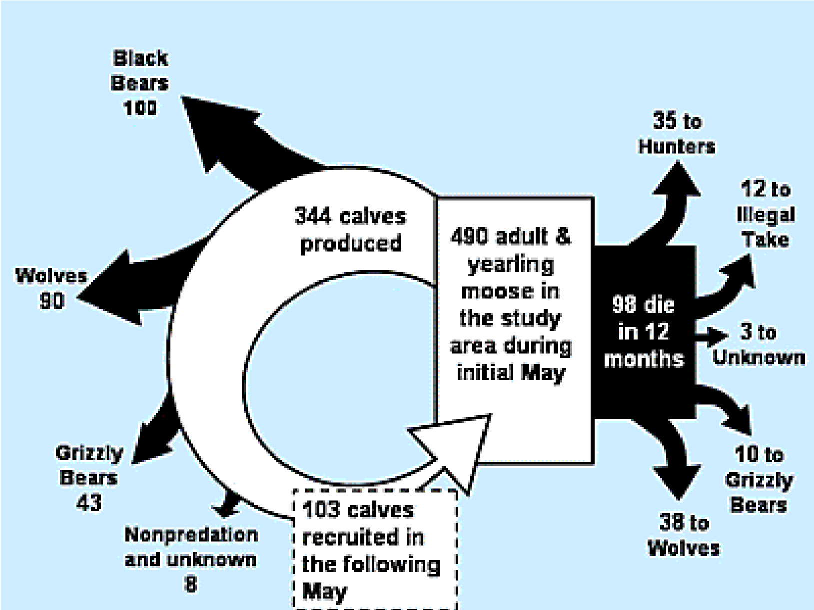
Describing population change

- $N_{t+1} = N_t + B + I – D – E$
- Future abundance = Current Abundance + Births and Immigrants – Deaths and Emigrants

Population Dynamics

- Simple, but
- Need to estimate population parameters and many factors can influence each parameter
  - E.g., Mortality related to: harvest, environment, age, disease, habitat, predation, gender
  - And many these factors change over time and space



Population Models

- Thus, reality is not possible and we instead model population dynamics
  - Simplification and abstraction of reality
- Capture-recapture models
- Indices – generally poor models
- Life Tables
- Exponential Population Change
- Logistic Population Change
- Predator-Prey Models

How can we describe (model) this change in population size?

- λ = finite (geometric) rate of increase
- λ = *N*t / *N*o
  - *N*o = population at starting time
  - *N*t = population at some time in future
- increase or decrease
- discrete - change per unit time (e.g., year)
  - λ > 1.0 increase
  - λ < 1.0 decrease
  - λ = 1.0 stable (stationary)

Population projections

- $N_{t+1} = N_t \lambda$
- $N_{t+2} = N_{t+1} \lambda = N_t \lambda_1 \lambda_2 = N_t \lambda^2$
- $N_{t+3} = N_{t+2} \lambda = N_t \lambda_1 \lambda_2 \lambda_3 = N_t \lambda^3$
- $N_t = N_0 \lambda^t$
- $\lambda = N_{t+1}/N_t$
- $\lambda = \sqrt{(N_{t+2}/N_t)} = (N_{t+2}/N_t)^{1/2}$
- $\lambda = \sqrt[3]{(N_{t+3}/N_t)} = (N_{t+3}/N_t)^{1/3}$
- $\lambda = \sqrt[t]{(N_t/N_0)} = (N_t/N_0)^{1/t}$

Example: Introduced wolf populations in Rocky Mts.

- N_{1998} = 275
- N_{1999} = 322
- N_{2000} = 433
- $\lambda_{1998\text{-}1999}$ = 322/275 = 1.17 = 17% increase
- $\lambda_{1999\text{-}2000}$ = 433/322 = 1.34 = 34% increase

Example: Introduced wolf populations in Rocky Mts.

- What if we did a census in 1998 and in 2000 but wanted to know the average rate of increase per year?
- $\lambda_{1998\text{-}2000} = (433/275)^{1/2} = 1.25$

- So far, so good
- We can estimate rate of increase for discrete time units
- What if we want to compare rates of increase for species that reproduce on different time scales?
- Moose (once per year) vs. hares (multiple times per year)

How can we describe this change in population size in continuous terms?

- r = intrinsic (instantaneous) rate of increase (Malthusian parameter)
- Both λ and r express rates of change in birth, death,immigration, and emigration rate (BIDE)
- $e^r = \lambda$ or $\ell n(\lambda) = r$
  (e = base of natural log = 2.71828)

remember, $N_t = N_0 \lambda^t$

$dN/dt = rN$

$N_t = N_0 e^{rt}$

Example: Introduced wolf populations in Rocky Mts.

- $N_{1998} = 275$
- $N_{1999} = 322$
- $N_{2000} = 433$
- $r_{1998\text{-}1999} = \ell n(322/275) = \ell n(1.17) = 0.16$
- $r_{1999\text{-}2000} = \ell n(433/322) = \ell n(1.34) = 0.29$
- When r is small, $\lambda \approx 1 + r$

Which to use?

- Instantaneous rates easier to deal with mathematically
  - >0 = increase; <0 = decrease
- Instantaneous rates are symmetric around zero
  - $r = 0.5$ is converse of $r = -0.5$ ($\lambda = 1.649$ versus $\lambda = 0.607$)
- Instantaneous rates convert to different time scales easily
  - r /year = X, then r /day = X/365

- Moose: λ = 1.07/yr; hare: λ = 1.03/month
- Moose: r = 0.0677/yr; hare: r = 0.0296/month
- Moose: r = 0.0056/month

Equivalent

Doubling time

- Continuous approach allows easy calculation of population doubling time
- $N_{t(double)}$ = population size 2X what it is currently
- If $N_t / N_0 = \lambda^t$ then $N_{t(double)}/N_0 = 2 = \lambda^{t(double)}$
- Since $\ell n(\lambda) = r$ then $\ell n\ 2 = t_{(double)}(\ell n\ \lambda)$
- $t_{(double)} = \ell n\ 2 / \ell n\ \lambda = \ell n\ 2 / r$
- Moose doubling time: ℓn 2 / 0.0056 = 123.8 months
- Hare doubling time: ℓn 2 / 0.0296 = 23.4 months