LECTURE 11

Selective Removal Methods

Summary Closed Population Methods

Definition Demographic Parameters &Estimation (15.1)

Population Sizes, Population Growth Rates

Survival Rates

Movement Rates

Reproductive Rates

Detailed Survival Rate Estimation

(Ch 15.2-15.6, 16, 17)

Homework Sets 4 and 5

4/1.b.c I thought g(0)=1 might be quite unlikely.

4/ 2. Using the distance bins vs exact. If the assumptions all hold then the exact distances would be better and give a smaller SE (better precision). However, using the bins might reduce the measurement error in distances.

4/3. Two main possibilities-foxes move off the line or the transect was a road and hence there was a non uniform distn of foxes.

5/2. It is important to emphasize that none of the estimates are very good. I suspect extreme heterogeneity where some taxis have very low detection probabilities.

5/3 Most of you got the cell structures right. A few missed the trap response one. Check with me if you have questions

SELECTIVE REMOVAL OR CHANGE-IN-RATIO MODELS

I will motivate the estimation approach intuitively but not go into nearly as much detail as I did with the capture-recapture models as these methods are not so widely used.

The estimation approach is very similar to the Lincoln-Petersen model for capture-recapture models

I will also discuss the assumptions of the approach.

I will give a motivating example based on a study carried out by Dr Lancia and students at Remington Farms on a deer population.

SELECTIVE REMOVAL OR CHANGE-IN-RATIO MODELS

Different ages or sexes are removed selectively so the proportions of the ages or sexes change after the removal

Deer with a controlled hunt is a good example:

-Removals selectively made towards males in harvest --

-Removals (harvest) are known.

- Also need an unbiased estimate of the proportion of males both before and after the hunt.

Time 1		Time 2
Sample	Removal	Sample
$p_1 = \frac{N_{11}}{N_1}$	————	$p_2 = \frac{N_{21}}{N_2}$
prop type 1		prop type 1
Need Estimate	$\downarrow$	Need Estimate
r_{11}, r_{12}
$r_1 = r_{11} + r_{12}$

Motivation for Estimation Approach

$$p_1 = \frac{N_{11}}{N_1} \text{ proportion of type 1 animals at t 1.}$$

$$p_2 = \frac{N_{21}}{N_2} = \frac{N_{11} - r_{11}}{N_1 - r_1} = \frac{N_1 p_1 - r_{11}}{N_1 - r_1}$$

Rearrangement gives

$$N_1 = \frac{r_{11} - r_1 p_2}{p_1 - p_2}$$

Theoretical Result

$$N_1 = \frac{r_{11} - r_1 p_2}{p_1 - p_2}$$

Estimation

$$\hat{N}_1 = \frac{r_{11} - r_1 \hat{p}_2}{\hat{p}_1 - \hat{p}_2}$$

$$\hat{N}_1 = \frac{r_{11} - r_1 \left(\frac{n_{12}}{n_2} \right)}{\left(\frac{n_{11}}{n_1} \right) - \left(\frac{n_{12}}{n_2} \right)}$$

This is Equation 14.40 p.327

Theoretical Variance for $\hat{N}_1$

$$Var(\hat{N}_1) = \frac{N_1^2 Var(\hat{p}_1) + N_2^2 Var(\hat{p}_2)}{(p_1 - p_2)^2}$$

Note the importance of the difference $(p_1 - p_2)$ to the variance.

There must be a change - in ratio!!!!! or the method wont work at all.

Selective Removal!!!!!!!!!!!!!!!!

Assumptions:

1. Closed Population (except for the removals).
2. Both types of animals are equally catchable (or sightable) in each of the two samples before and after the removals.
3. The number of removals is exactly known.

Remington Farms Deer Herd Example

Pre Hunt

$\hat{p}_1 = 0.0963$

Post Hunt

$\hat{p}_2 = 0.0381$

$\downarrow$

$r_{11} = 56$ Antlered

$r_{21} = 54$ Antlerless

$r_1 = 110$

$$\hat{N}_1 = \frac{r_{11} - r_1 \hat{p}_2}{\hat{p}_1 - \hat{p}_2} = \frac{56 - 110x0.0381}{0.0963 - 0.0381}$$

$$= 890 \left(\text{total deer}\right)$$

Remington Farms Deer Herd Example

Estimates Summary

$$\hat{N}_1 = \frac{56 - 110x0.0381}{0.0963 - 0.0381}$$

$$= 890\left(\text{total deer}\right)$$

$$\hat{N}_{11} = 86(\text{antlered deer } 890x0.0963)$$

$$\hat{N}_{21} = 804(\text{antlerless deer})$$

Note Box 5 next gives the SEs and a summary of the example in a slightly different notation

Box 5. Using the CIR method to estimate population size of antlered and antlerless deer.

Antlered (x-type) and antlerless (y-type) deer were observed during 54 prehunt and 52 posthunt road counts on Remington Farms, Maryland (Conner et al. 1986). One hundred and twenty x-type and 1,126 y-type animals were observed before 56 antlered deer (R_x) and 54 antlerless deer (R_y) were removed by hunters during a 1-week season. After the season, 43 x-type and 1,086 y-type deer were observed. Therefore,

$$\hat{P}_1 = x_1/n_1 = 120/1{,}246 = 0.0963$$

$$\hat{P}_2 = x_2/n_2 = 43/1{,}129 = 0.0381$$

$$\begin{aligned}\hat{N}_1 &= (R_x - R\hat{P}_2)/(\hat{P}_1 - \hat{P}_2) \\ &= \{56 - 110(0.0381)\}/(0.0963 - 0.0381) \\ &= 51.809/0.0582 \\ &= 890\ (\widehat{SE} = 149)\end{aligned}$$

$$\begin{aligned}\hat{X}_1 &= \hat{P}_1\hat{N}_1 = 0.0963(890) \\ &= 86\ (\widehat{SE} = 14).\end{aligned}$$

In this example both x and y types were removed. Because the y-type (antlerless) animals were probably more observable than the x-type animals, λ was probably >1.0, and the population estimates were likely to be biased high.

Validity of Assumptions in the Example

1. Closed Population (except for the removals). (OK, Fairly short time period, perhaps some migration)
2. Both types of animals are equally catchable (or sightable) in each of the two samples before and after the removals.(Antlerless more sightable than antlered deer and this probably means the estimates are biased high).
3. The number of removals is exactly known.(OK as controlled hunt.)

SUMMARY CLOSED POPN ABUNDANCE ESTIMATION

All can be viewed as methods to estimate β in $\hat{N} = C / \alpha\hat{\beta}$

COUNT METHODS

- Double Sampling (e.g.,complete ground count, incomplete aerial count)
- Multiple Observers (Independent, Dependent)
- Distance Methods (Line Transects, Variable Circular Plots)

CAPTURE METHODS

- Capture-Recapture Method using marked animals.
- Removal Method (Equal and Unequal but known Effort)
- Change-in-Ratio or Selective Removal (“Counts” to get ratios, “capture” to do removals)

NOTE: Deciding when to use each method can be quite tricky

CLOSED POPN ABUNDANCE ESTIMATION

COUNT METHODS

- Very widely used in different forms and tend to be cheaper when you consider they may be on a very large spatial scale.
- Multiple observers is one important method
- Distance sampling is also quite widely used and has an enormous literature now.
- Combining multiple observers and distance sampling is sometimes a good idea. Why?

CLOSED POPN ABUNDANCE ESTIMATION

CAPTURE METHODS

- Capture-Recapture Method- expensive and often on fairly small spatial scale.Lots of sophisticated modelling. Reasonably widely used for some wildlife populations but less so in fisheries unless very controlled popns in a pond or small lake. Hard to get capture probabilities high enough, hard to deal with the large movements of marine fish.

- Removal Methods of all kinds

-cheaper than capture-recapture but don’t work very well unless a lot of population removed or unless ratio changes a lot.Can usually only be used on exploited or pest populations where no one cares about the physical removals.Not all that much used.

-Electrofishing in blocked off sections of streams the fish are held out alive in tanks and then replaced at end of study. So physical removal but animals survive the removal study. Good option for stream studies if popn size important.

CLOSED POPN ABUNDANCE ESTIMATION

CAPTURE METHODS

- Capture-Recapture Method

- Will be very important in a whole variety of guises when we move to open populations.

- Radio telemetry methods are a kind of mark-recapture method with a special kind of mark that enables an animal to be relocated with almost certainty.

- We will combine marking and then removal at the recapture phase when we discuss band return models to estimate survival and mortality rates

ESTIMATION OF DEMOGRAPHIC PARAMETERS FOR OPEN POPULATIONS

Definition Demographic Parameters &Estimation (15.1)

Population Sizes

Population Growth Rates

Survival Rates

Movement Rates

Reproductive Rates

Begin Detailed Survival Rate Estimation (15.2-15.6, 16, 17)

Population Sizes

This is similar to before with closed population but now with the population being open then the population size changes over time (1,2,..,k).

Population sizes are N_1, N_2,…, N_k.

Note: In the Definition Slides that follow

There are problems in estimation if unequal detection probability is not considered.

Population Growth Rates

$$\lambda_i = \frac{N_{i+1}}{N_i}$$

A common index based estimator of this growth rate is:

$$\hat{\lambda}_i = \frac{C_{i+1}}{C_i}$$

but

$$E(\hat{\lambda}_i) \approx \frac{\beta_{i+1} N_{i+1}}{\beta_i N_i} \neq \lambda_i$$

unless

$$\beta_{i+1} = \beta_i$$

Survival Rates

Ideal

$$\hat{\varphi}_i = \frac{M_{i+1}}{R_i}$$

Naive Estimator

$$\hat{\varphi}_i = \frac{m_{i+1}}{R_i}$$

$$E(m_{i+1}) = M_{i+1} p_{i+1}$$

Estimator adjusted for detection probability

$$\hat{\varphi}_i = \frac{\hat{M}_{i+1}}{R_i} = \frac{m_{i+1}}{R_i \; \hat{p}_{i+1}}$$

Movement Rates

Ideal Movt Between Two Areas

$$\hat{\psi}_i^{12} = \frac{M_{i+1}^{12}}{M_{i+1}^{11} + M_{i+1}^{12}}$$

Counts Naive Estimator

$$\hat{\psi}_i^{12} = \frac{m_{i+1}^{12}}{m_{i+1}^{11} + m_{i+1}^{12}}$$

NOTE : Counts should be adjusted

for unequal detection probabilities

$$\hat{\psi}_i^{12} = \frac{\hat{M}_{i+1}^{12}}{\hat{M}_{i+1}^{11} + \hat{M}_{i+1}^{12}}$$

Reproductive Rates

Ideal Estimator of Age Ratio (Juvenile vs Adult)

$$\hat{A}_i = \frac{N_i^{(0)}}{N_i^{(1)}}$$

Naive Estimator based on age counts

$$\hat{A}_i = \frac{n_i^{(0)}}{n_i^{(1)}}$$

Estimator Adjusted for detection probability differences

$$\hat{A}_i = \frac{\hat{N}_i^{(0)}}{\hat{N}_i^{(1)}}$$

Survival Rate Estimation

The Binomial Model

Direct Observation (usually not feasible)

Non-marked Animals

Age-based methods (life tables and catch curves)

Methods for Nesting Studies

Mayfield (Mayfield 1961) and extensions

Survival Rate Estimation

Marked Animals

- Radio-Tagging Survival Methods

  MAYFIELD and MICROMORT (Heisey and Fuller 1985)

  KAPLAN MEIER (Pollock et al. 1989a,b)

  MARK

- Tag-Return Methods (usually Exploited Populations) Ch 16.

  (Brownie et al. 1985)

- Capture-Recapture Methods (Research Studies) Ch 17.

Survival Rate Estimation

Direct Observation-The Binomial Model

n – animals followed ("perfect" radio tag, zoo animals etc).

x – no. of the n animals that survive some time interval.

MLE of S

$$\hat{S} = \frac{x}{n}$$

$$Va\hat{r}(\hat{S}) = \frac{\hat{S}(1-\hat{S})}{n}$$

Survival Rate Estimation

Direct Observation-The Binomial Model

Example- 100 animals followed and 90 survive.

$$\hat{S} = \frac{x}{n} = 90/100 = 0.9$$

$$Va\hat{r}(\hat{S}) = \frac{\hat{S}(1-\hat{S})}{n} = \frac{0.9x0.1}{100}$$

$$= 0.0009$$

$$SE(\hat{S}) = 0.03$$

Survival Rate Estimation-The Binomial Model

Compare Two Groups Survival Rates

$$Z = \frac{\hat{S}_A - \hat{S}_B}{\sqrt{Va\hat{r}(\hat{S}_A) + Va\hat{r}(\hat{S}_B)}}$$

Standard Normal Test Statistic

Survival Rate Estimation-The Binomial Model

Compare Two Groups Survival Rates

Alternately use 2x2 chi - square contingency table test.

Survives	Dies	Total
x_A	$n_A - x_A$	n_A
x_B	$n_B - x_B$	n_B

Survival Rate Estimation-The Binomial Model

Example p 344 Text

Winter Mortality radioed mule deer fawns

Survives	Dies	Total	
19	38	57	*Treatment Area
21	38	59	Control Area

* Ignores 4 deer where radios failed

Survival Rate Estimation-The Binomial Model

Winter Mortality radioed mule deer fawns

Treatment Area

$\hat{S}_A = 19/57 = 0.333$

95% CI (0.211 - 0.456)

Control Area

$\hat{S}_B = 21/59 = 0.356$

95% CI (0.234 - 0.478)

Z Test or chi-square test could be done to compare

Survival Rate Estimation-The Binomial Model

Z Test Comparison

$H_0 \;\; S_A = S_B$

$H_1 \;\; S_A \neq S_B$

$$Z = \frac{\hat{S}_A - \hat{S}_B}{\sqrt{Va\hat{r}(\hat{S}_A) + Va\hat{r}(\hat{S}_B)}}$$

$$= \frac{0.333 - 0.356}{\sqrt{[0.333x0.667]/57 + [0.356x0.644]/59}}$$

$$= \frac{-0.023}{\sqrt{(0.0039 + 0.0039)}}$$

$= -0.023/0.088$

$= -0.26$

$\text{P value} \approx 0.80$

Fail to reject H_0.

Note: Book has equivalent chi square test with p value = 0.81

Survival Rate Estimation

Age-based methods

Life Tables

Cohort Life Tables are a conceptual device used in population Ecology. See Table 15.1. Survival rates usually will be age and time (cohort) dependent.

Cohort Life Tables Table 15.1.

TABLE 15.1 Example Cohort Life Table[a]

	Cohort $t = 0$			Cohort $t = 1$		
Year (t)	Age (i)	$[N_i(t)]$	$S_i(t)$	Age (i)	$[N_i(t)]$	$S_i(t)$
0	0	1000	0.25	—	—	—
1	1	250	0.16	0	1200	0.33
2	2	40	0.25	1	400	0.31
3	3	10	0.30	2	125	0.40
4	4	3	0.33	3	50	0.80
5	5	1	0.00	4	40	0.75
6	6	0	—	5	30	—

[a]Also known as age-specific (horizontal) life table (Seber, 1982).

Survival Rate Estimation

Cohort Life Tables are a conceptual device in modeling.They cannot be used for estimation directly. For wild animal populations we can sometimes get a random sample from the population of either:

-The age distribution of the animals that die in some time period.

-The age distribution of live animals at some point in time.

Key Question: Under what conditions does this give us useful information about age dependent survival?

Survival Rate Estimation

Life Tables based on a distribution of deaths of the population. Deevey (1947) in the Quarterly Review of Biology discusses an example where they searched an area around Mt McKinley and found 608 skulls of Dall mountain sheep and aged them.

The life table they constructed based on this example is presented in the next figure.

l_i - prob of survival to age i

d_i – proportion of total deaths in interval i to i+1.

S_i – conditional prob of survival from i to i+1.

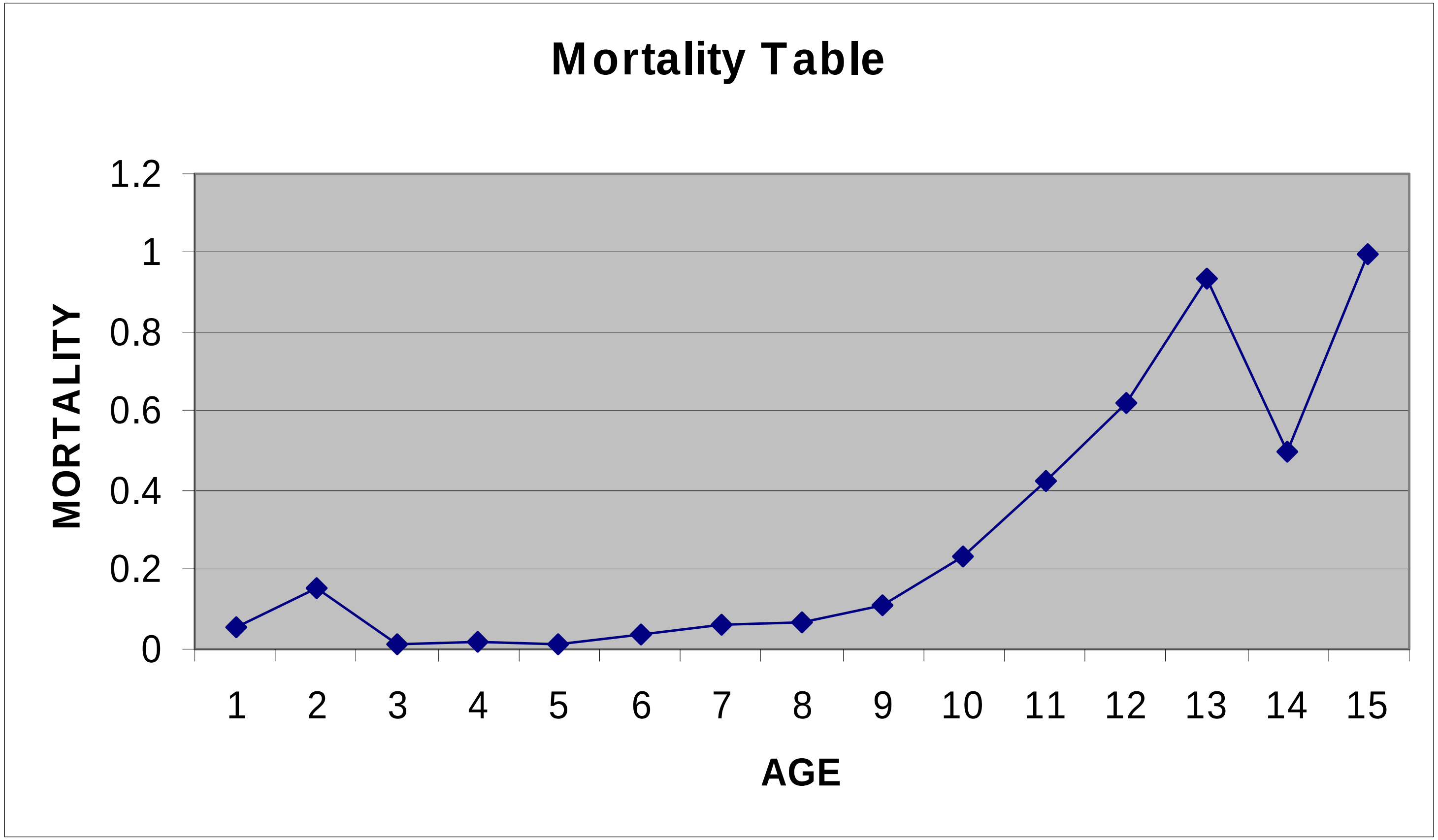
q_i – conditional prob of death in that interval. I also show the SE based on the binomial distribution.

Remember when we write down this Table we are oversimplifying as the animals all died at different times and were from different cohorts.

Mountain Sheep Example

Age	No deaths	"Cohort" size	l(i)	d(i)	S(i)	q(i)	SEq(i)
0-0.5	33	608	1	0.054	0.946	0.054	0.0092
0.5-1	88	575	0.946	0.145	0.847	0.153	0.0150
1	7	487	0.801	0.012	0.985	0.015	0.0055
2	8	480	0.789	0.013	0.984	0.016	0.0058
3	7	472	0.776	0.012	0.985	0.015	0.0057
4	18	465	0.764	0.03	0.961	0.039	0.0090
5	28	446	0.734	0.046	0.937	0.063	0.0115
6	29	418	0.688	0.048	0.930	0.070	0.0125
7	42	389	0.64	0.069	0.892	0.108	0.0157
8	80	347	0.571	0.132	0.769	0.231	0.0226
9	114	267	0.439	0.187	0.574	0.426	0.0303
10	95	153	0.252	0.156	0.381	0.619	0.0392
11	55	58	0.096	0.09	0.063	0.937	0.0317
12	2	4	0.006	0.003	0.500	0.500	0.2618
13	2	2	0.003	0.003	0.000	1.000	0.0000

Dall Mountain Sheep



Survival Rate Estimation

Life Table Methods

Assumptions

-Survival and reproduction constant over time

(stable age distribution).

-Population is stationary (λ=1)

-Sampling is random with respect to age

-Aging is Accurate

Survival Rate Estimation

Validity of Assumptions for the Dall Sheep

-Survival and reproduction constant over time

(stable age distribution).-?? Not discussed.

-Population is stationary (λ=1)-Probably reasonable as National Park population at carrying capacity?

-Sampling is random with respect to age- Younger Ages less detectable and durable?

-Aging accurate-Reasonable.

Survival Rate Estimation

Age-based methods

Life Tables based on the distribution of live animals

The key question is can we obtain unbiased survival estimates by age if we have a random sample from the age distribution of animals in a population at time t for ages 0,1,…,k.

Another question is how we might obtain a random sample? We sometimes have harvest samples which we might hope are random at least above some minimum age.

We consider a simple example of a herring catch distribution from Seber’s book in the next lecture