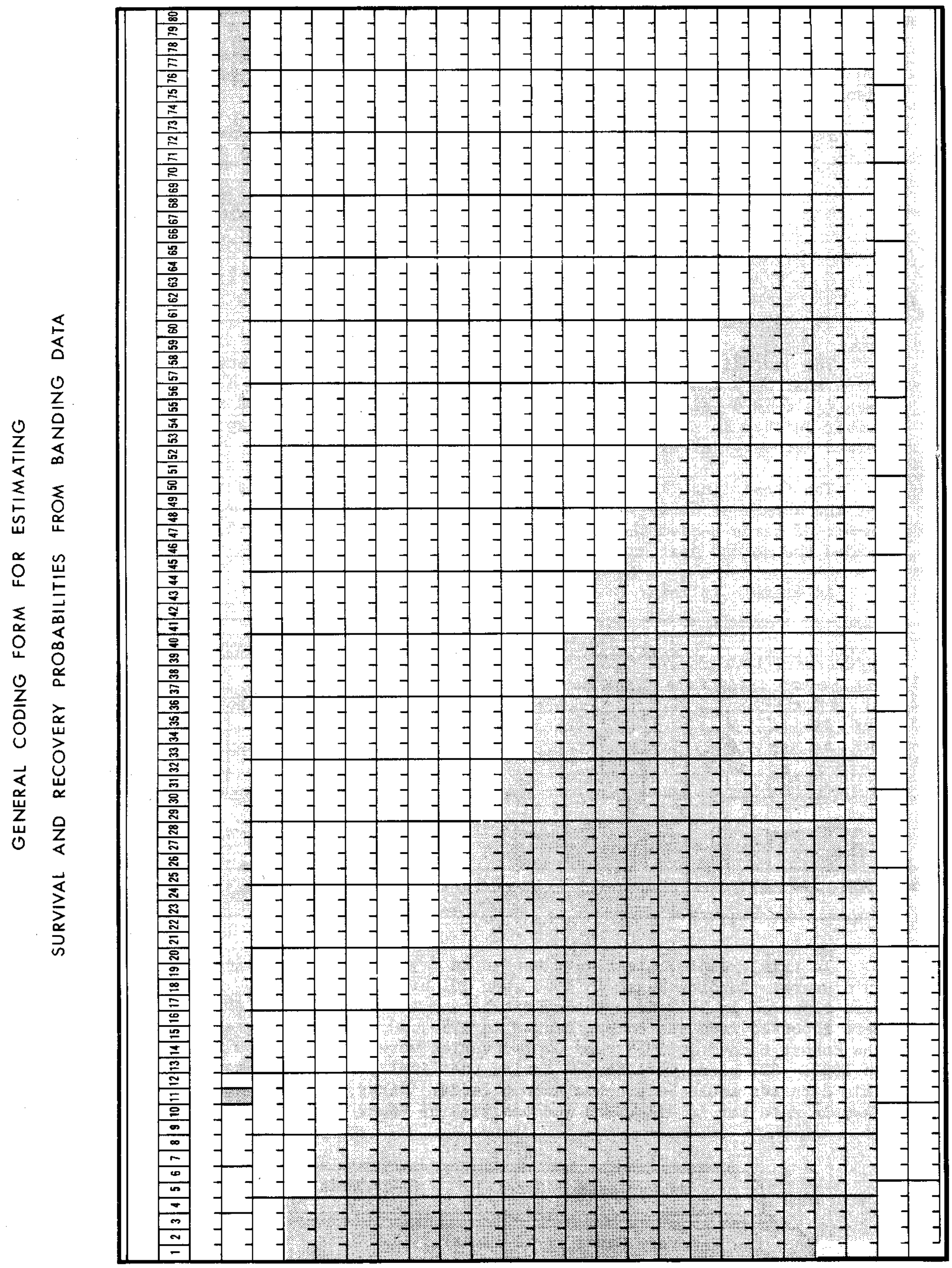


Figure 6.3 Coding instructions for adult and young recovery data.

Instructions for Program Brownie

The form is to be used in conjunction with the FORTRAN IV computer program to estimate age-specific survival and recovery rates from banding and recovery data (see Brownie and Robson. 1974. Cornell Biometrics Unit. Paper 514-M. 27pp). The information on this coding form is to be punched onto standard 80-column cards. Each line represents one card. All numbers must be integers (no decimal points) and must be in the right-most columns in each field. Nothing should be coded in the shaded areas of the form. No blank cards should be included.

The first line (card) is used to identify the data set: e.g., YOUNG AND ADULT MALLARDS BANDED IN SOUTHWESTERN SASKATCHEWAN, 1956 TO 1959. This is a Header Card and will identify the information on the computer output.

The second line (card) is a Parameter Card and contains 4 fields:

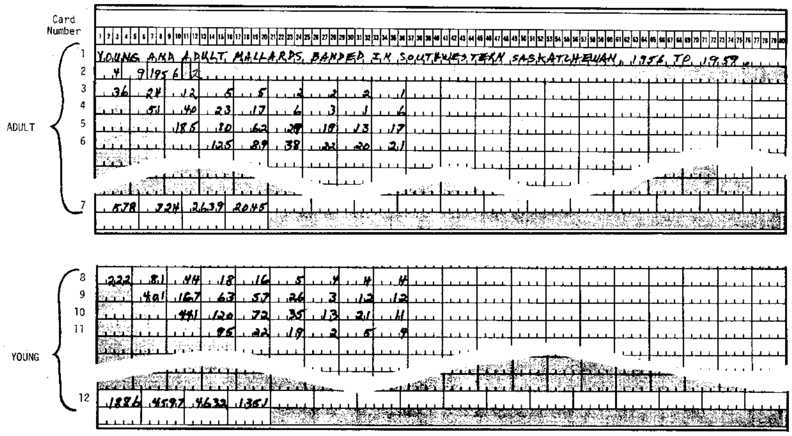
1. The number of years of banding must appear in columns 1-3 (maximum is 20).
2. The number of years of recovery must appear in columns 4-6 (maximum is 20).
3. The first year of the banding study must appear in columns 7-10 (e.g., 1950).
4. A numeric code to denote the type of analysis desired must appear in column 12:
   - 1 a statistical test that the survival and recovery rates are equal for adult males and adult females. If this case is specified, recovery and banding for adult males and adult females are entered, rather than age classes.
   - 2 parameter estimation and testing for banding studies involving both young and adult birds--this is the usual case and if this code is left blank, it is the default value. The adult recovery data and banding totals are entered before the associated information for young--see example below.
   - 3 parameter estimation and testing for banding studies involving young, subadult, and adult birds. In this case, three recovery matrices and banding totals are entered, in the following order: adult, young, and subadult.

[The next lines (group of cards) are for the array of recovery information. There must be a minimum of 2 years of recovery information and a maximum of 20. Each field is four columns wide. The number of these cards should agree with the number punched in columns 1-3 of the Parameter Card. This group of cards represents the recovery data for adults.

The next line (2 lines if more than 16 years of banding are involved) is for the number of adult birds banded each year. Each field is 5 columns wide. The number of adult birds banded the first year must appear in columns 1-5, the number banded the second year must appear in columns 6-10, etc.]

Information concerning the recovery data and banding totals for young are entered on the following cards--similar to the bracketed information above. A second coding form is required for coding the recovery and banding data for young birds (however, lines 1 and 2 should be ignored). The number of years of banding and recovery years must match those of the adult data. No column or row total in the recovery arrays should be zero.

An example follows for young and adult data (information for the test of males vs. females should be entered in a similar manner):



In this example birds were banded in 4 years and recoveries were recorded in 9 years (line 2). Banding began in 1956 when 578 adult birds and 1886 young birds were banded (lines 7 and 12). In 1956, 36 recoveries were reported from the adults banded in 1956 (line 3). In 1958, 167 recoveries were reported from the young birds banded in 1957 (line 9). 2045 adult birds and 1351 young birds were banded during the final year of the study (lines 7 and 12). This data set would be punched onto 12 cards (two coding forms would be required). Other data sets could follow. The order of the data cards is illustrated below for the two most common cases:

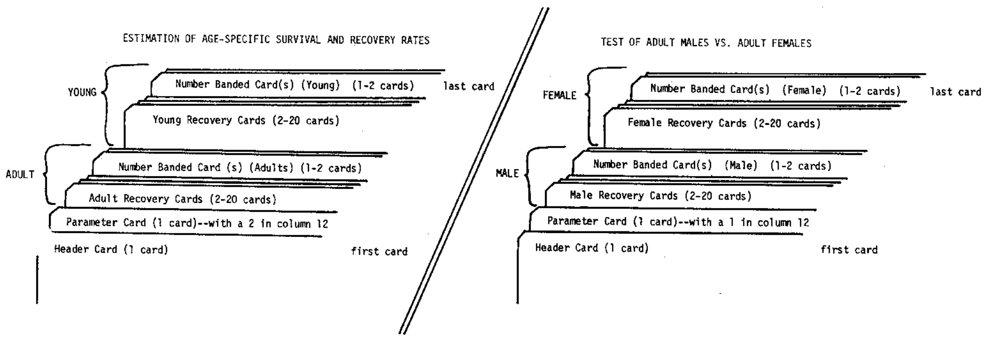


Figure 6.4 General coding form for adult and young recovery data.