F&WL 502
Lab 11 – Occupancy models for single-species, multi-season

Today's lab will be based on exercise 4 that is provided with Program PRESENCE. The dataset consists of detection/non-detection of northern spotted owls on multiple sites in multiple seasons (first year = 1997). We will model rates of (1) occupancy, (2) detection, (3) colonization, and (4) extinction. Here, we'll use the parameters ψ for occupancy rate, p for detection rate, γ for colonization rate (going from un-occupied to occupied from 1 year to the next), and ε for the local extinction rate (from 1 year to the next). Given this, $(1-\varepsilon)$ is the rate at which occupied sites remain occupied, and $(1-\gamma)$ is the rate at which un-occupied sites remain un-occupied.

		t	
		Occupied	Not occupied
t+1	Occupied	$(1-\varepsilon)$ Local persistence	γ Colonization
	Not occupied	ε Local extinction	$(1-\gamma)$

1. Start Program PRESENCE, click "File/New Project," provide a title (e.g., "owl multi-season"), choose to use the dataset "nso.pao", record the information presented on sites, occasions, and occasions/season, and then click on "OK".
    a. How many total sites, occasions, and seasons were used in the study?
    b. How many occasions per season were there?
    c. Were any covariates present in the dataset for either sites or occasions?
    d. View the data and report on whether all sites were visited on all occasions or not. If they were not, how often does it appear that most sites were visited (just a ballpark estimate from looking at the data for a bit).

2. You're now presented with a 'Results Browser' window. To run our first model, click Run/Analysis:multi-season' from the menu-bar. This now spawns 2 windows: (a) 'Setup Numerical Estimation Run' window and (b) a 'Design Matrix' window. Focus your attention on the 'Setup' window and notice that we have 4 possible model parameterizations. For now, we'll use the first (default) option. Next, manipulate the Design Matrix and run a model, we'll call 'psi,gamma(.),eps(.),p(yr)' because the initial occupancy rate is the same for all sites (remember, we're only estimating the <u>initial occupancy rate</u> with this parameterization of the model), colonization and extinction are held constant across years, and detection varies by season but is held constant within a season for all sites.
    a. Report $\hat{\psi}$, $\hat{\gamma}$,& $\hat{\varepsilon}$ (and their associated SE's).
    b. Based on the estimates of p_i, does it appear that there was time variation in detection rate? Explain.

    NOTE: it turns out that researchers working with these data found strong evidence of year-specific estimates of detection, so we'll stay with that structure throughout all of our modeling.

We will evaluate hypotheses represented by 6 different models.

- Model 1 = <u>no change in occupancy</u> $=\psi(.), p(year)$, which hypothesizes that the occupancy status doesn't change among years. We achieve this by fixing $\hat{\gamma}$,& $\hat{\varepsilon}$ = 0 (do this on the 'Setup Numerical Estimation Run' window by using the 'Fix Parameters' button.

- Model 2 = random changes in occupancy = $\psi(1997)$, $\varepsilon=(1-\gamma)$, $p(year)$. This may not apply well to this species, but it is a model of interest if you think that the probability that a breeding pair will occupy a site in the next year is independent of whether the site is occupied or not in the current year (such as might be expected if site fidelity is low or site choices are made at random over the set of sites being studied). We get at this hypothesis by setting $\varepsilon=(1-\gamma)$ in each year. In Model 2, we'll hold colonization and extinction rates constant through time. In Model 3, we'll allow colonization and extinction rates to vary across years. By comparing results for Models 2 & 3, we can evaluate whether colonization and extinction appear to be time-varying or not. To run these two models, we need a different model parameterization than the default on the 'Setup Numerical Estimation Run' window so go ahead and choose the last option. Before you run Model 2, be sure to
    - set detection to be year specific and
    - **clear any fixed parameter values that you may have set up previously**.

- Model 3 = random changes in occupancy = $\psi(1997)$, $\gamma(\text{year})\{\varepsilon=(1-\gamma)\}$, $p(year)$. One way to evaluate equilibrium is by checking whether colonization and extinction rates vary in time (another way, as nicely discussed by MacKenzie et al. in their book is to check whether or not occupancy rates are constant through time; the 2 approaches are not equivalent and both can be evaluated). If local extinction and colonization rates are constant, the population's occupancy rate may be at, or headed for, an equilibrium level.

- Model 4 = $\psi(1997)$, $\gamma(.),\varepsilon(.)$, $p(year)$ - this model does not set $\varepsilon=(1-\gamma)$ and thus the probability of being occupied at time $t+1$ is allowed to depend on the occupancy state at time t, i.e., it can follow a 1st-order Markovian process. Think about this for a bit: if extinction rate (ε) is different from $(1-\gamma)$ (which is the rate at which empty patches stay empty), (or conversely, if $(1-\varepsilon)$ is different from γ), then the probability that a site will change states depends on what state it is in currently. Model 4 holds the local extinction and colonization rates constant while allowing them to be different from one another. To set this model up, use the default model parameterization on the setup window.

		t	
		Occupied	Not occupied
t+1	Occupied	$(1-\varepsilon)$	γ
	Not occupied	ε	$(1-\gamma)$

Markovian example		t	
		Occupied	Not occupied
t+1	Occupied	0.8	0.6
	Not occupied	0.2	0.4

Non-Markovian example		t	
		Occupied	Not occupied
t+1	Occupied	0.8	0.8
	Not occupied	0.2	0.2

Model 4 holds the local extinction and colonization rates constant through time while allowing them to be different from one another. To set this model up, use the default model parameterization on the setup window.

- Model 5 = $\psi(1997)$, $\gamma(\text{year}),\varepsilon(year)$, $p(year)$ - this model allows local extinction and colonization rates to be different from one another and to vary over time, which is a non-equilibrium version of Model 4 (so, Model 4 can be seen as the equilibrium version of this pair).

- Model 6 = $\psi(.), \gamma(.), p(year)$, which like Model 1 and unlike Models 2-5 suggests that occupancy is constant over years. This model allows colonization to occur but holds it constant through the years. For occupancy rate to be constant, the local extinction rate must also be constant. If this is true, then local extinction rate (ε) is defined completely by occupancy rate (ψ) and colonization rate (γ), where $\varepsilon = \gamma \cdot \frac{(1-\psi)}{\psi}$. Because ε is a derived parameter in this model, we drop it from the model name to make that point clearer. To achieve this model, we use yet a different model parameterization on the 'Setup Numerical Estimation Run' window. For this model, use the 2nd option (Seasonal occupancy [which we'll hold constant], and colonization, detection).

3. Once you've run all 6 models, look at the Results Browser window. If you click the right button on your mouse, you can see options for printing the results. If you've done the modeling right, you'll get the following -2*ln(L) scores for models 1 through 6: (1) 1542.56, (2) 1429.53, (3) 1429.32, (4) 1337.52, (5) 1327.64, and (6) 1337.95. Once you've achieved those values, provide your model-selection results and write-up a paragraph on what you learned about the 6 hypotheses described by the 6 competing models.

4. What are your best estimates of occupancy rate, colonization rate, and the rate of local extinction from the top model?

5. Does it appear that changes in occupancy are best represented by a random process, a Markov process, or a process with no changes in occupancy? Explain.

6. What are your annual estimates of *p*? Based on those estimates, does it appear that one can count on having $p^* = 1.0$ if one does 3 surveys in any year, most years, all years? Explain.