Population Ecology

Density dependence, regulation, compensatory mortality, and harvest

ESRM 450

Wildlife Ecology and Conservation

Wildlife Populations

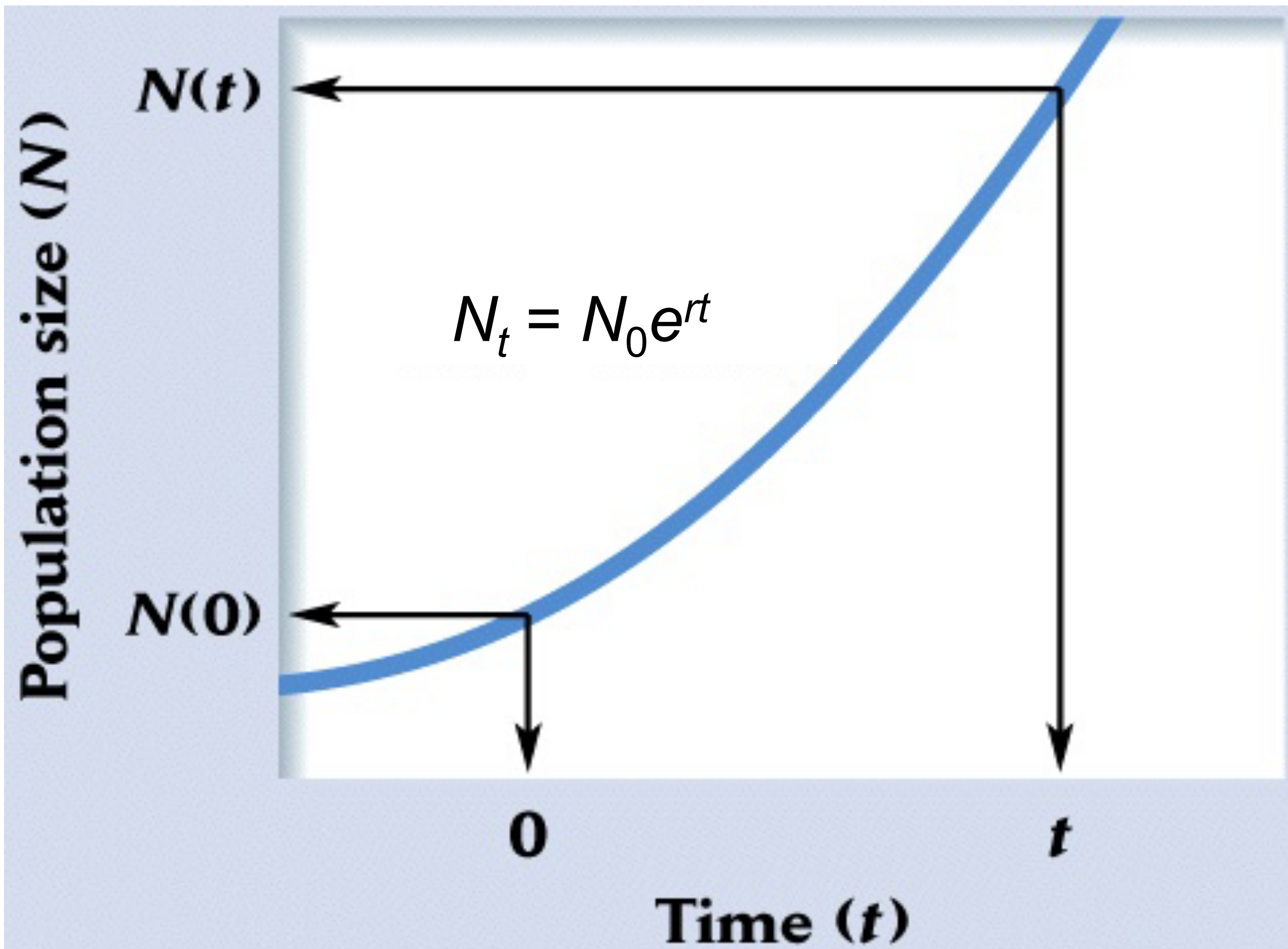
Groups of animals, all of the same species, that live together and reproduce

Gotelli, N.J. (1998) *A Primer of Ecology*

Population Growth

- Populations increase in proportion to their size
- *e.g.*, at a 10% annual rate if increase
  - a population of 100 adds 10 individuals in one year
  - A population of 1000 adds 100 individuals in one year
- Allowed to grow unchecked, populations growing at a constant rate will rapidly approach infinity…

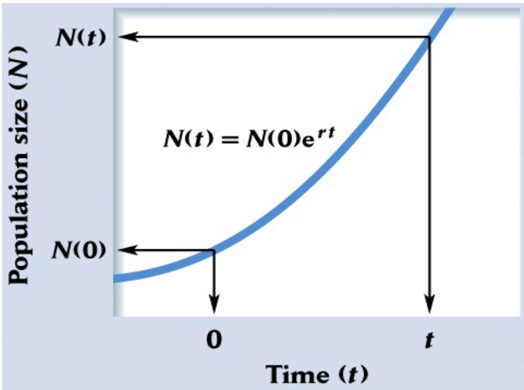
Exponential Growth



Exponential Growth Model – A Cornerstone of Population Ecology

- All populations have *potential* for exponential growth
  - Exponential models valuable because they recognize the multiplicative nature of population growth (positive feedback yields accelerating growth)

- Realistically describes growth of many populations in the short term
  - i.e., resources are often ***temporarily unlimited*** (pest outbreaks, weed invasions, humans)



Wildlife Populations Have Great Capacity for Growth

- e.g., population growth of the ring-necked pheasant (*Phasianus colchicus*)
  - 8 individuals introduced to Protection Island, Washington, in 1937, increased to 1,325 adults in 5 years:
    - 166-fold increase!
    - Aside - *Unforgiven*

Yet, Infinite Population Sizes Not Observed

- Despite potential for exponential increase, most populations remain at relatively stable levels or fluctuate around equilibria
  - Paradox noted by Malthus and Darwin
  - for population growth to be checked, a decrease in the birth rate or an increase in the death rate (or both) must occur as overall population size gets large
  - What causes these changes in birth and death rates?

Crowding

- As populations grow, crowding…
  - Reduces access to food (other resources) for individuals and their offspring
  - Aggravates social strife
  - Promotes the spread of disease
  - Attracts the attention of predators

- As a result, population growth slows and eventually halts

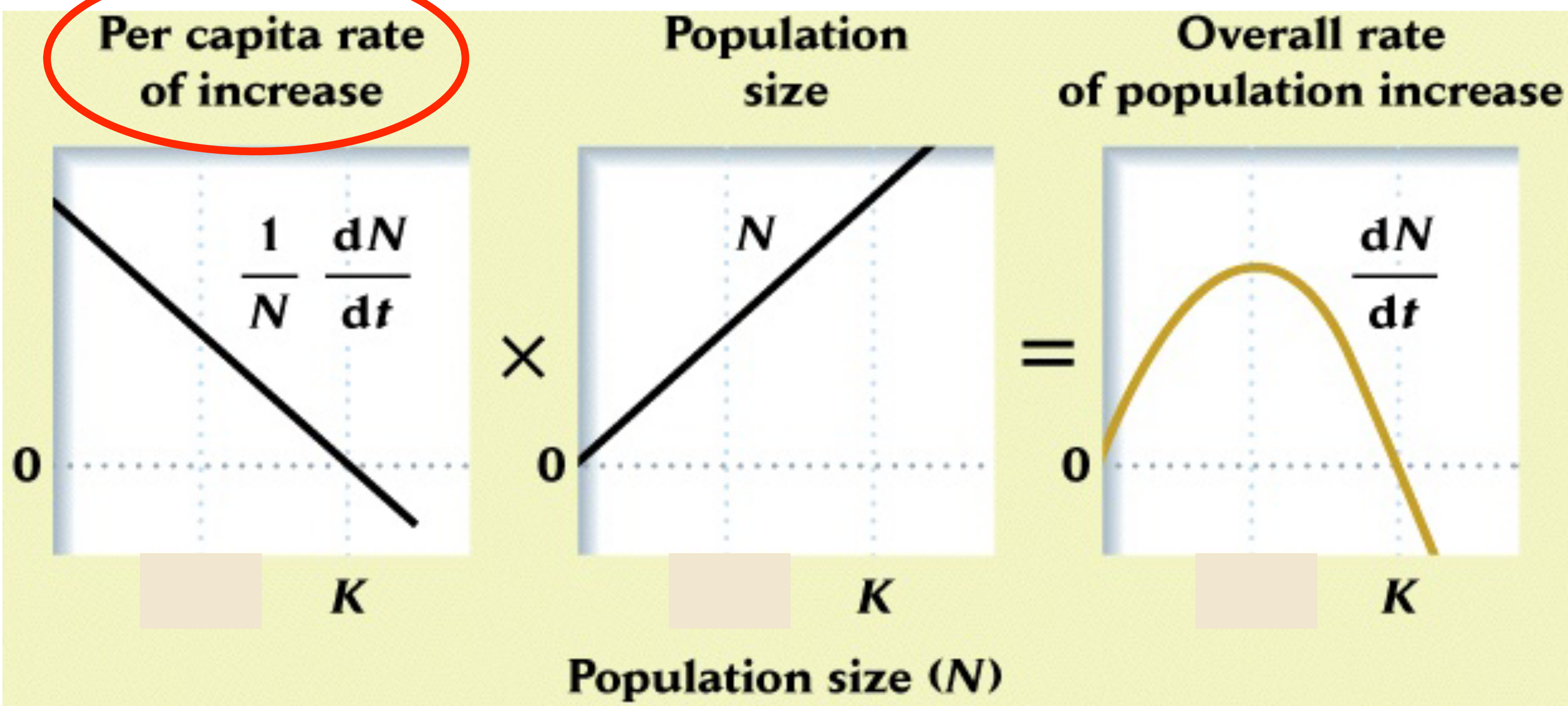
- Process known as **DENSITY DEPENDENCE**
  - decreasing per capita growth rate with increasing population size

The Logistic Growth Model

- Populations with density dependence (decreasing per capita growth rate with increasing population size) modeled using the logistic growth equation
- Logistic model incorporates idea that populations tend to level off at **carrying capacity (K)**
- **K**: population size at which no more individuals can be supported over long time periods

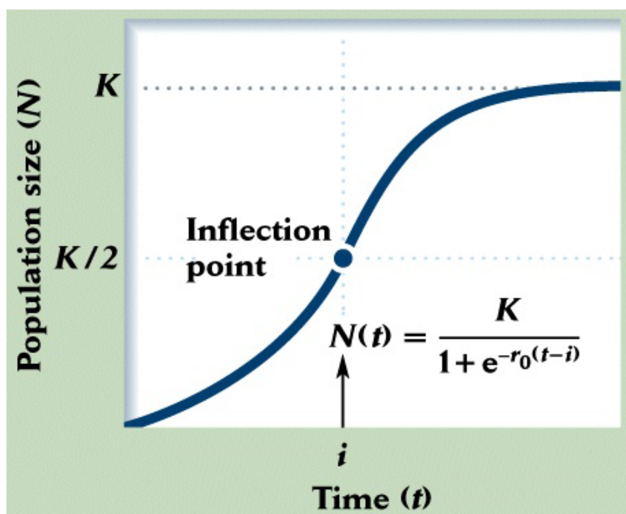
The Logistic Growth Model

Density dependence



Logistic Growth Curve

- Graph of population size (*N*) versus time (*t*) for logistic growth features S-shaped curve (**sigmoid growth**)
  - Populations below *K* increase
  - Populations above *K* decrease
  - Populations at *K* remain constant
- Inflection point at *K*/2 separates **accelerating** and **decelerating** phases of growth



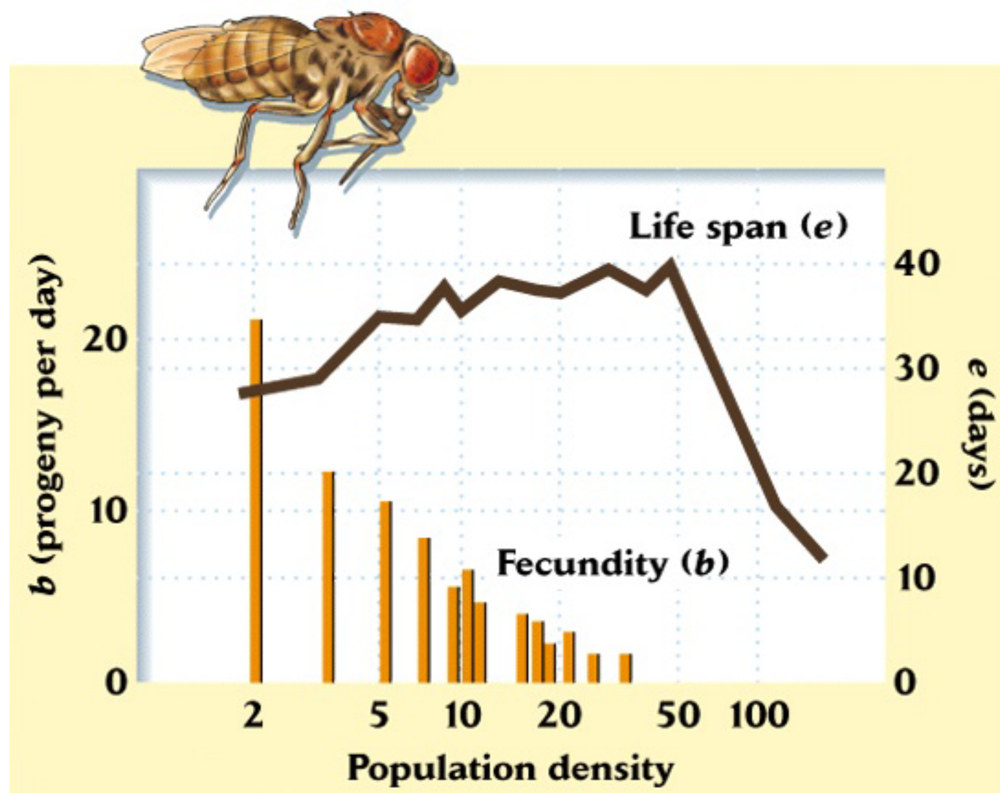
Not All Factors Cause Populations to Level Off at *K*

- Those that do are called **Density-dependent factors**
  - Increase in intensity with crowding
  - Process called **REGULATION**
  - *e.g.*, food supply and places to live
  - also, effects of predators, parasites, and diseases (sometimes)

- **Density-independent factors** may influence population size but *cannot* regulate it (limiting factors)
  - Affect numbers but don’t slow per capita growth with crowding
  - *e.g.*, temperature, precipitation, catastrophic events
  - Can keep populations small if severe & common

Evidence for Density-Dependence

- **Density-dependence** difficult to demonstrate in field
  - Requires manipulation
    - Alter density, measure vital rates (fecundity and survival)
  - or Natural Experimentation
    - Take advantage of natural fluctuations in density (problem – exogenous factors)
- Evidence comes mainly from lab experiments
  - e.g., fruit flies: fecundity and life span decline with increasing density in laboratory populations



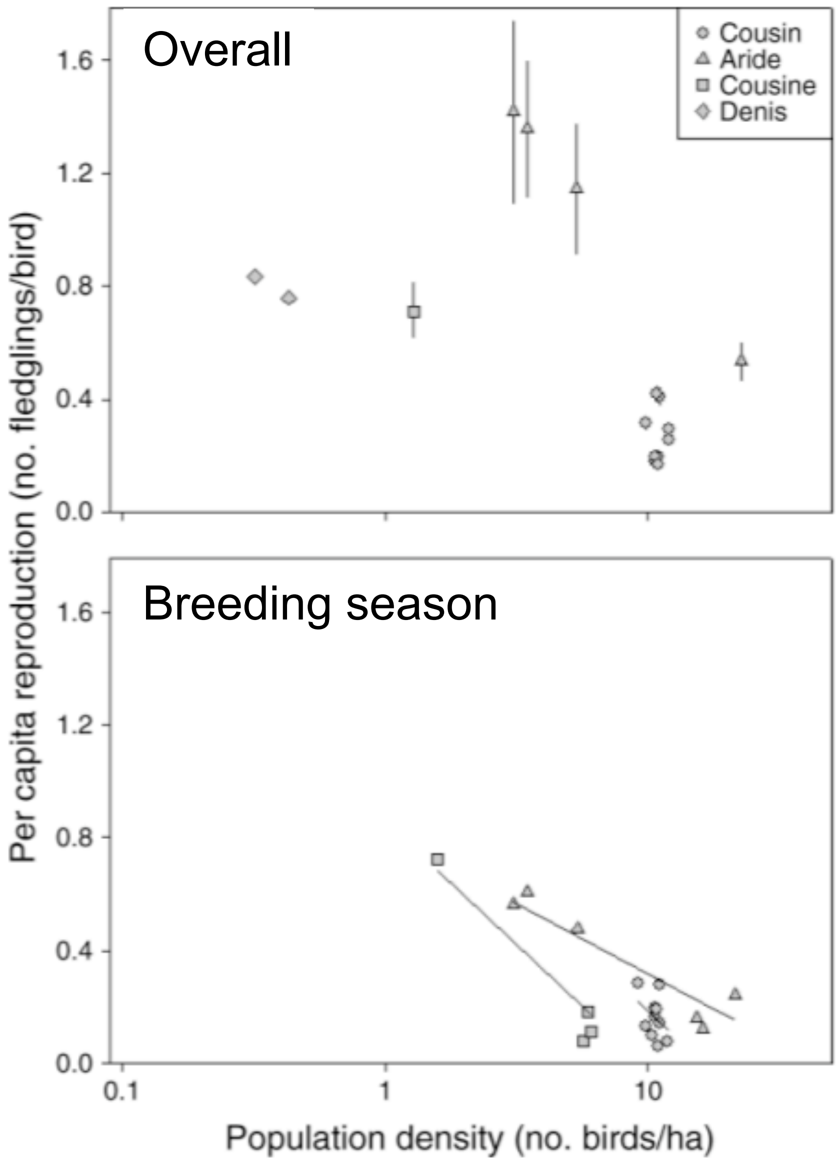
Pearl (1927) *Q Rev Biol*

Field Evidence

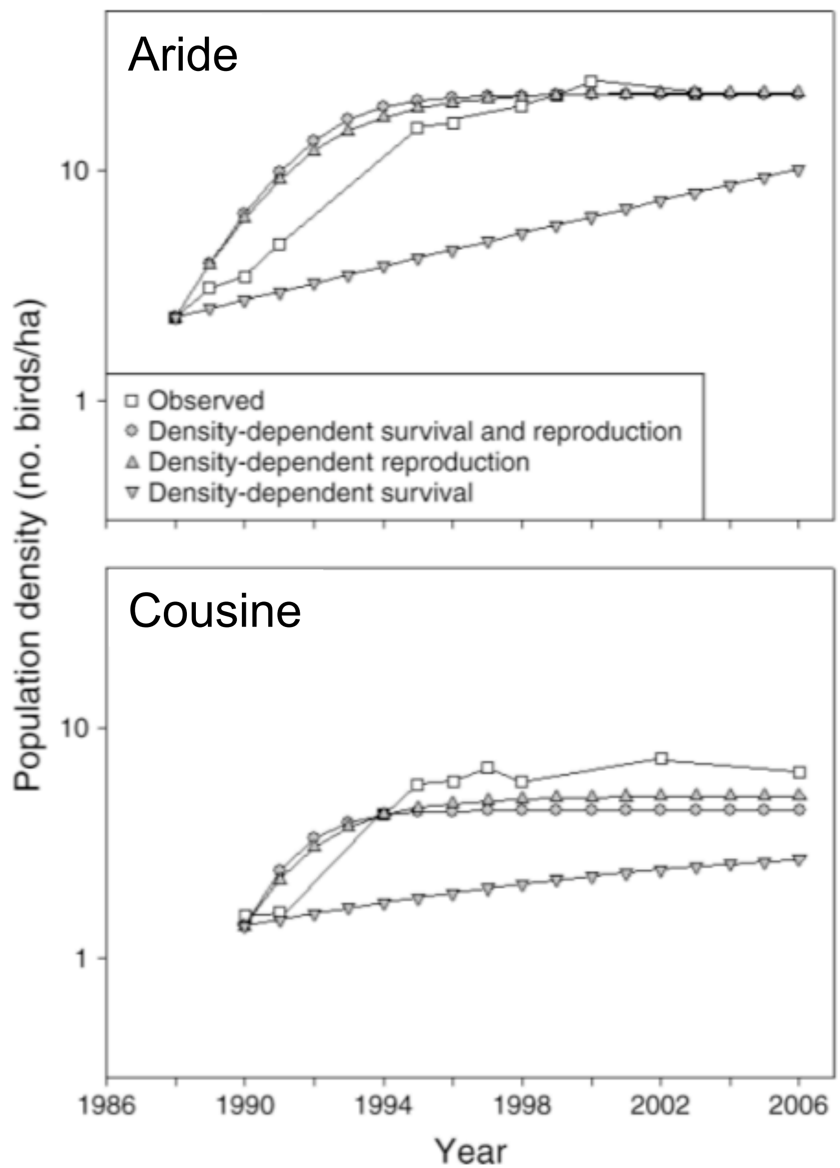
Seychelles Warbler (*Acrocephalus sechellensis*)

- Island warbler populations underwent bottleneck mid-20th century, then recovered
- Thus, researchers were able to measure population size and individual vital rates during recovery
  - Island setting provided for replicates (multiple islands)…
  - …and minimized influence of exogenous factors like predators (i.e., islands acted as outdoor laboratories)

Brouwer *et al*. (2009) *Ecology*



Individual reproduction declined with increasing population size on 4 islands



Populations leveled off in accord with projections based on density-dependent reproduction

Population Ecology and Conservation

- An understanding of population dynamics has great applied value
  - Identification of high quality habitat (*e.g.*, comparison of growth rates)
  - Evaluation of the prospects for threatened wildlife populations (population viability analysis, PVA)
  - Promotion of sustainable exploitation (harvest)

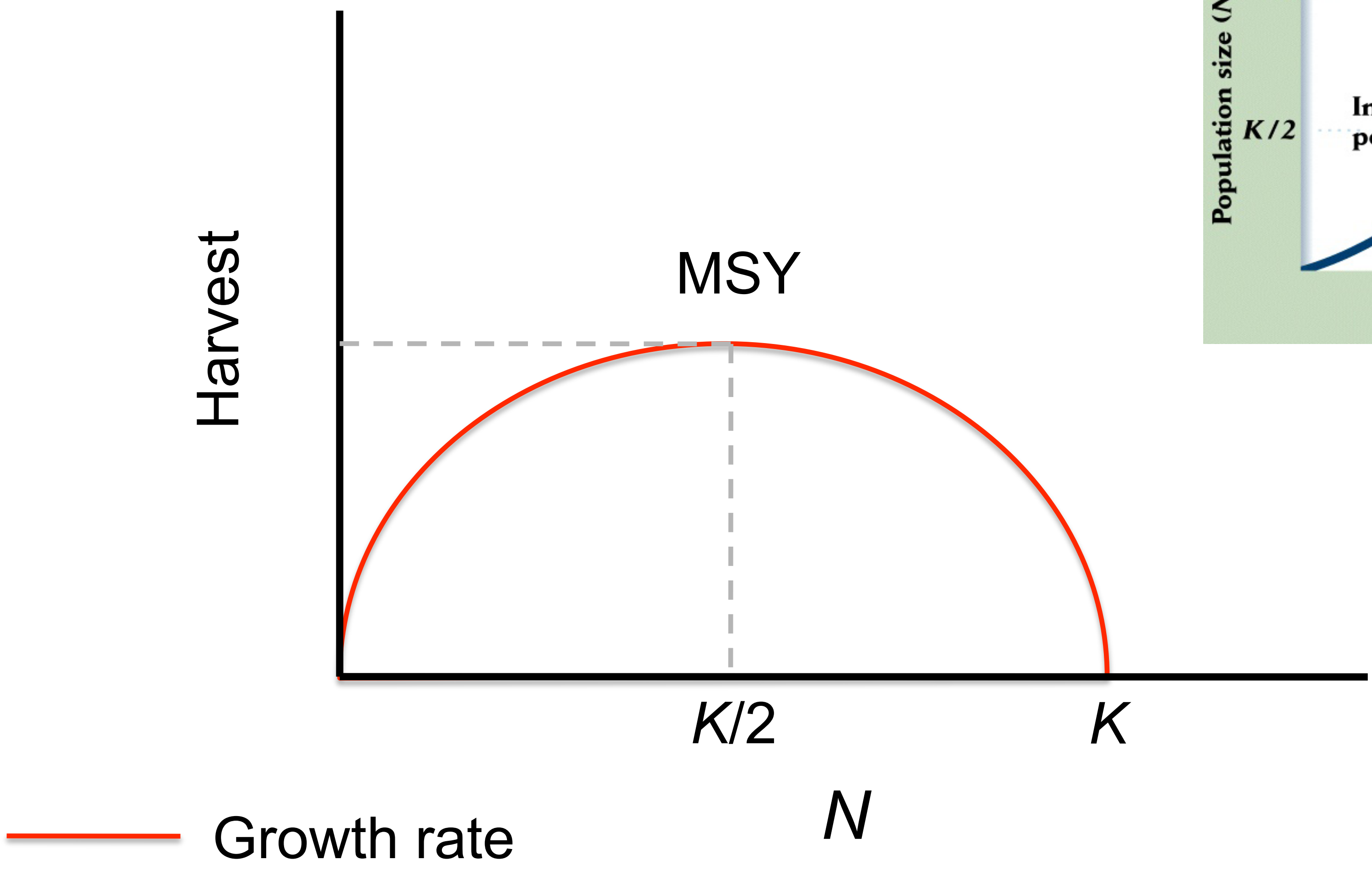
Population Viability Analysis

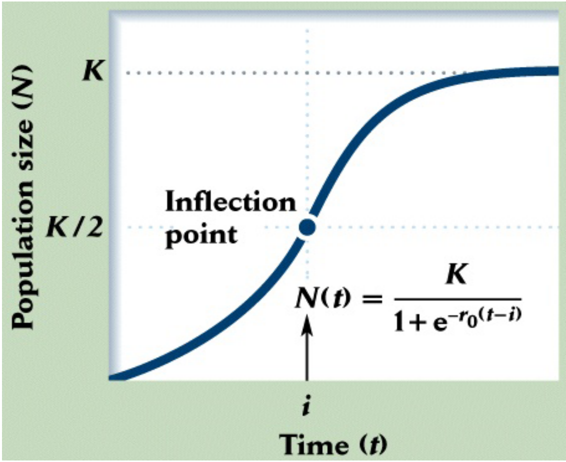
- **PVA**: Examination of interacting factors that place populations (and species) at risk of extinction
  - Forecasting tool allowing us to assess threats to population persistence and to determine how best to intervene before population declines become irreversible
- At their core, population viability analyses are only as good as the model of population growth on which they are based
  - Model must be parameterized with reliable demographic information (vital rates)
  - *i.e.*, solid field work is key!

Promotion of Sustainable Harvest

- A key insight from the logistic growth model is that, under the assumption of density dependence, decreased crowding should improve survival and reproduction
  - Thus, removal of individuals from a population (harvest) that is compensated by improved survival and reproduction (i.e., **compensatory**) should be sustainable; removes only the “doomed surplus”
  - Conversely, harvest that is not fully compensated by improved survival and reproduction (i.e., **additive**) is not sustainable
  - From the logistic model, populations can be reduced by up to 50% of K before harvest mortality becomes additive
    - This harvest setting is the **maximum sustainable yield,** or **MSY**
    - **MSY**: highest harvest rate that a population can match with its own recruitment (increased survival and reproduction)

Promotion of Sustainable Harvest - MSY





Problems With MSY

- Must know K
- Must be able to control harvest such that it does not exceed K/2
- What if growth doesn't conform to logistic?