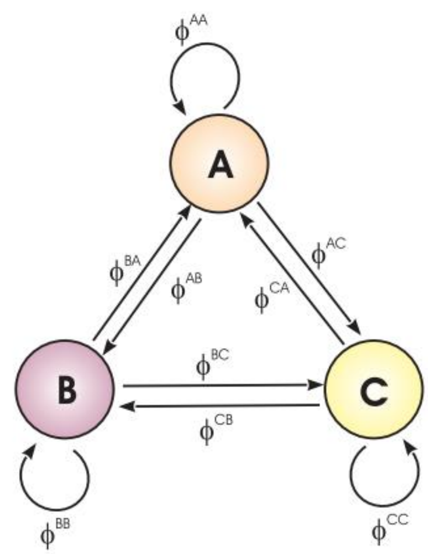
WILD 502
Lab 06 – Multi-strata models

This week's lab provides a hands-on exercise with multi-strata models. If you need help beyond what we've covered in class, you can use Chapter 10 of Cooch & White to help you in Program MARK. The exercise today considers data from animals in 3 different patches (A, B, & C) over 7 years that all belong to a single group. The data are live encounters of animals coded to indicate which patch the individual was captured in on each occasion; a '0' indicates that the animal was not caught on a given occasion. Because there are no individual covariates, the encounter histories sometimes provide data for >1 individual per row. If you examine the whole dataset, you'll see that transitions between all possible pairs of sites occur such that the figure below of transitions is appropriate.

lab06.inp

```
A000000 55;
ACC0000 1;
ACCCC00 1;
A00CCC0 1;
AA00000 5;
AAC0000 3;
A0CCC00 1;
A00A000 1;
AB00000 1;
AC00000 4;
A000C0C 1;
```



It's important to be clear about what the relevant parameters are here. As is so often the case, the Williams et al. book and the Cooch & White chapter (#10) are really useful here and complement each other nicely. We can think of the parameters in 2 different ways. First, as

> ϕ_i^{rs} = the probability that an animal alive in state r at time i is alive and in state s at time i+1
>
> p_i^s = the probability that a marked animal alive in state s at time i is recaptured or resighted at time i.

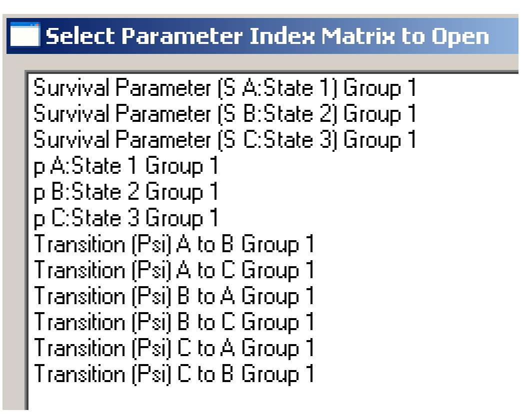
Thus, φ is the joint probability that an animal alive in state r at time i is alive and in state s at time $i+1$. So, it's the probability of surviving *and* making the transition.

In Program MARK, φ is split apart into survival (S) and transition (ψ) probabilities such that there are 3 types of parameters: S, ψ, and p. It's important to be very clear about what's being assumed here.   Chapter 10 of Cooch & White (page 10-4) sums it up nicely for us.

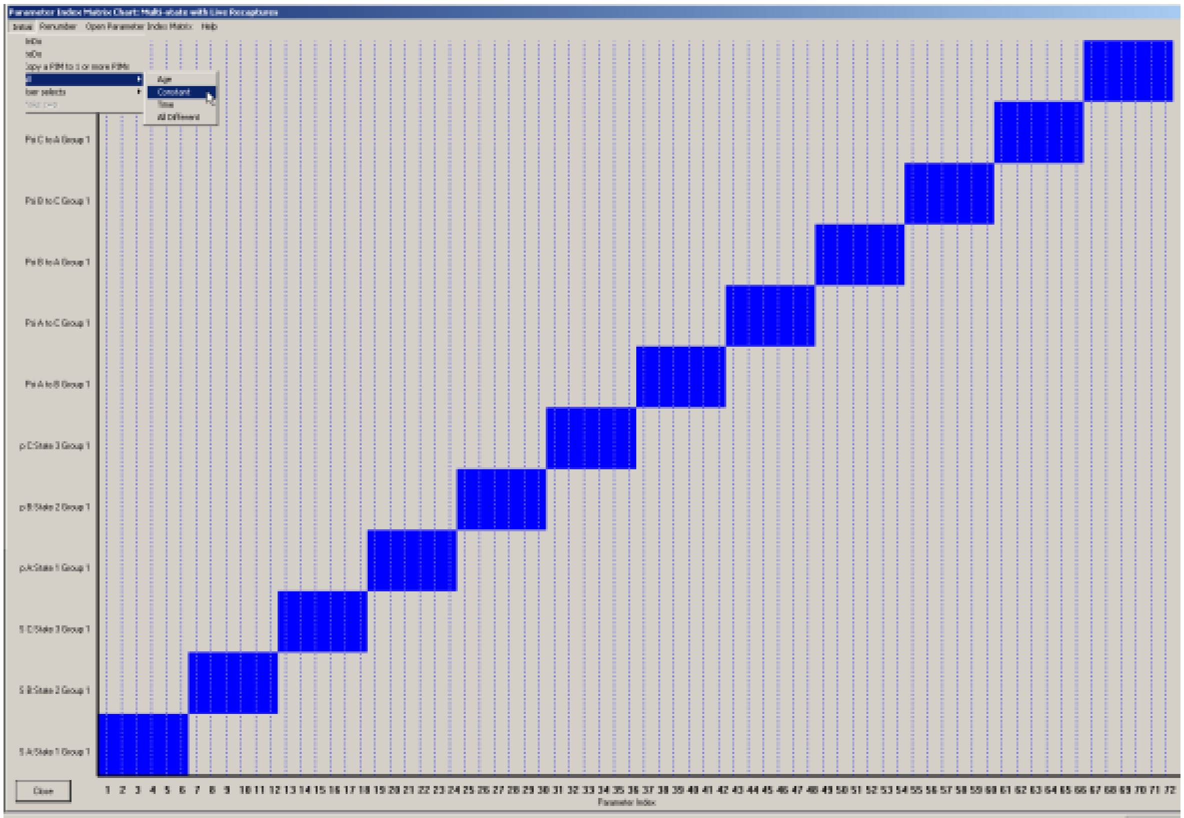
> *If we assume that survival from time i to i+1 does not depend on state at time i+1, then we can write*
>
> $$\phi_i^{rs} = S_i^r \psi_i^{rs}$$
>
> *where (i) S_i^r is the probability of survival from time i to $i+1$, given that the individual is in state r at time i , and (ii) ψ^{rs} is the conditional probability that an animal in state r at time i is in state s at time i+1, given that the animal is alive at i+1*

Note: although MARK labels the survival parameter as S, it may still represent apparent survival rather than true survival depending on whether or not patches A, B, and C include all the possible locations the animals may inhabit or not. Here, we'll use superscripts to indicate states and subscripts to indicate occasions. So, $\hat{S}_1^A$ represents the estimated survival rate between occasions 1 and 2 for animals that were in patch A at time 1. For ψ, we'll need to provide a 2-letter superscript to indicate both the starting and the ending patch, e.g., $\hat{\psi}_1^{AB}$ indicates the probability that an animal in state A at time 1 is in state B at time 2, given that the animal remains alive at 2 (this 'given' part is what makes the probability conditional, i.e., conditional on being alive).

Go ahead and set up a new *Multi-state Recaptures Only* project for this week's lab in MARK using *lab_06.inp*: 7 occasions, 1 group, 3 states (A, B, & C), and 0 individual covariates. Once you've done that, you should look at the PIMs that are available. You'll see that for 3 states & 1 group, we have state-specific PIMs for S (3) & p (3), as well as 6 PIMs for Psi that represent the probabilities of leaving a state (probability of staying, e.g., A to A, is obtained by subtraction).



By default, MARK will make each parameter time-varying. But, for the models you'll run this week, you won't need time variation. So, go ahead and use the PIM chart and its associated menus to make all parameters constant through time.



Once you've done this you'll have 12 parameters (3 S's, 3 p's, & 6 ψ's). Why are there only 6 ψ's and not 9? Well, if you have estimates of $\hat{\psi}_1^{AB}$ & $\hat{\psi}_1^{AC}$, then you can estimate $\hat{\psi}_1^{AA}$ as $1-\hat{\psi}_1^{AB}-\hat{\psi}_1^{AC}$. So, you only need to estimate 6 of the ψ's to be able to obtain estimates of all 9.

Lab Assignment

1. Run the models in the table below and provide a table of model-selection results.

Model #	Model Structure		
	Survival	***p***	***Transitions***
1	$S(.)$	$p(.)$	$\psi .^{rs}$, i.e., $\psi^{AB} \neq \psi^{AC} \neq \psi^{BA} \neq \psi^{BC} \neq \psi^{CA} \neq \psi^{CB}$
2	$S(.)$	$p(states)$	$\psi .^{rs}$
3	$S(states)$	$p(.)$	$\psi .^{rs}$
4	$S(states)$	$p(states)$	$\psi .^{rs}$

2. Describe the strength of evidence for the top-supported model and the structure of the top model.

3. Provide a table of real parameter estimates from the top model. Include SE's in parentheses after each parameter estimate. NOTE: $SE(1-\hat{\psi}_1^{AB}-\hat{\psi}_1^{AC})=\sqrt{\mathrm{var}(\hat{\psi}_1^{AB})+\mathrm{var}(\hat{\psi}_1^{AC})+2\cdot\mathrm{cov}(\hat{\psi}_1^{AB},\hat{\psi}_1^{AC})}$

State	**Parameter Estimates**	
	$\hat{p}.$	$\hat{S}.$
A		
B		
C		

Estimated Transition Rates ($\hat{\psi}_{.}^{rs}$)				
		From (time *t*)		
		A	**B**	**C**
To (time *t+1*)	**A**			
	B			
	C			

4. What inferences can you make about survival rates in the 3 different types of patches?

5. What inferences can you make about transition rates between the different patch types?

6. Based on the estimated rates, calculate how many animals would be alive and each patch at the end of 1, 2, 3, 4, & 5 years if you started with 1,000 animals in each type of patch at time 0. Show your work.

State	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
# in A	1,000					
# in B	1,000					
# in C	1,000					
TOTAL	***3,000***					

7. Based on your answer to question 6, what proportion of the total number of animals alive in the system in year *t* were still alive and in the system at *t+1*? Provide the total #s of animals and the annual rate of change for each pair of adjacent years? E.g., if 2,000 were still alive in year 1, you'd report 2,000 in row 3, column 2 and 2/3 in row 4, column 2. Describe any pattern that you see in the proportional distribution change over time.

	Yrs 0 & 1	Yrs 1 & 2	Yrs 2 & 3	Yrs 3 & 4	Yrs 4 & 5
# in year *t*	3,000				
# in year *t+1*					
Ppn remaining					

8. How does the proportional distribution of animals among patches change over time?

State	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Ppn in A	0.333					
Ppn in B	0.333					
Ppn in C	0.333					
TOTAL	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

9. How does the overall survival rate for the population in all 3 patches (question 7) compare with the patch-specific survival rates as time goes on? Why do you think that this is so?

10. Provide an example of a way in which multi-state models could be useful for a species of interest to you.

Please list any topics that you'd like to have further discussed on multi-state modeling.