Analysis of demographic data

SSA 200

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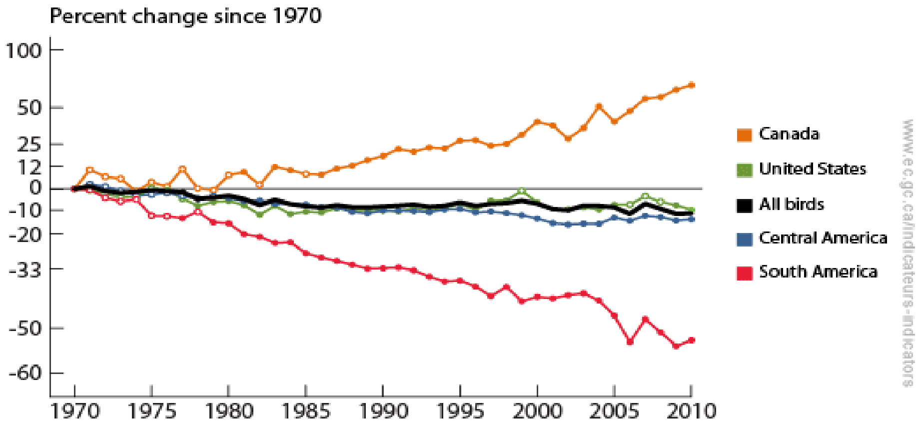
Estimating population vital rates

- Can use counts to model change in population size and the effect of covariates
- Intrinsic population characteristics govern population dynamics
- Stressors and threats often act directly on these rates
- This can help guide conservation actions to where it will be the most helpful and examine effects of potential management actions



Change in population size = births + immigration - deaths - emigration

Fecundity/Recruitment

- Nest/den monitoring
- Reproductive success/failure
- Number of offspring produced
- Age ratios

Survival

Apparent survival

- **Individual capture-mark-recapture**
- **Radio telemetry**

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Demographic data types

- Many different types, depends on ecology/life history of species of interest
  - Number of broods/litters per season
  - Breeding site fidelity
  - Etc.

Data types
Number of offspring per female
Ratio of young to adults (or size classes)
Nest/den success or failure
Number of young returning next year
Individual mark-recapture/resight
Radio telemetry
Others?

Demographic vital rate
Fecundity
Recruitment probability
Survival probability (seasonal or annual)
Breeding success probability

Estimating fecundity

- From a population growth perspective, recruitment into breeding population is more important than fecundity
  - A product of many events: reproductive success, juvenile survival, site fidelity/dispersal
- Often easier to collect data on breeding success than recruitment
- Can estimate from individual-level data (nest/den success) or population-level data (ratio of young to adults)

GLMs to estimate fecundity

- Include ecological covariates to determine important drivers of breeding success
- Type of GLM depends on response variable
    - Number of offspring per female →
    - Successful breeding (yes/no) →

Estimating survival/mortality

- Radio telemetry → known fate models
  - Assume perfect detection of individuals

- Individual capture-mark-recapture → Cormack-Jolly-Seber (CJS) models
  - Data can come from a variety of sampling methods
    - Physical recapture (trapping array)
    - Photographic re-encounter (camera traps)
    - Re-sightings (field-readable tags, individually-identifiable marks)
    - Noninvasive genetic sampling (hair snares, scat collection)
  - Assume **imperfect detection** of individuals

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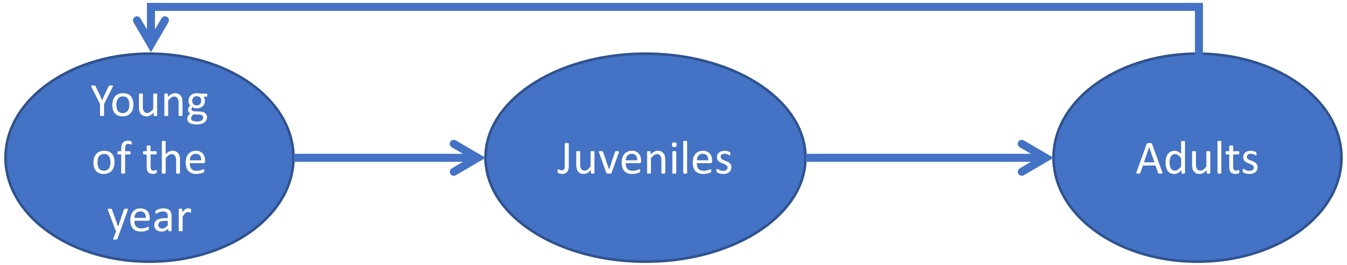
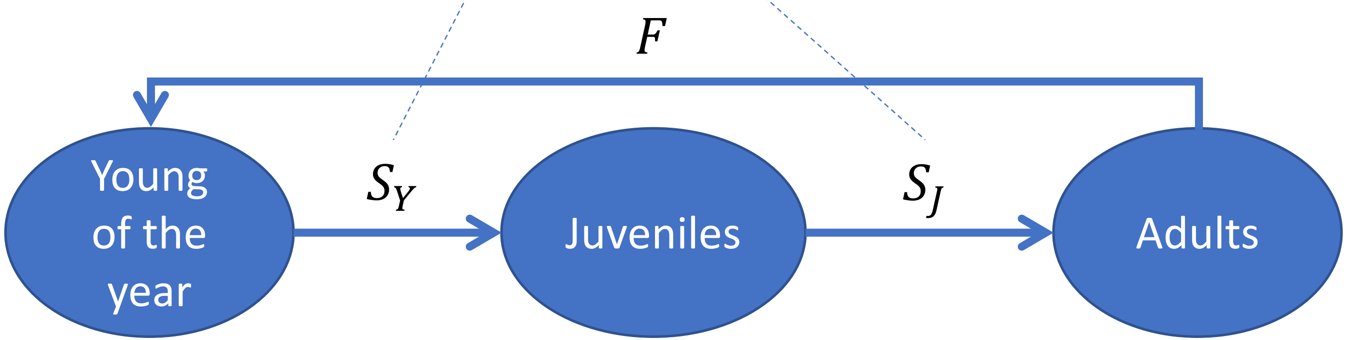
Matrix models for age- or stage-structure

- When vital rates vary by age or stage (e.g. size), matrix models are used to present and analyze demographics
  - Individuals always advance linearly through stages (they can’t shrink or become younger)



In each year, what proportion of the individuals in stage [*column number*]…

$$\begin{bmatrix} 0 & 0 & \boxed{F} \\ \boxed{S_Y} & 0 & 0 \\ 0 & \boxed{S_J} & 0 \end{bmatrix}$$ Transition into stage [*row number*]



Building a matrix model

- Can use combination of methods to fill in vital rates
  - Published in the literature
  - Primary analysis of data
  - Expert opinion

Applications of matrix models

- Which vital rate has the strongest effect on changing population growth rate (λ)?
  - Elasticity/sensitivity analysis
  - Implications for choosing conservation actions

Loggerhead sea turtle matrix model

"Slow" life history

- Sexual maturity at 17-33 years
- Lifespan 47-67 years

Key threats:

- Predation of eggs and small juveniles
- Mortality due to fishing trawls
- Loss of nesting habitat

Difficult to study

- Worldwide movements
- Hard to determine age

Crouse et al 1987
Crowder et al 1994

Stage-structured matrix model

$$\begin{bmatrix} P_1 & F_2 & F_3 & F_4 & F_5 \\ G_1 & P_2 & 0 & 0 & 0 \\ 0 & G_2 & P_3 & 0 & 0 \\ 0 & 0 & G_3 & P_4 & 0 \\ 0 & 0 & 0 & G_4 & P_5 \end{bmatrix}$$

Five stages:

1. Eggs/hatchlings
2. Small juveniles
3. Large juveniles
4. Subadults
5. Adults

Three demographic rates:

- **F**ertility
- **P**robability of surviving and remaining in the current stage
- Probability of surviving and **G**rowing into the next stage

$$\begin{array}{c} \begin{array}{ccccc} \mathit{1} & \mathit{2} & \mathit{3} & \mathit{4} & \mathit{5} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 0 & 76.5 \\ 0.675 & 0.703 & 0 & 0 & 0 \\ 0 & 0.047 & 0.657 & 0 & 0 \\ 0 & 0 & 0.019 & 0.682 & 0 \\ 0 & 0 & 0 & 0.061 & 0.8091 \end{bmatrix} \end{array}$$

Gathered data on survival and reproductive rates from other published studies

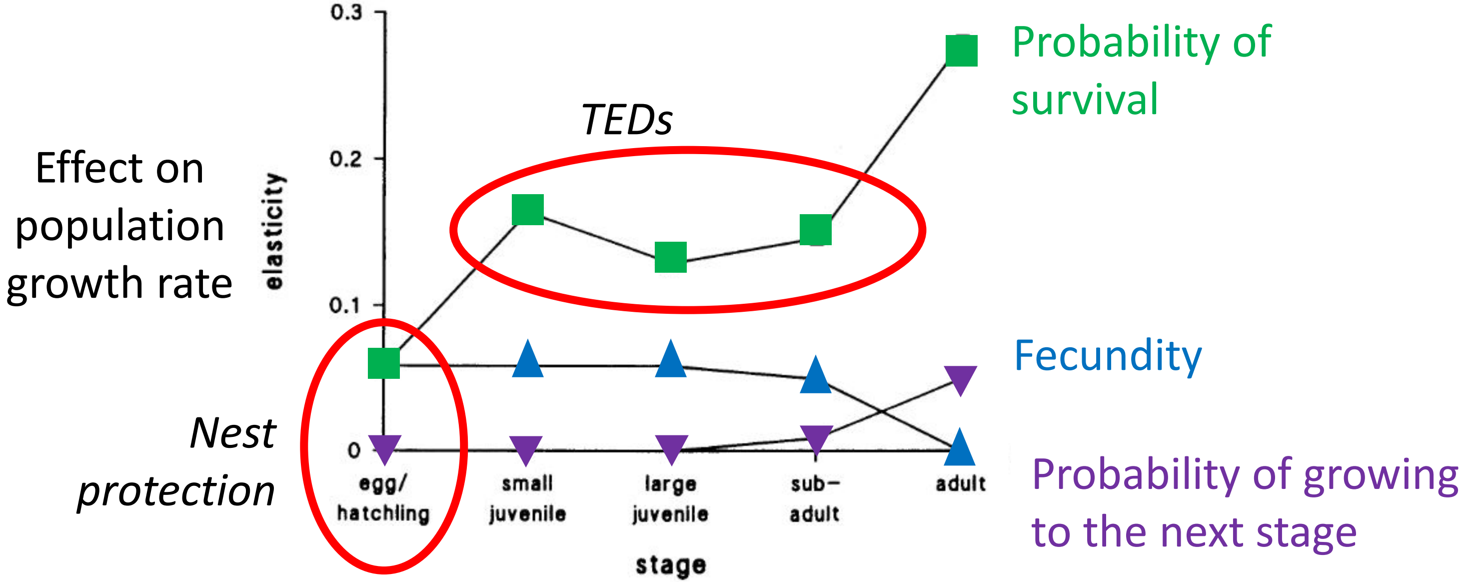


FIG. 1. The elasticity, or proportional sensitivity, of λ to changes in reproductive output (F), survival while remaining in the same stage (P), and survival with growth into the next stage (G). Because the elasticities sum to one (Caswell 1989), they can be compared directly in terms of their contribution to population growth rate, r.

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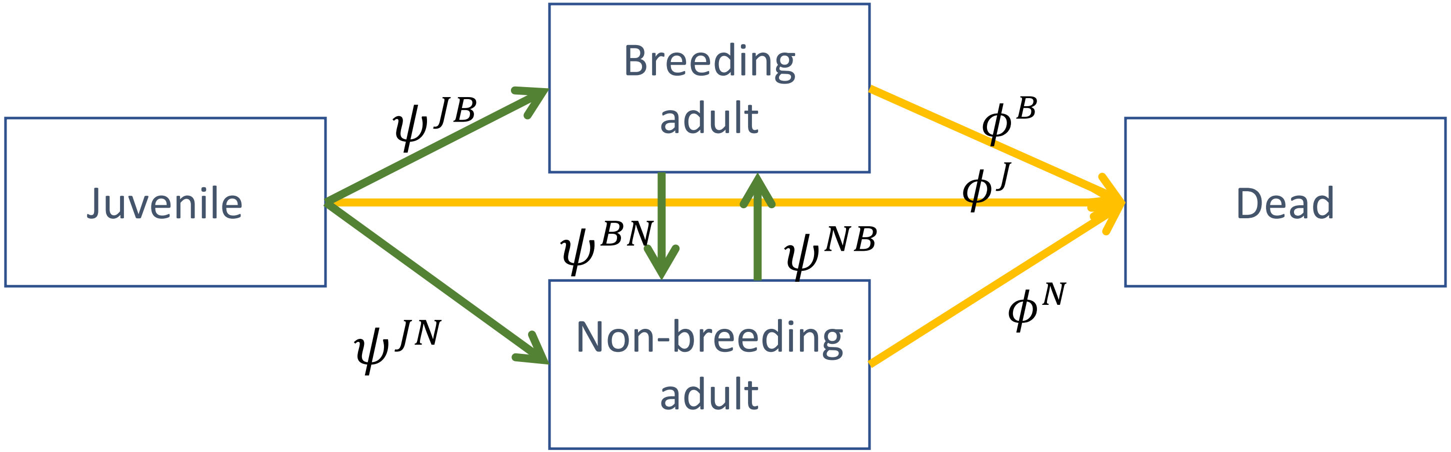
Multistate models

- Used to estimate transition probabilities among different physical sites or biological states
- Look similar to matrix models, but individuals can move back and forth between states
    - Breeder/non-breeder status
    - Disease status
    - Movement among study areas

- Very flexible and applicable to a range of situations

Example – breeding/non-breeding status



$$
\begin{array}{c c}
 & \begin{array}{cccc} \mathbf{J} & \mathbf{B} & \mathbf{N} & \mathbf{D} \end{array} \\
\begin{array}{c} \mathbf{J} \\ \mathbf{B} \\ \mathbf{N} \\ \mathbf{D} \end{array} &
\begin{bmatrix}
0 & \phi^{J}\psi^{JB} & \phi^{J}\psi^{JN} & 1-\phi^{J} \\
0 & \phi^{B}(1-\psi^{BN}) & \phi^{B}\psi^{BN} & 1-\phi^{B} \\
0 & \phi^{N}\psi^{NB} & \phi^{N}(1-\psi^{NB}) & 1-\phi^{N} \\
0 & 0 & 0 & 1
\end{bmatrix}
\end{array}
$$

Extensions of multistate models

- Range of applications, not just individual mark-recapture data
- Used in both estimation and projection
- Migratory connectivity
  - probability of moving among multiple breeding and wintering sites
- Multistate occupancy analysis
  - change in occupancy state of sites (e.g. many, few, or none detected, detected with and without breeding activity, etc.)
- Ecological succession
  - change in dominant land cover type over time

Integrated Population Models (IPMs)

- Relatively new approach to combining all sources of demographic information into one analysis
  - Typically **counts**, **mark-recapture,** and some measure of **fecundity**
- Pros:
  - More precise estimates of demographic rates
  - Can potentially estimate things you don’t have explicit data about (usually these things are hard to measure)
    - Immigration/emigration, juvenile survival
  - Can directly project population into the future while propagating all uncertainty
- Cons:
  - More complicated analysis, requires more time/expertise to develop

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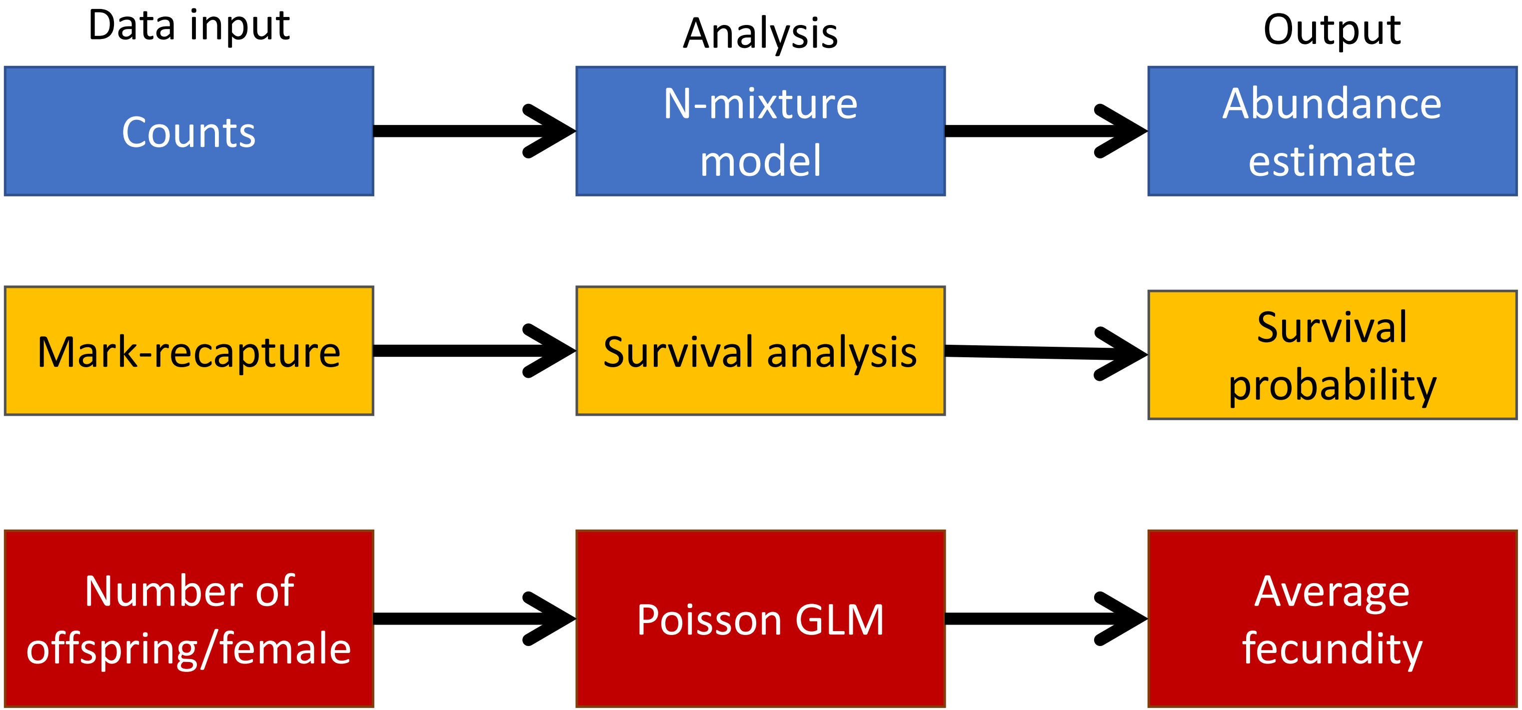
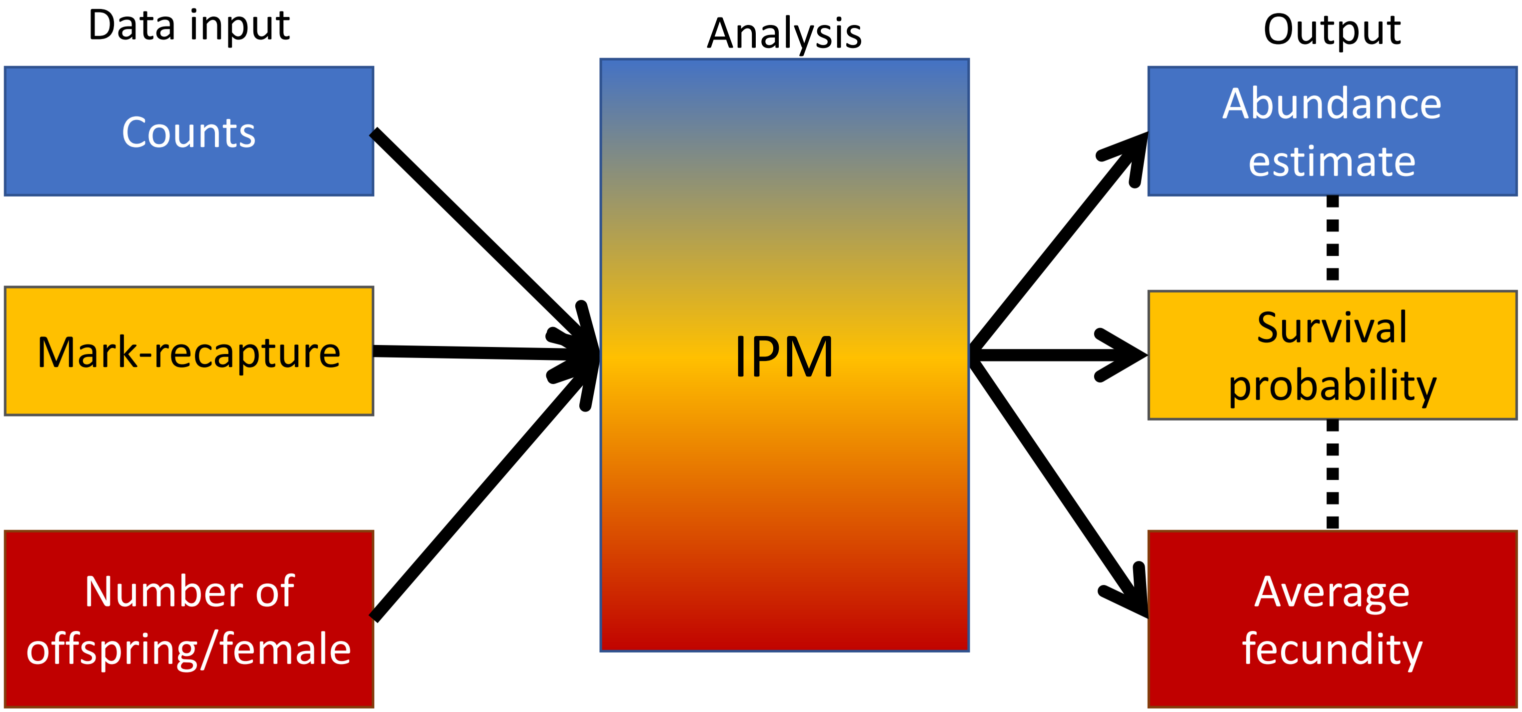
Non-integrated analysis

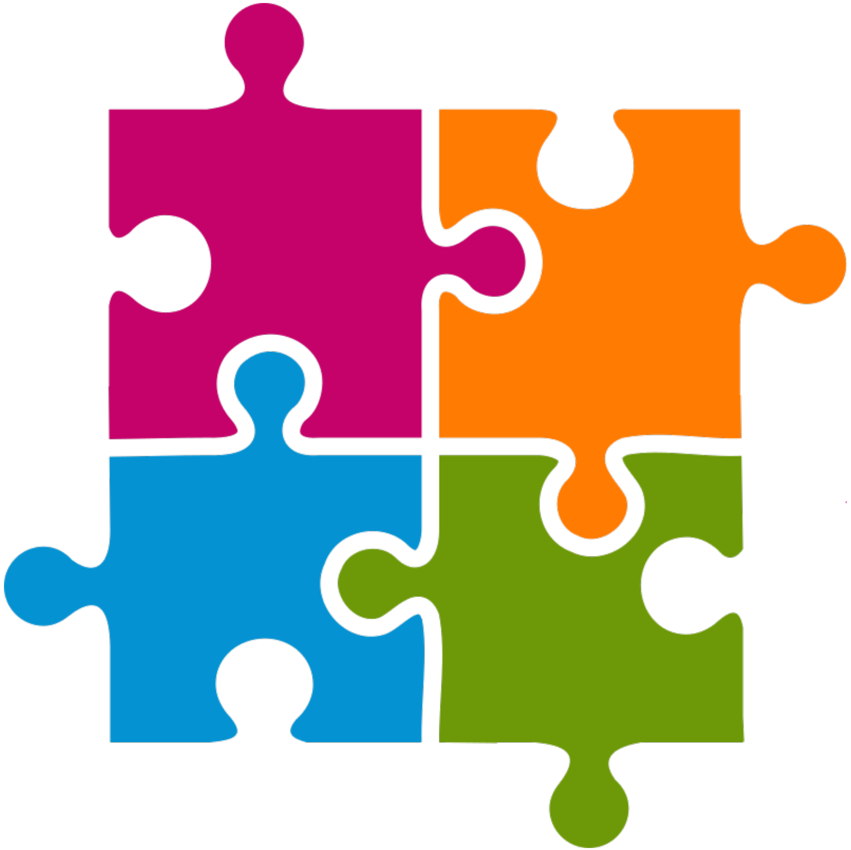


Integrated analysis



Change in population size = births + immigration - deaths - emigration

$\lambda =$



Do I need to use an IPM?

- Core assumption = all data are a product of the same underlying population processes
- Most useful when:
  - Individual analyses of different data sources give competing results
  - You want to estimate a demographic parameter without data (e.g. immigration rate)