Multi-strata Model for Live Recaptures

The multi-strata model of Brownie et al. (1993) and Hestbeck et al. (1991) allows animals to move between strata with transition probabilities. These models are an extention of the Cormack-Jolly-Seber model (CJS) (Cormack 1964, Jolly 1965, Seber 1965) live recapture model extended to multiple areas or strata. Define the probability of survival for an animal during interval i on strata j as S_{ij}, and the probability that the animal is captured during encounter occasion i on strata j as p_{ij}. In addition, the probability that an animal moves from strata j to strata k during interval i is ψ_{ijk}. If the ψ_{ijk} have the constraint that

$$\sum_{k=1}^{K} \psi_{ijk} = 1,$$

estimation is possible. The effect of this constraint is that animals that move off all the strata in the study, i.e., move outside the study area, cause the estimates of survival to be biased in the sense that "apparent survival" is estimated. That is, emigration off all the strata in the study results in "apparent survival" being survival times the probability that the animal remains on the study area.

A simple example will make this model clearer. Assume that 3 strata are sampled: A, B, and C. Encounter histories must include the information of which strata an animal was captured on. Thus, instead of using a "1" to indicate capture, we use the strata label. For 5 encounter occasions, a history such as

BCACC

could result. That is, the animal was initially captured on strata B, captured on strata C during the second occasion, captured on strata A on the third occasion, captured on strata C on the fourth occasion, and then on strata C on the fifth occasion. The cell probability describing this encounter history is

$$[S_{1B}\ \psi_{1BC}\ p_{2C}]\ [S_{2C}\ \psi_{2CA}\ p_{3A}]\ [S_{3A}\ \psi_{3AC}\ p_{4C}]\ [S_{4C}\ (1 - \psi_{4CA} - \psi_{4CB})\ p_{5C}],$$

where intervals between occasions are separated within brackets. Note that for the fourth interval, the probability of remaining on strata C is just 1 minus the sum of the probabilities of leaving strata C. This cell probability demonstrates a key assumption of this model: survival is modeled with the survival rate for the strata where the animal was captured, and then movement to a new strata takes place. That is, all mortality takes place before movement. An animal cannot move to a new strata where a different survival rate pertains, and then die. If it dies, it must do so on the current strata. If it lives, then it can move to a new strata. This assumption is critical if survival rates are different between the strata. If survival is constant across the strata, then the assumption is not important. Biologically, this assumption is difficult to accept, and limits the usefulness of the model.

The nastiness that results when an animal is not captured (i.e., a 0 is in the encounter

history) is difficult to demonstrate without matrix algebra. However, to give you a feeling for what happens, consider the encounter history

BC0CA .

The 0 on occasion 3 can be explained by 3 possibilities: the animal remained on C and was not captured:

$$S_{2C}(1 - \psi_{2CA} - \psi_{2CB})(1 - p_{3C})S_{3C}(1 - \psi_{3CA} - \psi_{3CB})p_{4C} ,$$

or the animal moved to strata A and was not captured, and then moved back to C:

$$S_{2C}\psi_{2CA}(1 - p_{3A})S_{3A}\psi_{3AC}p_{4C} ,$$

or the animal moved to strata B and was not captured, and then moved back to C:

$$S_{2C}\psi_{2CB}(1 - p_{3B})S_{3B}\psi_{3BC}p_{4C} .$$

For both of the cases where the animal moved, it has to return to strata C, because it was captured on strata C during the fourth occasion.

The number of parameters in this simple example is already large. There are 3 strata-specific survival rates for each interval, and 3 strata-specific capture probabilities for the last 4 occasions. In addition, each interval i has the transition probabilities ψ_{iAB}, ψ_{iAC}, ψ_{iBC}, ψ_{iBA}, ψ_{iCA}, and ψ_{iCB}. Thus, a total of 12 PIMs are created in Program MARK to estimate these parameters.

At this time, only the movement model without memory is implemented in Program MARK. Brownie et al. (1993) describe more complex models where the animal remembers where it was on the previous occasion. This memory model requires a very large amount of data to provide reasonable estimates because the number of parameters grows quickly, even more so than the model considered above.

Literature Cited

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