Mark-recapture methods for estimating survival and recruitment

Outline

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$$\hat{S} = \frac{\hat{M}}{R} \quad \text{where} \quad \hat{M} = \frac{m}{\hat{p}}$$

Tag recovery models

Purpose

Estimate survival from recovered tags

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Benefit

Because hunters are just about everywhere, we don't have to worry about animals leaving 'the study area' and we can estimate actual survival.

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- Animals are marked and released
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Three release years followed by 3 years of recoveries:

Number released	Period recovered		
	1	2	3
R_1	$m_{1,1}$	$m_{1,2}$	$m_{1,3}$
R_2		$m_{2,2}$	$m_{2,3}$
R_3			$m_{3,3}$

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Parameters

- Survival (S)
- Recovery rate (f)

Expected values

Period released	Number released	Period recovered		
		1	2	3
1	R_1	$R_1 f_1$	$R_1 S_1 f_2$	$R_1 S_1 S_2 f_3$
2	R_2		$R_2 f_2$	$R_2 S_2 f_3$
3	R_3			$R_3 f_3$

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Period released	Number released	Period recovered		
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2	R_2		$R_2 f_2$	$R_2 S_2 f_3$
3	R_3			$R_3 f_3$

Software programs like `MARK` find the most likely values of S and f, given the data.

Assumptions

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- No tag loss, mis-identification, etc...
- All animals have common survival and recovery rates
- Fates are independent

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Extensions

- Age-specific models
- Grouping variables
- Time variables
- Habitat variables

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A random sample of animals is marked and followed over many periods (usually years)

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- So, we often have to estimate "apparent survival" (Φ) instead of actual survival (S)

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A random sample of animals is marked and followed over many periods (usually years)

Notes

- When permanent emigration is possible, we can't be sure if an animal died or left study area
- So, we often have to estimate "apparent survival" (Φ) instead of actual survival (S)
- Apparent survival is the probability that an individual survives and does not permanently emigrate out of the study area

In CJS studies, we ignore the leading zeros in the capture histories because we aren't interested in how animals enter the sample

	Year 1	Year 2	Year 3
Animal 1	1	0	0
Animal 2		1	0
Animal 3			1
Animal 4	1	1	1
Animal 5		1	1

In CJS studies, we ignore the leading zeros in the capture histories because we aren't interested in how animals enter the sample

All we care about is survival, so we "condition" on first encounter

	Year 1	Year 2	Year 3
Animal 1	1	0	0
Animal 2		1	0
Animal 3			1
Animal 4	1	1	1
Animal 5		1	1

Estimation is accomplished by finding the values of p and Φ that best align the expected values with the observed capture histories

Capture history	Expected values
111	$\Phi_1 p_2 \Phi_2 p_3$
110	$\Phi_1 p_2 (1 - \Phi_2 p_3)$
101	$\Phi_1 (1 - p_2) \Phi_2 p_3$
100	$(1 - \Phi_1) + \Phi_1 (1 - p_2)(1 - \Phi_2 p_3)$

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- Same as tag-recovery, plus...
- Instantaneous recapture and release of animals
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Model can be extended to accommodate variation due to. . .

- Age
- Sex
- Habitat
- Geographical regions

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Randomly sample the population during every period and mark all newly captured unmarked animals

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Examples

- Constant-effort mist-netting
- Long-term small mammal trapping

We no longer “condition” on first encounter – Instead, we use all the data.

The leading zeros provide information about when individuals are recruited into the population

	Year 1	Year 2	Year 3
Animal 1	1	0	0
Animal 2	0	1	0
Animal 3	0	1	1
Animal 4	1	1	1
Animal 5	0	1	1

Assumptions

- All the assumptions of CJS model, plus...
- Every animal — marked or unmarked — has the same probability of capture

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The standard JS model doesn't work very well, but it is extremely powerful when combined with *the robust design*.

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Relax assumptions and increase precision by collecting more data

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Key concept

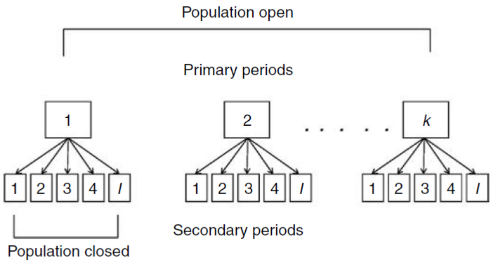
We now have two types of sampling periods:

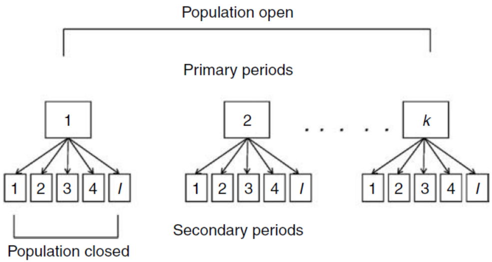
(1) Primary sampling periods between which the population is assumed to be demographically open

(2) Secondary sampling periods over which the population is assumed closed

The replicate surveys with each primary period give us direct information about capture probability, which makes it easier to estimate the other parameters.

Robust design capture histories





Example with 2 primary periods and 3 secondary periods

	Primary period 1			Primary period 2		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Animal 1	0	0	1	1	0	0
Animal 2	0	0	0	0	0	0
Animal 3	0	0	0	1	0	0
Animal 4	1	1	1	0	0	0
Animal 5	0	0	0	1	1	0

Method	Data	Survival	Recruitment	Abundance
Tag recovery	Recoveries	Yes	No	No
CJS	Mark-recap	Yes[1]	No	No
JS	Mark-recap	Yes[1]	Yes	Yes

Each of these three methods is widely used in practice. The best option depends on the objectives

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[1] Apparent survival