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SHORT COMMUNICATION

TAG LOSS AND THE MULTI-SAMPLE SINGLE RECAPTURE CENSUS

Summary: Tag loss caused by an underlying Poisson process biases downwards the estimate(s) of the survival parameter(s) in a multi-sample single recapture census. A simple approximate correction is possible in this case. The less plausible assumption of homogenous tag loss is also examined and it is shown that the survival parameter(s) again can be simply corrected.

Keywords: negative exponential; tag loss; multi-sample single recapture.

Introduction

The first multi-sample, single recapture census model was developed by Seber (1962). In this model N_i adult animals are released at the start of the ith year i = 1,2...,I. Those animals that are subsequently caught are not released again. Let R_{ij} be the number recovered in year j from the adults released at the start of the ith year, i= 1,2,...,I; j=i,...,J (Table 1). Thus R_i is the ith row total, C_j is the jth colum total in Table 1. Let the block totals be defined by

$T_1=R_1$

$T_i=R_i+T_{i-1} - C_{i-1}$, i=2,..,I , and if J >I then

$T_{I+k}=T_{I+k-1} - C_{I+k-1}$, k= 1,2,...,J-1.

For this model the two basic parameters are a survival rate S per year and a recovery rate f per year. The expected recoveries are as in Table 2. The maximum likelihood estimates are

$f_i= \frac{R_i C_i}{N_i T_i}$ = 1,2,...,J and

$S_i = \frac{R_i}{N_i} \frac{T_i - C_i}{T_i} \frac{N_{i+1}}{R_{i+1}}$, i=1,2,...,J-1

Nelson, Anderson and Burnham (1980) studied the effects of tag loss on the multi-sample single recapture census. They found that survival rates are only slightly negatively biased and concluded that tag loss is only a problem with long lived species experiencing especially severe tag loss. They also found that recovery rates are mostly affected by initial tag loss. Their interest in birds led them to postulate tag retention rate functions of time which were either a straight line or a concave downwards curve. Beverton and Holt (1957) and Gulland (1963) assumed a function curving the other way for fish, namely a negative exponential which arises from a Poisson process. Sometimes tags are insecurely attached and a number falloff fairly quickly or the animals themselves try to dislodge the tags. Nelson *et al.* (1980) mention that this happens for raptorial species. Mills (1972) refers.to earlier studies which indicate that

Table 1: *Table of actual recoveries for Seber's model.*

Year released	Number released	Year of recovery 1	2	3	4	5=J	Row totals
1	N_1	R_{11}	R_{12}	R_{13}	R_{14}	R_{15}	$R_1=T_1$
2	N_2		R_{22}	R_{23}	R_{24}	R_{25}	R_2
3=I	N_3			R_{33}	R_{34}	R_{35}	R_3
Column totals		C_1	C_2	C_3	C_4	$C_5=T_5$	

Table 2: *Expected recoveries for Seber's model.*

Year tagged	Number tagged	Expected recoveries $E(R_{ij})$ 1	2	3	4
1	N_1	N_1f_1	$N_1S_1f_2$	$N_1S_1S_2f_3$	$N_1S_1S_2S_3f_4$
1	N_2		N_2f_2	$N_2S_2f_3$	$N_2S_2S_3f_4$
3	N_3			N_3f_3	$N_3S_3f_4$

Table 3: *Expected recoveries for Seber's model with negative exponential tag loss.*

Number tagged	Expected recoveries $E(R_{ij})$ 1	2	3	4
N_1	$N_1\theta_0f_1$	$N_1\theta_0\theta S_1f_2$	$N_1\theta_0\theta^2S_1S_2f_3$	$N_1\theta_0\theta^3S_1S_2S_3f_4$
N_2		$N_2\theta_0f_2$	$N_2\theta_0\theta S_2f_3$	$N_2\theta_0\theta^2S_2S_3f_4$
N_3			$N_3\theta_0f_3$	$N_3\theta_0\theta S_3f_4$

herring gulls *(Larus argentatus)* actively remove tags. Thus it seems reasonable to consider the case of an initial tag retention rate of θ_0 followed by a tag retention rate of θ for each succeeding year (Table 3).

With this pattern of tag loss we note that each S has a θ that may be bracketed with it leaving θ_0 to be bracketed with the remaining f. Thus $E(\hat{f}_i) = \theta_0 f_i$ and $E(\hat{S}_i) \approx \theta S_i$ Thus both $\hat{f}_i$ and $\hat{S}_i$ are biased. For this pattern of tag loss the effects of initial and post-initial losses are completely separated. If approximately unbiased estimates of θ_0 and θ are available from an independent survey let

$\hat{f}_i^c = \dfrac{\hat{f}_i}{\hat{\theta}_0}$ and $\hat{S}_i^c = \dfrac{\hat{S}_i}{\hat{\theta}}$ be the corrected estimates. Then

using the delta method $E(\hat{f}_i^c) \approx f_i + \dfrac{f_i}{\theta_0^2} Var(\hat{\theta}_0)$

standard error of θ_0 is fairly small, say less than 0.1, and θ_0 bigger than 0.9 then the bias may be neglected. If it is not possible to neglect the bias then a programme of double tagging needs to be instituted but this is beyond the scope of this note. Also by the delta method

$$Var(\hat{f}_i^c) \approx \frac{1}{\hat{\theta}_0^2} Var(\hat{f}_i) + \frac{\hat{f}_i^2}{\hat{\theta}_0^4} Var(\hat{\theta}_0)$$

Similarly for $\hat{S}_i^c$.

Brownie *et al.,* (1978) extended the range of multi-sample single recapture census models. Seberís model became their model 1. Model 0 allowed for a different capture rate in an animalís first year of release. Model 2 assumed constant survival rates from year to year. Model 3 assumed constant capture rates as well. The above simple correction for tag loss may be applied to all these models even where explicit formulae for $\hat{f}_i$ and $\hat{S}_i$ are not possible. Brownie *et al.* (1978) also considered some models where young and or sub-adults were released as well. If we are prepared to accept that tag retention rates are the same for adults, sub-adults and young then this correction may be applied to these models as well.

Amason and Mills (1981) examined the Jolly-Scber method for homogenous tag loss, that is the tag retention rate for the jth year is θ_j and is thus independent of the age of the tag. The expected recoveries under homogenous tag loss are as in Table 4. Then $E(\hat{f}_i) = \theta_i f_i$, i=1,2,....,J and $E(\hat{S}_i) \approx \theta_i S_i$, i= 1,2, ...,J-1. Thus a similar correction can be made provided θ_i is calculated from an independent survey.

Other patterns of tag retention rates cause the effects of initial and post-initial losses to be confounded and hence simple corrections are not generally available.

Table 4: *Expected recoveries for Seber's model With homogeneous tag loss.*

Number tagged	Expected recoveries $E(R_{ij})$ 1	2	3	4
N_1	$N_1\theta_1 f_1$	$N_1\theta_1\theta_2 S_1 f_2$	$N_1\theta_1\theta_2\theta_3 S_1 S_2 f_3$	$N_1\theta_1\theta_2\theta_3\theta_4 S_1 S_2 S_3 f_4$
N_2		$N_2\theta_2 f_2$	$N_2\theta_2\theta_3 S_2 f_3$	$N_2\theta_2\theta_3\theta_4 S_2 S_3 f_4$
N_3			$N_3\theta_3 f_3$	$N_3\theta_3\theta_4 S_3 f_4$

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