FW663 -- Laboratory Exercise

Program MARK with Mark-Recapture Data

This exercise brings us to the land of the living! That is, instead of estimating survival from dead animal recoveries, we will now estimate survival from live animal recaptures. The basic model is the Cormack-Jolly-Seber (CJS) model. Instead of *S* and *r*, we will be estimating apparent survival φ and recapture probability *p*. Keep in mind the distinction between φ and *S*: $\varphi = SF = S(1 - E)$, where *F* is fidelity and equals 1 - *E* where *E* is emigration. That is, φ estimates the probability that the animal is still alive and remains on the study area available for recapture, in contrast to *S* which is the probability that the animal is still alive. We will be using Program MARK to compute estimates of φ and *p*.

The data we will be analyzing in this exercise concerns survival of male and female European Dippers from eastern France (Lebreton et al. 1992). Birds were banded for 7 consecutive years during early summer along streams, providing 6 re-encounter occasions. The 2 sexes are treated as 2 groups, and tests are constructed to test for differences between groups. The encounter histories matrix is available in the file

DIPPER.INP.

Copy this file to your local directory.

The purpose of this exercise is to get you familiar with manipulating the PIMs in MARK. Start with a model that has group and time-specific parameters for both φ and *p*. The appropriate PIMs for this model follow. The notation for this model from Lebreton et al. (1992) would be {φ(*g***t*) *p*(*g***t*)}. Check Table 1 at the end of this exercise to determine the proper number of parameters for this model. Question: how come the number of estimable parameters for this model is 22, not 24?

Model {φ(*g***t*) *p*(*g***t*)}.

Apparent Survival Parameter Index Matrices

Males, Group 1

1	2	3	4	5	6
	2	3	4	5	6
		3	4	5	6
			4	5	6
				5	6
					6

Females, Group 2

7	8	9	10	11	12
	8	9	10	11	12
		9	10	11	12
			10	11	12
				11	12
					12

Recapture Parameter Index Matrices

Males, Group 1

13	14	15	16	17	18
	14	15	16	17	18
		15	16	17	18
			16	17	18
				17	18
					18

Females, Group 2

19	20	21	22	23	24
	20	21	22	23	24
		21	22	23	24
			22	23	24
				23	24
					24

The following are the parameter index matrices for the model with the same time-specific φ and *p* estimates for each group. The Lebreton et al. notation for this model would be {φ(*t*) *p*(*t*)}, i.e., each group (gender) has the same time-specific parameter for each time, for both survival and recaptures. Question: how come the number of estimable parameters for this model is 11, not 12?

Model {φ(*t*) *p*(*t*)}.

Apparent Survival Parameter Index Matrices

Males, Group 1

1	2	3	4	5	6
	2	3	4	5	6
		3	4	5	6
			4	5	6
				5	6
					6

Females, Group 2

1	2	3	4	5	6
	2	3	4	5	6
		3	4	5	6
			4	5	6
				5	6
					6

Recapture Parameter Index Matrices

Males, Group 1

7	8	9	10	11	12
	8	9	10	11	12
		9	10	11	12
			10	11	12
				11	12
					12

Females, Group 2

7	8	9	10	11	12
	8	9	10	11	12
		9	10	11	12
			10	11	12
				11	12
					12

For this exercise, you should determine the best-fitting model for the series of models for all combinations of $g*t$, including no effect from either source, and try to find an improved model. One possibility is that the capture probabilities are the same for all years, but survival is different for each year. The Lebreton et al. notation for this model would be $\{\varphi(t)\ p(.)\}$. The parameter index matrices for this model would be

Model $\{\varphi(t)\ p(.)\}$.

Apparent Survival Parameter Index Matrices

Males, Group 1

1	2	3	4	5	6
	2	3	4	5	6
		3	4	5	6
			4	5	6
				5	6
					6

Females, Group 2

1	2	3	4	5	6
	2	3	4	5	6
		3	4	5	6
			4	5	6
				5	6
					6

Recapture Parameter Index Matrices

Males, Group 1

7	7	7	7	7	7
	7	7	7	7	7
		7	7	7	7
			7	7	7
				7	7
					7

Females, Group 2

7	7	7	7	7	7
	7	7	7	7	7
		7	7	7	7
			7	7	7
				7	7
					7

Another model you might want to try is constant survival for all times and groups, and constant recaptures for all times and groups. The Lebreton et al. model notation would be $\{\varphi(.)\ p(.)\}$, i.e., constant survival and recaptures. The parameter index matrices for this model are as follows.

Model {φ(.) *p*(.)}.

Apparent Survival Parameter Index Matrices

Males, Group 1

1	1	1	1	1	1
	1	1	1	1	1
		1	1	1	1
			1	1	1
				1	1
					1

Females, Group 2

1	1	1	1	1	1
	1	1	1	1	1
		1	1	1	1
			1	1	1
				1	1
					1

Recapture Parameter Index Matrices

Males, Group 1

2	2	2	2	2	2
	2	2	2	2	2
		2	2	2	2
			2	2	2
				2	2
					2

Females, Group 2

2	2	2	2	2	2
	2	2	2	2	2
		2	2	2	2
			2	2	2
				2	2
					2

Something else to think about is that years 2 and 3 were flood years, when the expected survival and/or recapture rates may be different from the rest. Test the hypothesis that parameters in these years are different than the remainder.

At a minimum, fit the following models and variations of them to the encounter histories to develop you model fitting skills with MARK:

{φ(.) *p*(.)} {φ(t) *p*(t)} {φ(g) *p*(g)} {φ(g*t) *p*(g*t)} .

Determine which of the above models provides the best fit, and try to improve on the fit of this model with additional models. Compare your results with the analysis presented in Lebreton et al. (1992), and the table below.

The following is for later, after you understand the use of the Design Matrix. If you already know about use of the design matrix, you are ready to generate models that incorporate time as a continuous variable, i.e., *T*. Instead of specifying the time covariate as categorical, specify it as continuous, using the design matrix capability of Program MARK. Now, only 1 degree of freedom is used to model time, and the model examines trends in survival or recapture as linear functions. Generate results for the following models:

$\{\varphi(g+T)\ p(g+T)\}$
$\{\varphi(g+T)\ p(g)\}$
$\{\varphi(T)\ p(T)\}$

Questions for Consideration

1. Does the global model $\{\varphi(g*t)\ p(g*t)\}$ fit the data? Since we haven't talked about GOF yet, you probably can't answer this question. However, the solution involves running Program RELEASE from within MARK.

2. Is there evidence in the dipper data of sex-specific effects? What impact does the small sample size have on your conclusion?

3. Is there evidence in the dipper data of time-specific effects? What impact does the small sample size have on your conclusion?

4. How do you know when you are "over-fitting" the data? What is the danger of testing hypotheses suggested to you by the data? Vice versa, what is the danger of "under-fitting" the data?

5. How would you detect if animals emigrated from the study area, and hence φ is much less than S?

6. Is there evidence in the dipper data of sex-specific effects with a linear trend in time? No sex-specific effects and just a linear trend in time? No time trend? Note that you can't answer this question until you have learned to use the design matrix in MARK.

7. What does the graph of survival rates look like for the best-approximating model? For *p*? Note that MARK provides you with the capability to graph estimates directly using one

of the buttons at the top of the Results Browser window. Move your cursor across these buttons slowly to have a message pop up and learn what each does.

8. What is the danger of testing hypotheses suggested by the *T* model when one or more years do not conform to the linear model?

Literature Cited

Burnham, K. P., D. R. Anderson, G. C. White, C. Brownie, and K. H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society Monograph 5:1-437.

Lebreton, J.-D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: case studies and recent advances. Ecological Monographs 62:67-118.

Results

You should obtain the following results in your MARK Results Browser window when you have run all 16 possible models based on group, time, and dot for both φ and *p*.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par.	Deviance
{Phi(.) p(.) PIM}	670.866	0	0.41212	1	2	84.360551
{Phi(.) p(g) PIM}	672.2502	1.3842	0.20628	0.5005	3	83.716260
{Phi(g) p(.) PIM}	672.7331	1.8671	0.16203	0.3932	3	84.199093
{Phi(t) p(.) PIM}	673.998	3.132	0.08608	0.2089	7	77.252974
{Phi(g) p(g) PIM}	674.2468	3.3808	0.07601	0.1844	4	83.674702
{Phi(t) p(g) PIM}	675.5036	4.6376	0.04055	0.0984	8	76.681197
{Phi(.) p(t) PIM}	678.7481	7.8821	0.00801	0.0194	7	82.003060
{Phi(t) p(t) PIM}	679.5879	8.7219	0.00526	0.0128	11	74.473101
{Phi(g) p(t) PIM}	680.6496	9.7836	0.00309	0.0075	8	81.827159
{Phi(g*t) p(.) PIM}	685.1244	14.2584	0.00033	0.0008	13	75.763806
{Phi(g*t) p(g) PIM}	686.9215	16.0555	0.00013	0.0003	14	75.422480
{Phi(.) p(g*t) PIM}	689.1344	18.2684	0.00004	0.0001	13	79.773822
{Phi(t) p(g*t) PIM}	690.0335	19.1675	0.00003	0.0001	17	72.05640
{Phi(g*t) p(t) PIM}	690.9733	20.1073	0.00002	0	17	72.996173
{Phi(g) p(g*t) PIM}	691.2716	20.4056	0.00002	0	14	79.772560
{Phi(g*t) p(g*t) PIM}	700.4622	29.5962	0	0	22	71.473973

The modeling results including the flood models are in the DIPPER.DBF file included on the FW663 web site.

Table 1. Number of identifiable parameters in various Cormack-Jolly-Seber models. The parameter *t* is the number of time occasions (including the first capture occasion), *g* is the number of groups, and *T* is the linear effect over time. Note that *t* in this table is 1 greater than the number of re-encounter occasions used in Program MARK, i.e., *t* = number of encounter occasions, or *t* = number of re-encounter occasions + 1.

φ	*p*							
	*g*t*	*g+t*	*t*	*g*	*g*T*	*g+T*	*T*	-
*g*t*	*g(2t-3)*	*gt+t-3*	*(g+1)(t-1)-1*	*tg*	*g(t+1)*	*gt+1*	*g(t-1)+2*	*[(t-1)g]+1*
g+t	*gt+t-3*	*2(g+t)-5*	*2(t-2)+g*	*2g+(t-2)*	*3g+t-2*	*2g+t-1*	*g+t+1*	*g+t-1*
t	*(g+1)(t-1)-1*	*2(t-2)+g*	*2t-3*	*g+t-1*	*2g+t-1*	*g+t*	*t+1*	*t*
g	*tg*	*2g+(t-2)*	*g+t-1*	*2g*	*3g*	*2g+1*	*g+2*	*g+1*
*g*T*	*g(t+1)*	*3g+t-2*	*2g+t-1*	*3g*	*4g*	*3g+1*	*2g+2*	*2g+1*
g+T	*gt+1*	2g+t-1	*g+t*	*2g+1*	*3g+1*	*2(g+1)*	*g+3*	*g+2*
T	*g(t-1)+2*	*g+t+1*	*t+1*	*g+2*	*2g+2*	*g+3*	*4*	*3*
-	*[(t-1)g]+1*	*g+t-1*	*t*	*g+1*	*2g+1*	*g+2*	*3*	*2*

European Dipper Data – MARK Input File

Each bird is recorded as a separate encounter history. The three columns that follow each represent a line of input in the input file DIPPER.INP .

```
/* European Dipper
Data, Live
Recaptures, 7
occasions, 2 groups
 Group 1=Males Group
2=Females */
1111110  1 0 ;
1111100  0 1 ;
1111000  1 0 ;
1111000  0 1 ;
1101110  0 1 ;
1100000  1 0 ;
1100000  1 0 ;
1100000  1 0 ;
1100000  1 0 ;
1100000  0 1 ;
1100000  0 1 ;
1010000  1 0 ;
1010000  0 1 ;
1000000  1 0 ;
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1000000  1 0 ;
1000000  1 0 ;
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1000000  0 1 ;
1000000  0 1 ;
0111111  0 1 ;
0111111  0 1 ;
0111110  0 1 ;
0111100  1 0 ;
0111100  0 1 ;
0111100  0 1 ;
0111000  1 0 ;
0111000  0 1 ;
0110110  0 1 ;
0110000  1 0 ;
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0110000  1 0 ;
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The following input file provides the same exact analysis, but birds with the same encounter history have been aggregated, so the input file is much smaller. These encounter histories are in the file AGGREGATED_DIPPER.INP .

```
/* European Dipper Data, Live
Recaptures, 7 occasions, 2 groups
 Group 1=Males Group 2=Females */
0000001  17  22;
0000010  11  12;
0000011  12  11;
0000100   9   7;
0000110   3   6;
0000111  10   6;
0001000   6  10;
0001001   1   1;
0001011   0   1;
0001100   6   5;
0001110   3   4;
0001111   6   2;
0010000  11  18;
0010110   1   0;
0011000   8   4;
0011100   4   2;
0011110   1   1;
0011111   0   2;
0100000  11  18;
0110000   7   4;
0110110   0   1;
0111000   1   1;
0111100   1   2;
0111110   0   1;
0111111   0   2;
1000000   5   4;
1010000   1   1;
1100000   4   2;
1101110   0   1;
1111000   1   1;
1111100   0   1;
1111110   1   0;
```