Lecture 13

Estimating survival: Open capture-mark-recapture models

WILD6900 (Spring 2020)

Readings

> Kéry & Schaub 171-239
>
> Powell & Gale chp. 10

From closed-population models to open-population models

All CMR studies have a similar basic design:

During each sampling occasion

- individuals are captured
- marked or identified
- released alive

But whats happens next?

- In the M_0 model, we assumed the population was closed to any change in N during our study
    - No births, deaths, emigration, or immigration
    - Any 0 in the capture histories was due to detection error

From closed-population models to open-population models

Open population models relax this assumption

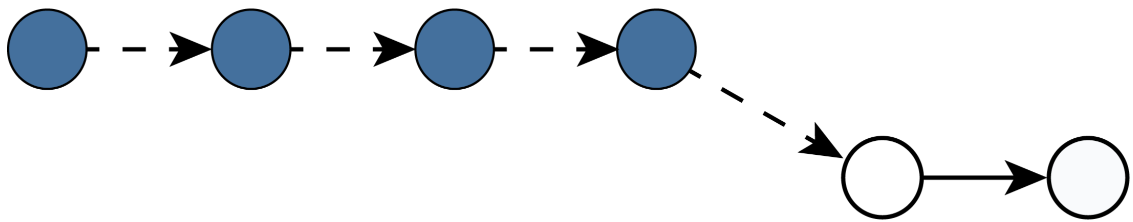
- Individuals can enter (births or immigration) or leave the population (deaths or emigration) between sampling occasions
- 0's in the capture histories could be because individuals are there but not detected or because they are not there

Many different forms of open population models

- Allow estimation of:
    - survival
    - recruitment
    - movement

Open-population models

In this lecture, we will focus on estimating survival/emigration



Open-population models

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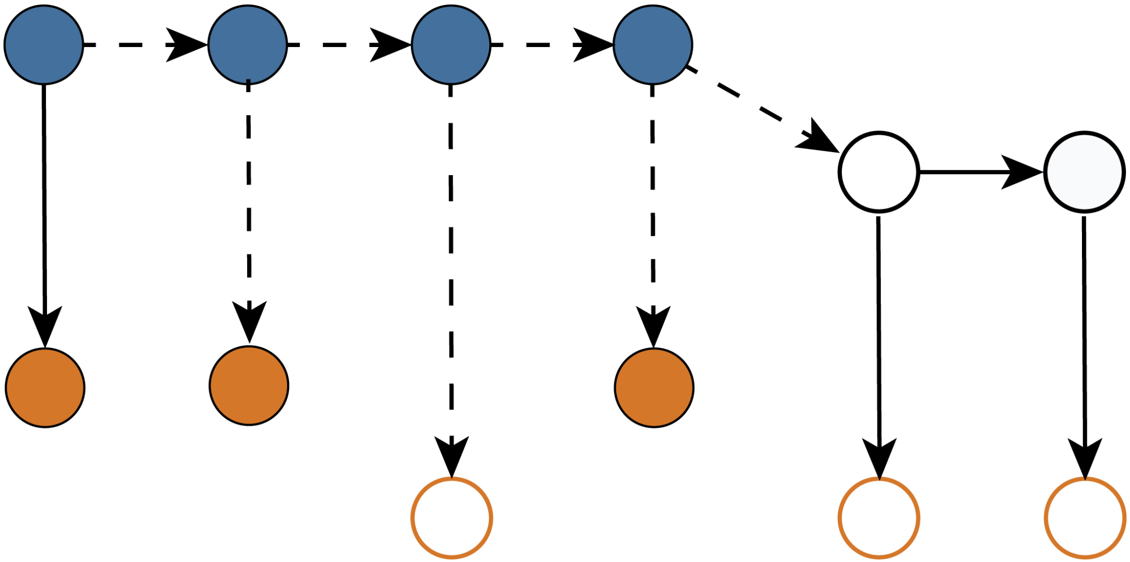

- *Condition on first capture*

Open-population models

On the occassion after release, 4 possible scenarios:

- 1) Individual survives and is re-captured (capture history = `11`)
- 2) Individual survives but is not recaptured (capture history = `10`)
- 3) Individual dies and is **not available** for recapture (capture history = `10`)
- 4) Individual survives but leaves the study area and is **not available** for recapture (capture history = `10`)

Open-population models

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- 3) Individual dies and is **not available** for recapture (capture history = `10`)
- 4) Individual survives but leaves the study area and is **not available** for recapture (capture history = `10`)

Not possible to distuingish between scenarios 3 & 4 without additional data

- $\phi_t = s_t \times (1 - \epsilon_t)$
- ϕ_t: **Apparent survival** (prob. individual survives *and* remains within study area)

Cormack-Jolly-Seber model

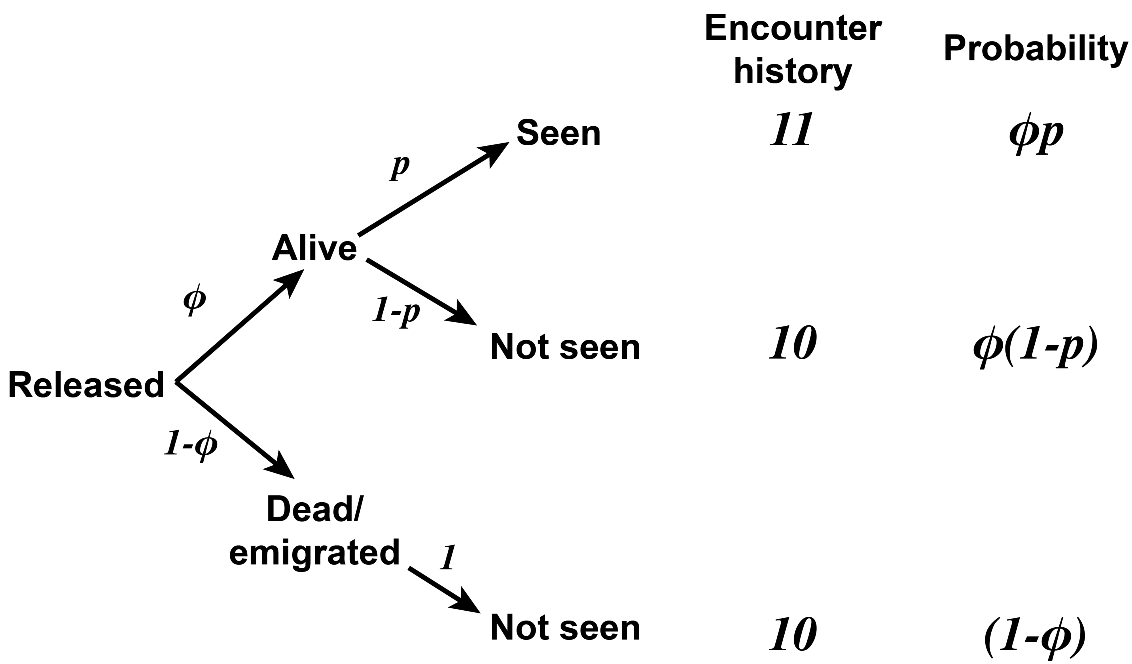
How do we distinguish between scenarios 2 & 3/4?

CJS model

- Parameters
    - ϕ: Apparent survival probability
    - p: Recapture probability

Cormack-Jolly-Seber model

How do we distinguish between scenarios 2 & 3/4?



Cormack-Jolly-Seber model

Individual	Capture history	Probability
Indv 1	111	$\phi_1 p_2 \phi_2 p_3$
Indv 2	101	
Indv 3	110	
Indv 4	100	

Individual 1

- survived interval 1 (ϕ_1), recaptured on occasion 2 (p_2), survived occasion 2 (ϕ_2), recapture on occasion 3 (p_3)

Cormack-Jolly-Seber model

Individual	Capture history	Probability
Indv 1	111	$\phi_1 p_2 \phi_2 p_3$
Indv 2	101	$\phi_1(1-p_2)\phi_2 p_3$
Indv 3	110	
Indv 4	100	

Individual 2

- survived interval 1 (ϕ_1), not recaptured on occasion 2 $(1-p_2)$, survived occasion 2 (ϕ_2), recapture on occasion 3 (p_3)

Cormack-Jolly-Seber model

Individual	Capture history	Probability
Indv 1	111	$\phi_1 p_2 \phi_2 p_3$
Indv 2	101	$\phi_1 (1 - p_2) \phi_2 p_3$
Indv 3	110	$\phi_1 p_2 \phi_2 (1 - p_3) + (1 - \phi_2)$
Indv 4	100	

Individual 3

- survived interval 1 (ϕ_1), recaptured on occasion 2 (p_2)
    - survived occasion 2 (ϕ_2), not recaptured on occasion 3 $(1 - p_3)$; **or**
    - died during occasion 2 $(1 - \phi_2)$

Cormack-Jolly-Seber model

Individual	Capture history	Probability
Indv 1	111	$\phi_1 p_2 \phi_2 p_3$
Indv 2	101	$\phi_1 (1 - p_2) \phi_2 p_3$
Indv 3	110	$\phi_1 p_2 \phi_2 (1 - p_3) + (1 - \phi_2)$
Indv 4	100	$(1 - \phi_1) + \phi_1 (1 - p_2)(1 - \phi_2 p_3)$

Individual 4

- died during interval 1 $(1 - \phi_1)$; **or**
- survived occasion 1 (ϕ_1), not recaptured on occasion 2 $(1 - p_2)$, died during occasion 2 $(1 - \phi_2)$; **or**
- survived occasion 1 (ϕ_1), not recaptured on occasion 2 $(1 - p_2)$, survived occasion 2 (ϕ_2), not recaptured on occasion 3 $(1 - p_3)$

CJS model as a state-space model

Using the tools we've learned this semester, it's relativley straightfoward to write the CJS model as a state-space model:

Process model, capture occassion 1

$$z_{i,f_1} = 1$$

Process model, capture occasion 2+

$$z_{i,t} \sim Bernoulli(z_{i,t-1}\phi)$$

Observation model

$$y_{i,t} \sim Bernoulli(z_{i,t}p)$$

CJS model with time-variation

As for the other models we've seen this semester, it's possible to add temporal variation to the CJS model

$$logit(\phi_t) = \mu + \epsilon_t$$

$$\epsilon_t \sim normal(0, \tau_\phi)$$

$$logit(p_t) = \mu + \xi_t$$

$$\xi_t \sim normal(0, \tau_p)$$

Identifiability of the CJS model with time-variation

In the fully time-dependent model, ϕ_T and p_T are not identifiable

- the model will return posteriors for both parameters (because each has a prior) but the model will not be able to separately estimate both parameters
  - posteriors will actually be for $\phi_T \times p_T$

Identifiability of the CJS model with time-variation

Why is this?

- In a CMR study with two occassions (**note** - never do this!):
    - 100 individuals captured on first occasion
    - 60 of those individuals recaptured on the second occasion
- Expected number of recaptures $= N \times \phi \times p$
    - $60 = 100 \times 0.8 \times 0.75$
    - $60 = 100 \times 0.9 \times 0.667$
    - $60 = 100 \times 0.6 \times 1.00$
- No unique solution
    - Separating p from ϕ requires *internal* zeros

Identifiability of the CJS model with time-variation

What can you do:

1) Constant p

2) Covariates on ϕ and p

3) Informative priors

Assumptions of the CJS model

1) Every animal has the same chance of capture, p

2) Every animal has same probability of surviving ϕ

3) Marks are not lost

4) Samples are instantaneous (short periods)

5) All emigration is permanent (`101` must indicate $1 - p$)

6) Fates of animals are independent of other animals