Mortality

Mortality = (1-Survival)

- *Introduction*
- *Constant survival models for fish and birds (Catch curves)*
- *Age-/Stage-specific models*
- *Band recovery analysis*
- *MARK*

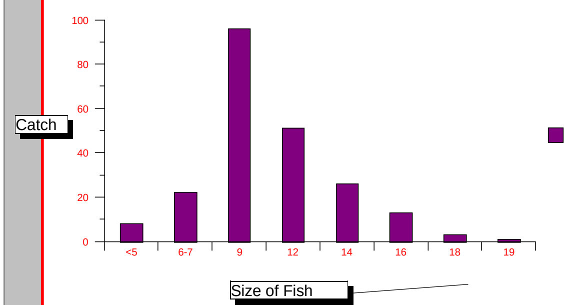
Introduction

- *Crude mortality rate = deaths/starting N*
- $= (N_x - N_{x+1})N_x$
- *Age-specific mortality rate*
- *Survival rate = 1-mortality rate*
- $= N_{x+1}/N_x$
- *Simplest approach (model) assumes constant rates for different ages/years*

Catch Curves

- *= "Kill Curves" in birds and mammals*
- *Based on these simplest assumptions about rates (i.e. constant for ages and years)*

Catch Curves



Catch Curves

- *If 100 are born and 50% survive, then there will be 50 one-year olds*
- *If 50% survive, 25 two-year olds*
- *If 50% survive, 12 three-year olds*
- *If 50 % survive, 6 four-year olds*

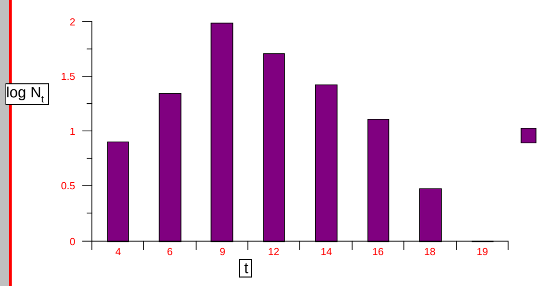
Catch Curves

- *Number alive = Number X Survival*
- $N_1 = N_o S$
- $N_2 = N_o S S$
- $N_2 = N_o S^2$
- $N_t = N_o S^t$
- $\log N_t = \log N_o + t \log S$

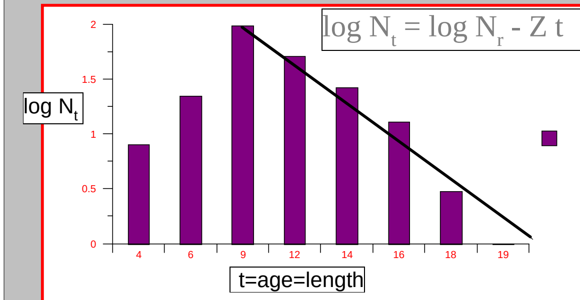
Catch Curves

- *Since S (survival rate) is less than 0*
- *log S is always negative*
- *Let Z = -log S*
- *Z = Instantaneous total mortality*
- *Then* $\log N_t = \log N_o - Z t$

Catch Curves



Catch Curves



Fishing and Natural Mortality

- Fishing: c=catch/N=$1-e^{-F}$
- Natural: n=natural deaths/N
- = $1-e^{-M}$
- Combining them as finite rates is complicated: Total= m+n+m*n
- But easy as instantaneous rates:
- Total mortality = $1-e^{-(F+M)}$= $1-e^{-Z}$
- (Z=F+M)

Catch Curves

- 1. Mortality is constant with age
- 2. No change in mortality over time
- 3. Fishing and natural mortality are uniform
- 4. Recruitment is constant
- 5. Fish fully recruited to gear by age r

Life Tables

- More realistic approach relaxes assumption of equal age-specific survival rates
- Ideal approach marks a “cohort” at birth/young age and counts how many still alive each year[=cohort life table]
- Summarize easily by plotting survivorship (lx = no. alive at age x)

Survivorship Curves

- Examples:
  - Mammals
  - Humans
  - Birds
  - Fish
- Types of Survivorship (Pearl 1930, Deevey 1947)
- Stage-specific rates?

Band Recovery Analysis

- Suppose we had banded 1603 adult male mallards in August of 1980
- How could we predict how many we would receive bands from in 1980, 1981, 1982, etc.?
- It will depend on the fraction of the birds shot in a year and turned in to us (<u>Band recovery rate</u>) and the survival of birds (<u>Survival rate</u>)

Band Recovery Analysis

- N_1 = Number banded in year 1
- f_1 = band recovery rate in year 1
- S_1 = survival rate in year1
- R_{12} = recoveries in year 2 from birds banded in year 1
- $R_{11} = N_1 f_1$
- $R_{12} = (N_1 S_1) f_2$

Program MARK

- We can use the program MARK written by Gary White at CSU to estimate these survival and recovery rates from banding data as well as estimates for a variety of other survival, recovery and mark-resight models.
- To do this we use the PIM or Parameter Information Matrix

Program MARK

- For band recovery data we
- Select Data Type =
  - Brownie et al. Recoveries or
  - Recoveries only

PIM - Parameter Information Matrix Survival Parameter (S)

- time = 1 2 3 4 5 6

Occasions 1 3 5

1	2	3	4	5	6	
	2	3	4	5	6	
		3	4	5	6	
			4	5	6	
				5	6	
					6	

PIM - Parameter Information Matrix Recovery Parameter (f)

- time = 1 2 3 4 5 6

7	8	9	10	11	12	
	8	9	10	11	12	
		9	10	11	12	
				11	12	
					12	

Comparing Models

- With MARK we can estimate a large variety of models.
- We can compare models using AIC or Akaike's Information Criterion.
- AIC measures the deviation of observed data from the model adjusted for the number of parameters in the model.
- AIC = -2 ln(L) + 2 n p
- The **lower** the AIC the **better** the model.
- For nested models we could also use Likelihood Ratio Tests.

Mark-recapture or -resight Data

- Select Data Type =
- Recaptures only

PIM - Parameter Information Matrix Apparent Survival Parameter (Phi)

- time = 1 2 3 4 5 6

1	2	3	4	5	6	
	2	3	4	5	6	
		3	4	5	6	
			4	5	6	
				5	6	
					6	

PIM - Parameter Information Matrix Recapture Parameter (p)

- time = 1 2 3 4 5 6

7	8	9	10	11	12	
	8	9	10	11	12	
		9	10	11	12	
				11	12	
					12	

CJS

- *These PIMs describe the Jolly-Seber model,*
- *more formally this is called*
- *fully time-dependent Cormack-Jolly-Seber model.*

Cohort Lifetable - Age-specific Survival (S_x)

- *time = 1 2 3 4 5 6*

1	2	3	4	5	6	

Time-specific Lifetable - Age-specific Survival (S_x)

- *time = 1 2 3 4 5 6*

1						
2						
3						
4						
5						
6						

Catch Curve - Survival (S)

- *time = 1 2 3 4 5 6*

1						
1						
1						
1						
1						
1						
1						