Population Regulation

 Copyright © 2015 Oxford University Press

Concepts

- What Limits Population Growth?
- Are Populations Ever Stable?
- How Do Regulatory Factors Interact?
- How Do Populations Interact?

 Copyright © 2015 Oxford University Press

Factors Affecting the Population Growth

- The concept that population growth is limited is fundamental in ecology.
- Linked with the Darwin's theory of natural selection:
  - Each individual has a high potential reproductive rate.
  - Eventually, the scarcity of resources limits the population.
  - When competition becomes intense, the inherent differences among individuals become an important source for natural selection.

 Copyright © 2015 Oxford University Press

Factors Affecting the Population Growth

- In the absence of resource limitations:

$$dN/dt = rN$$

- The intrinsic rate of growth *r*:

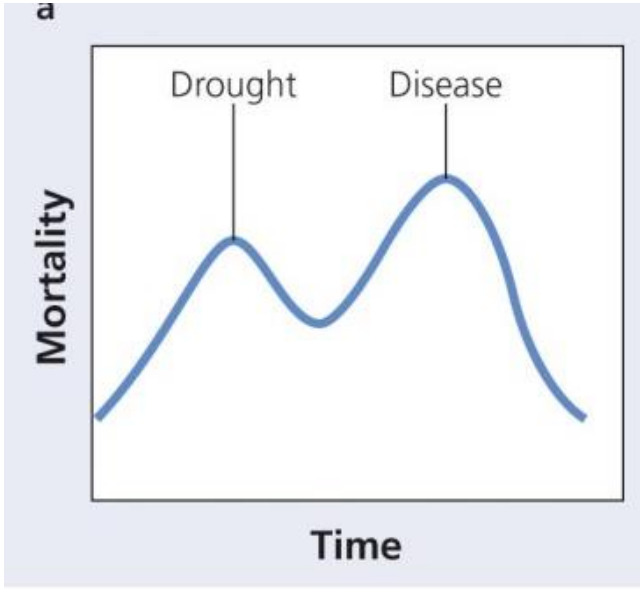
$$r = (b + i) - (d + e)$$

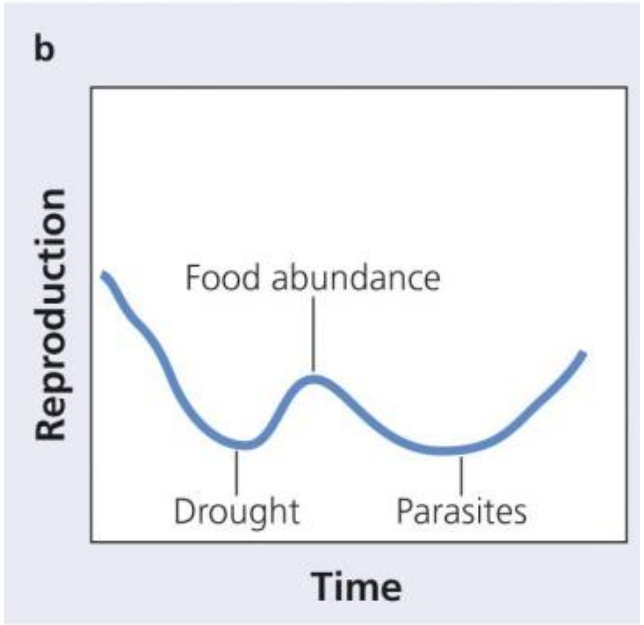
where *b* is the per capita birth rate, *i* is the per capita immigration rate, *d* is the per capita death rate, and *e* is the per capita emigration rate.

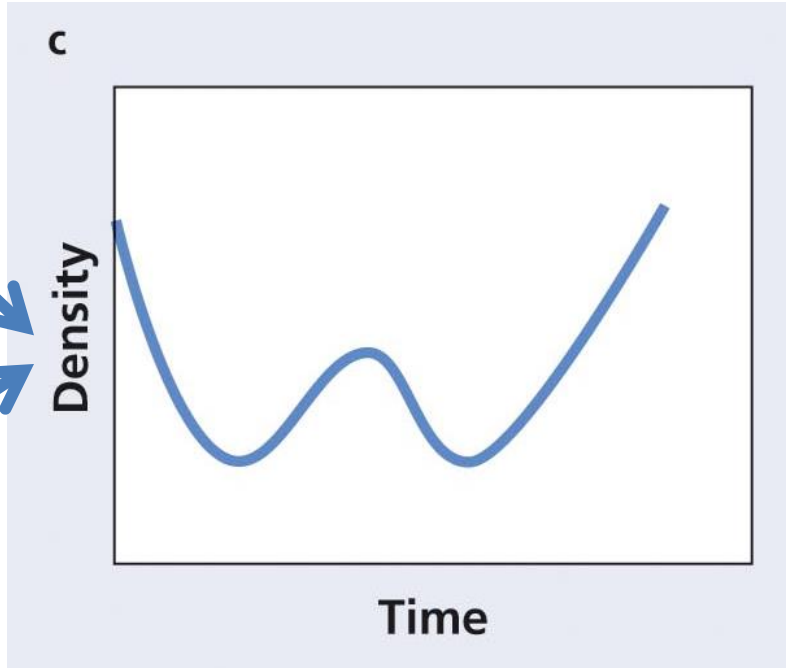
 Copyright © 2015 Oxford University Press

Factors Affecting the Population Growth

Biotic and abiotic







Copyright © 2015 Oxford University Press

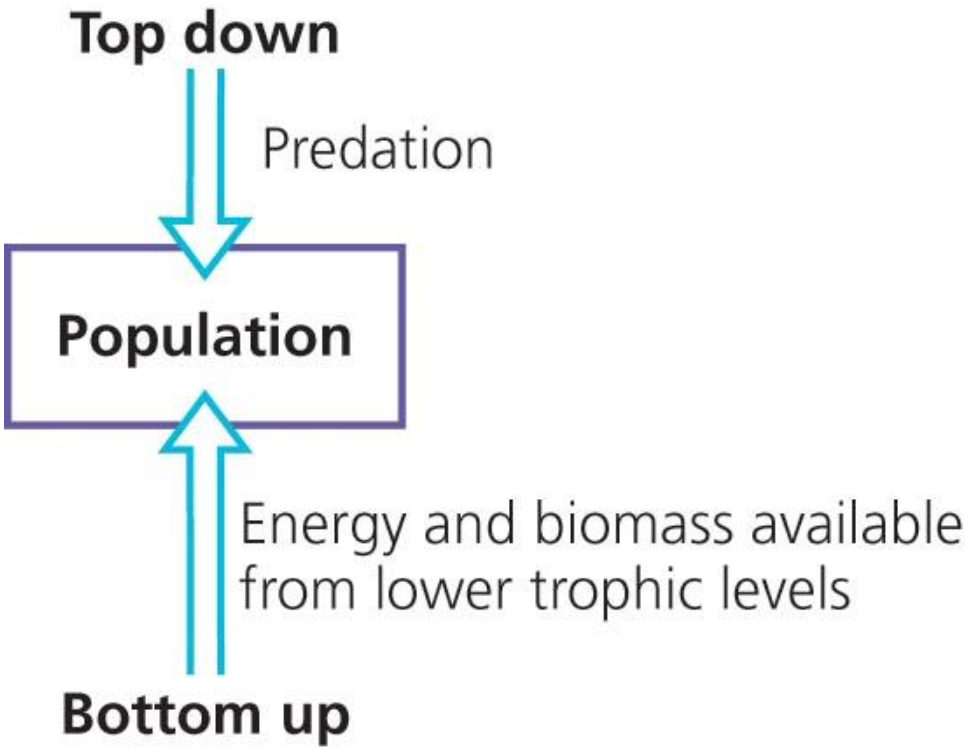
Factors Affecting the Population Growth

- Biotic factors—
  - Predators
  - Food supply
  - Competitors
  - Parasites
  - Pathogens
  - Mutualists

 Copyright © 2015 Oxford University Press

Factors Affecting the Population Growth

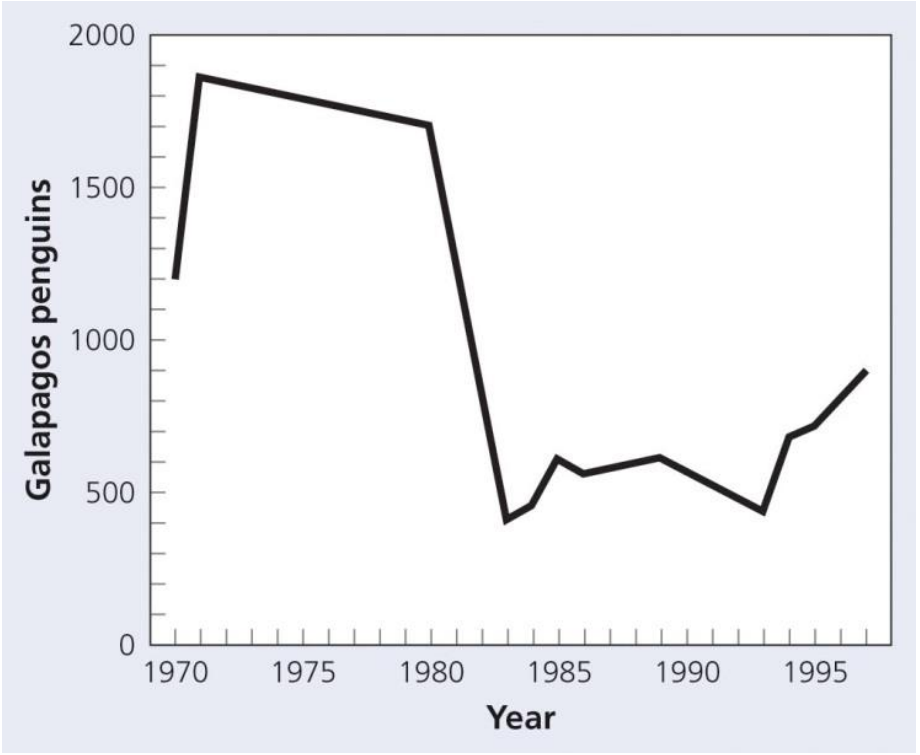
- Biotic factors can act in a top-down or bottom-up fashion.
- Refer to the direction of regulation through the food chain.



 Copyright © 2015 Oxford University Press

Bottom-up Biotic Factors

- Act on the population via limitations imposed by lower trophic levels.
- **Example:** El Niño-driven cycles of the population abundance of Galápagos penguins

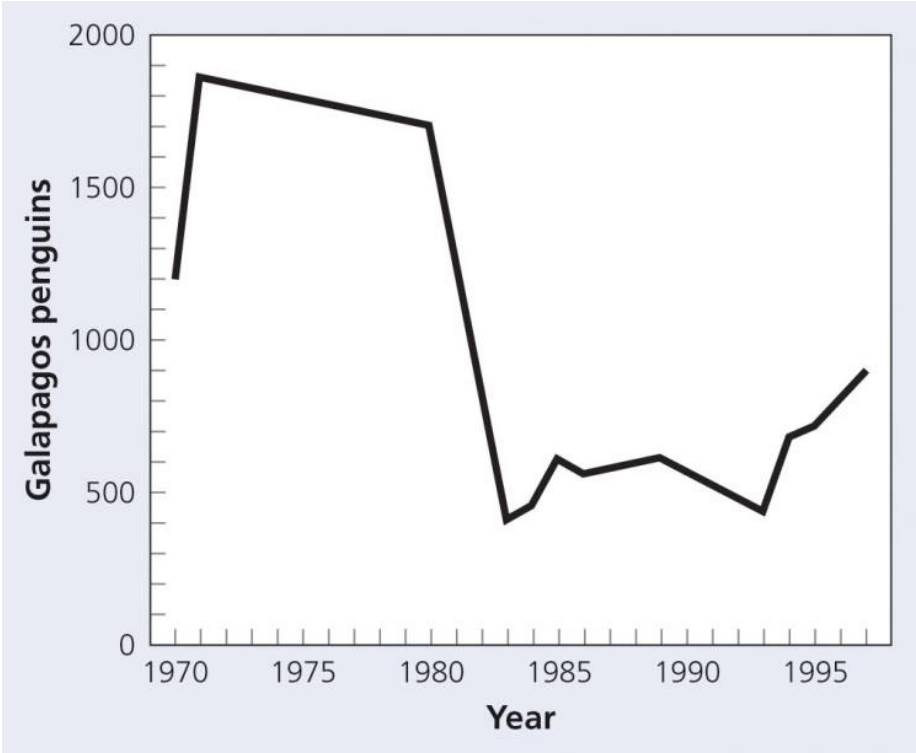


Valle and Coulter (1987)

 Copyright © 2015 Oxford University Press

Bottom-up Biotic Factors

- During an El Niño, warm water from the western Pacific flows eastward toward South America and the Galápagos.
- The cold, nutrient-rich water is replaced with warmer, less nutrient-rich water.

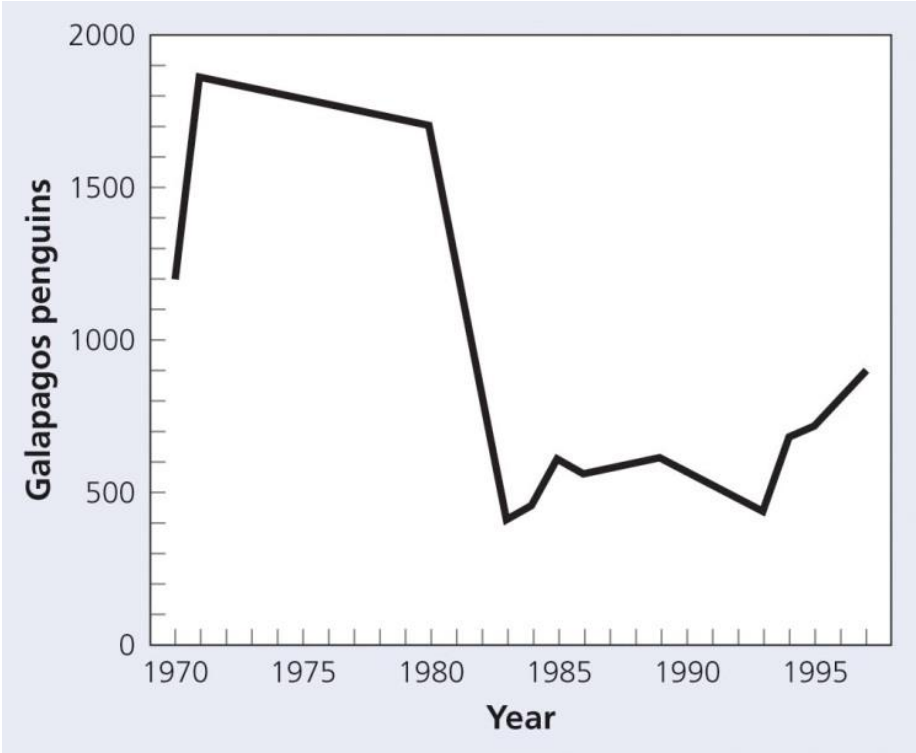


Valle and Coulter (1987)

 Copyright © 2015 Oxford University Press

Bottom-up Biotic Factors

- As a result, the marine food base collapses and the penguin population declines radically
- It may take years for the population to recover.

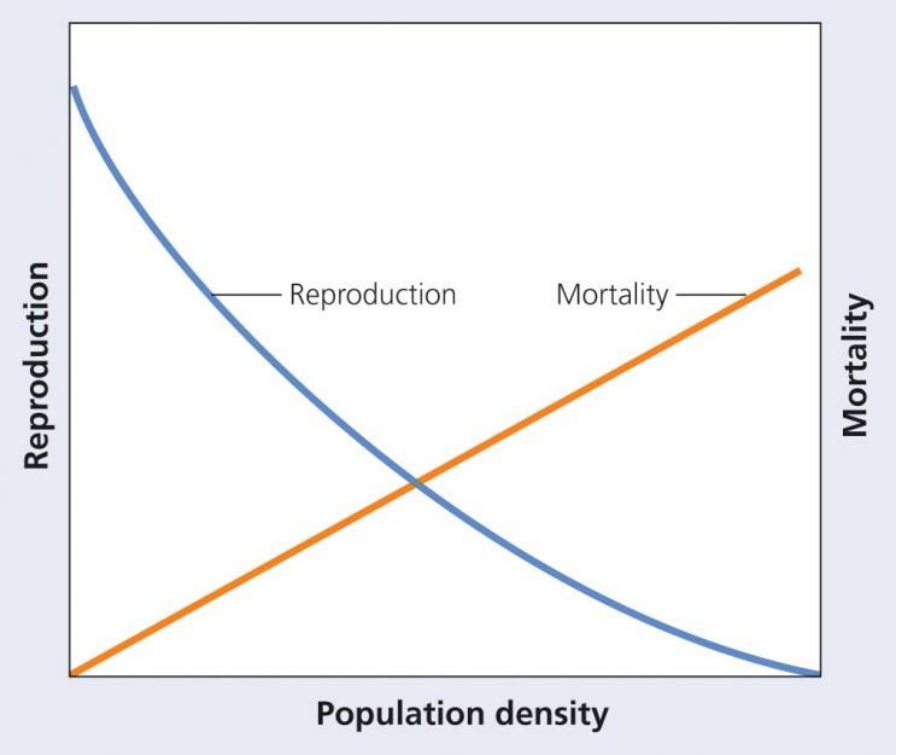


Valle and Coulter (1987)

 Copyright © 2015 Oxford University Press

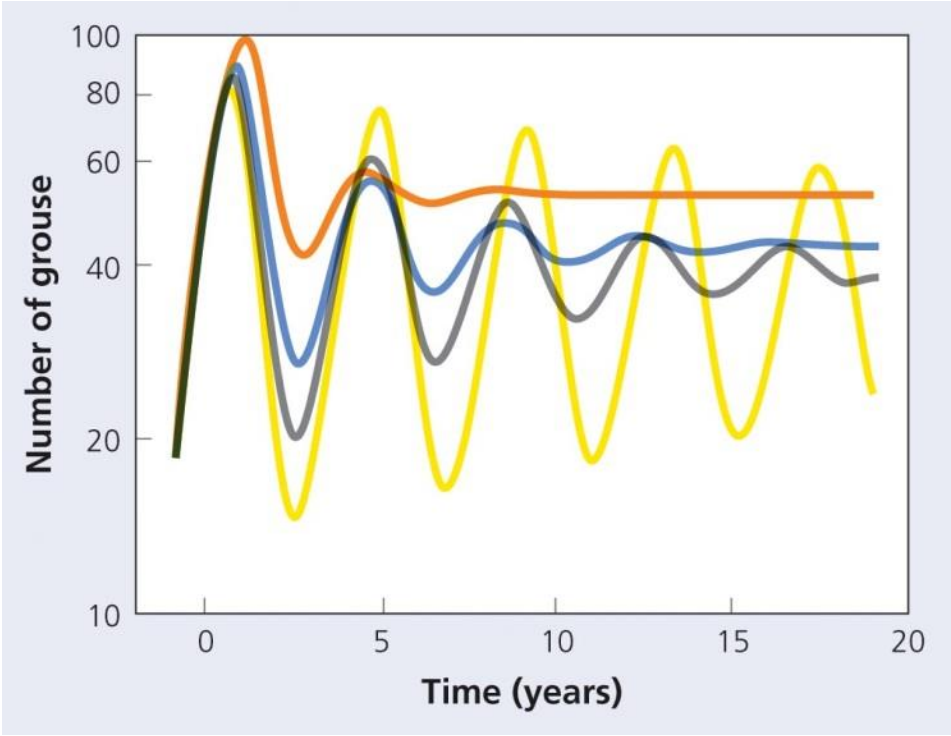
Density-Dependent Factors

- The effects of the density-dependent factors increase in intensity as the population increases.
- Bottom-up
  - E.g., the density-dependent effects on food supply
- Top-down
  - E.g., through the action of predators and parasites



Top-down Regulation of the Population Growth: Host-parasite relationships

- Cyclic dynamics of the red grouse (*Lagopus lagopus*) populations in Great Britain.
- Caused by the density-dependent effects of a parasitic nematode.
- When the parasite burden was experimentally reduced, the grouse population did not crash.



Line colors:
No treatment
5% treated
10% treated
20% treated

Hudson et al., 1998

 Copyright © 2015 Oxford University Press

Logistic Population Growth

$$\frac{dN}{dt} = rN\,(K-N)/K$$

or

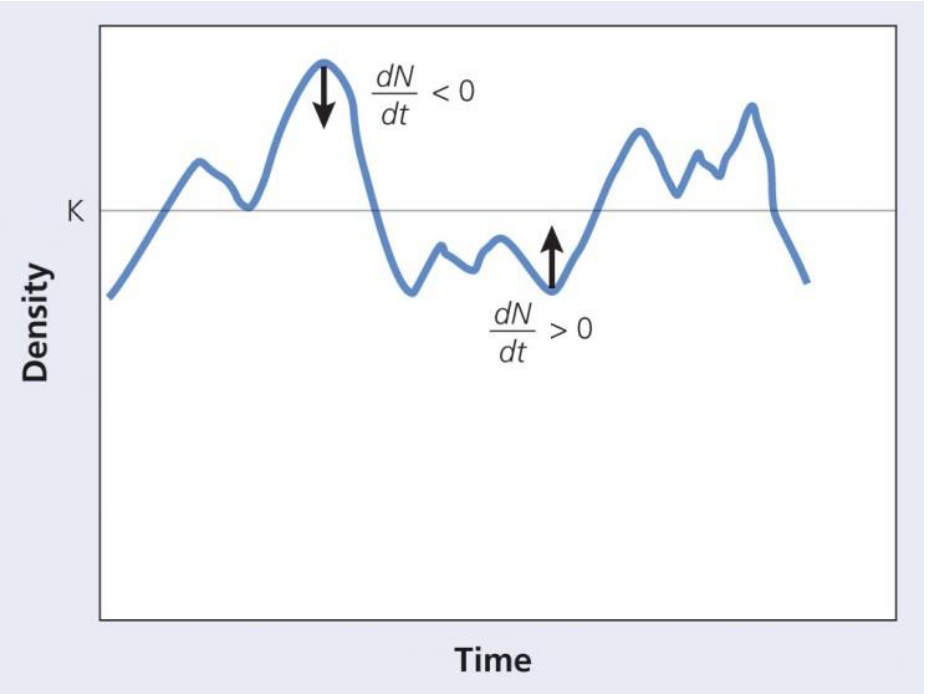
$$\frac{dN}{dt} = rN\,(1 - N/K)$$

where *K* is the carrying capacity (the maximum population size sustainable by the available resources).

 Copyright © 2015 Oxford University Press

Logistic Population Growth

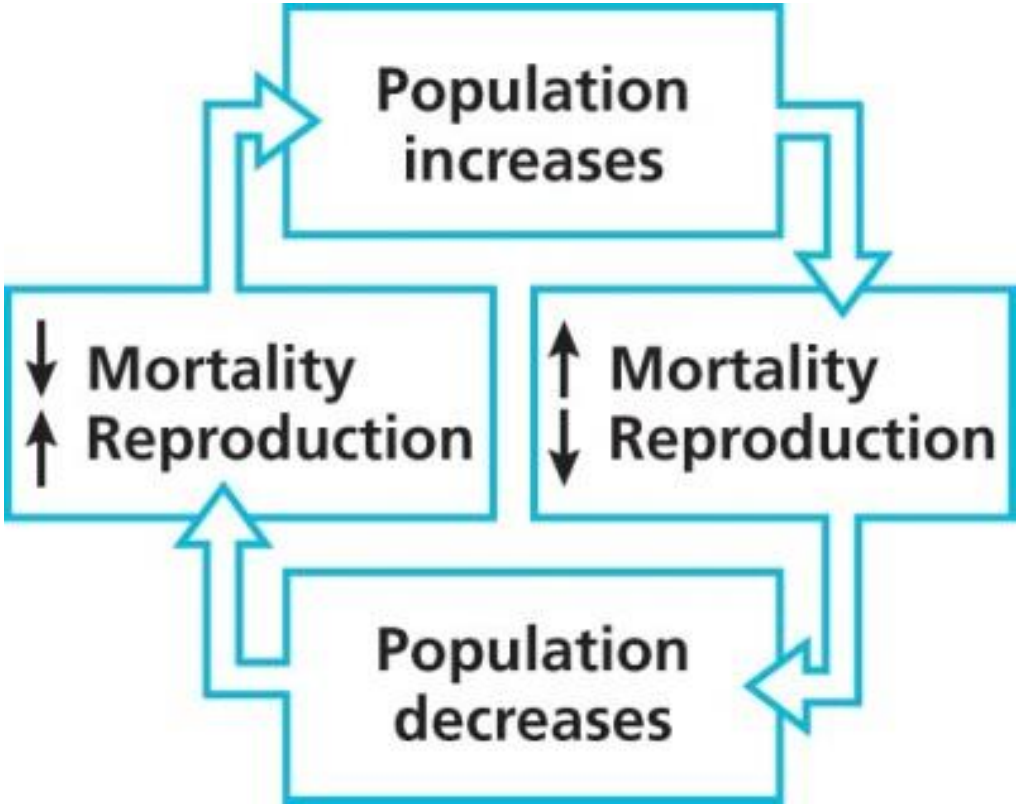
- If $N > K$, dN/dt is negative and the population declines.
- If $N < K$, dN/dt is positive, the population grows.
- If $N = K$: $dN/dt = 0$; the population is stable.



 Copyright © 2015 Oxford University Press

Density-Dependent Factors

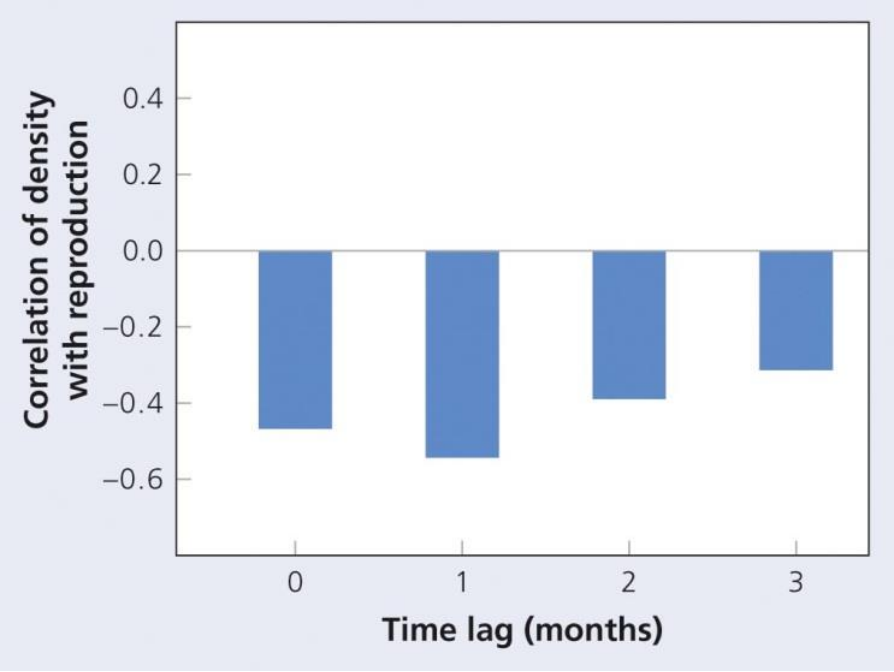
- Act as negative feedback systems on populations



 Copyright © 2015 Oxford University Press

Density-Dependent Factors

- Can be identified by the correlation between mortality or reproduction and population density.
- The correlation often involves time lag.

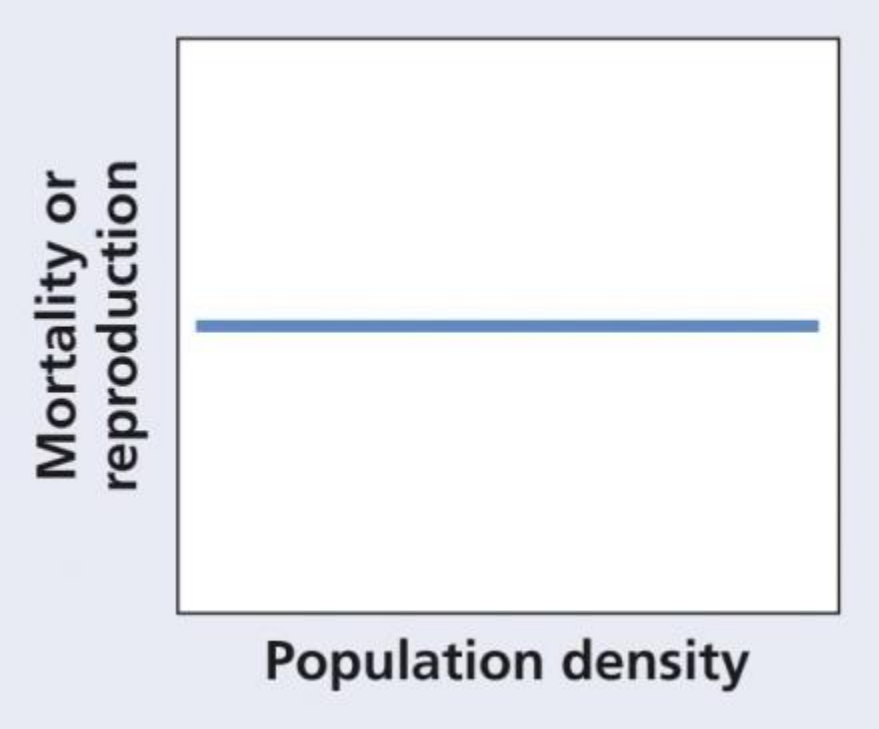


Example: The cotton rat (*Sigmodon hispidus*)

 Copyright © 2015 Oxford University Press

Density-Independent Factors

- Their effects do not change with population size.
- Abiotic factors (e.g., weather, fire, floods).
- Often unpredictable.



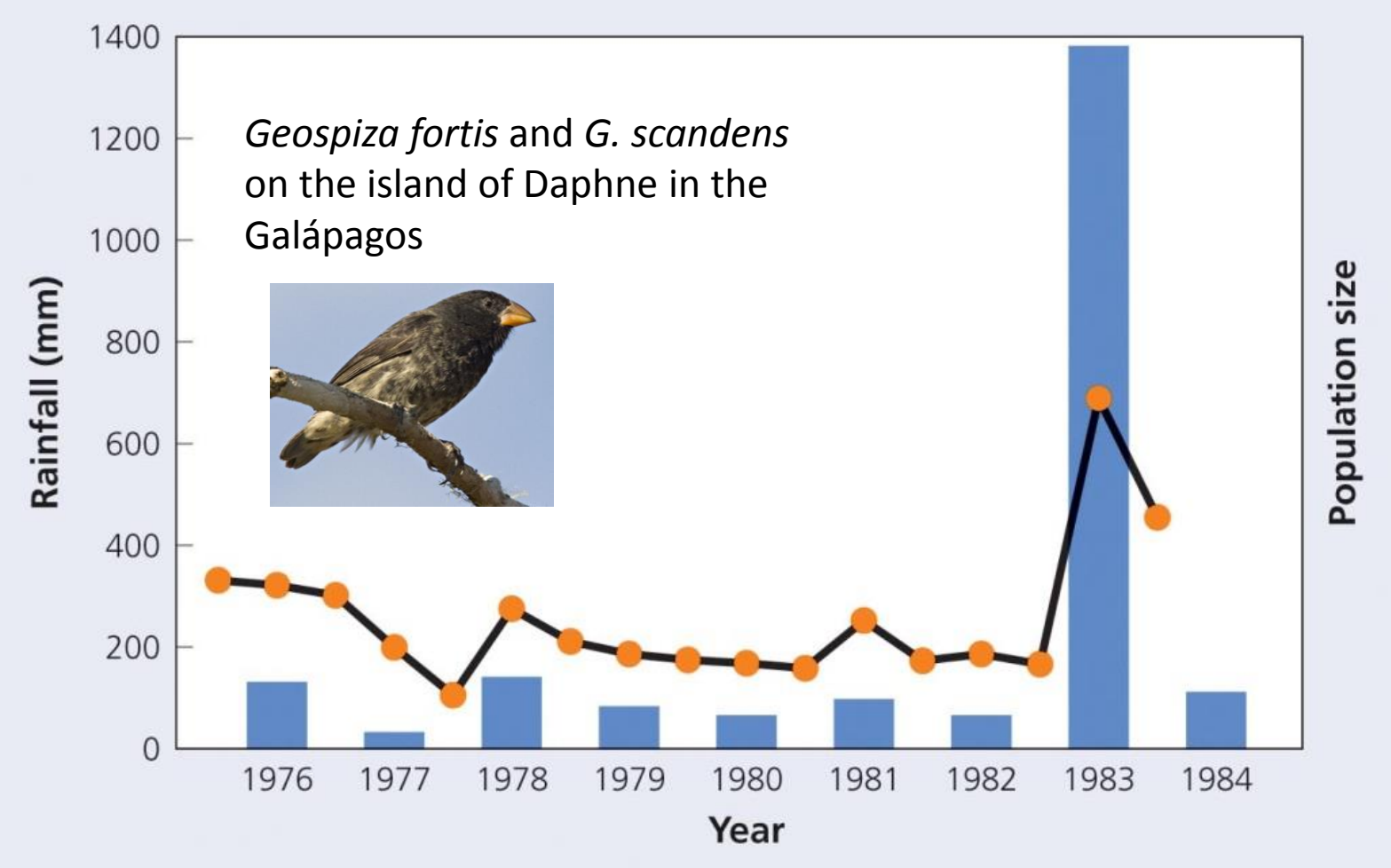
 Copyright © 2015 Oxford University Press

Density-Dependent vs. Density-Independent Factors

Density-dependent	Density-independent
• Population regulation • dN/dt = rN(K-N)/K	• Represent disturbance. • May prevent the population from reaching the equilibrium (K).

 Copyright © 2015 Oxford University Press

Effects of Drought on Darwin's finches



Effects of the rainfall are indirect (via altering the food availability)

 Copyright © 2015 Oxford University Press

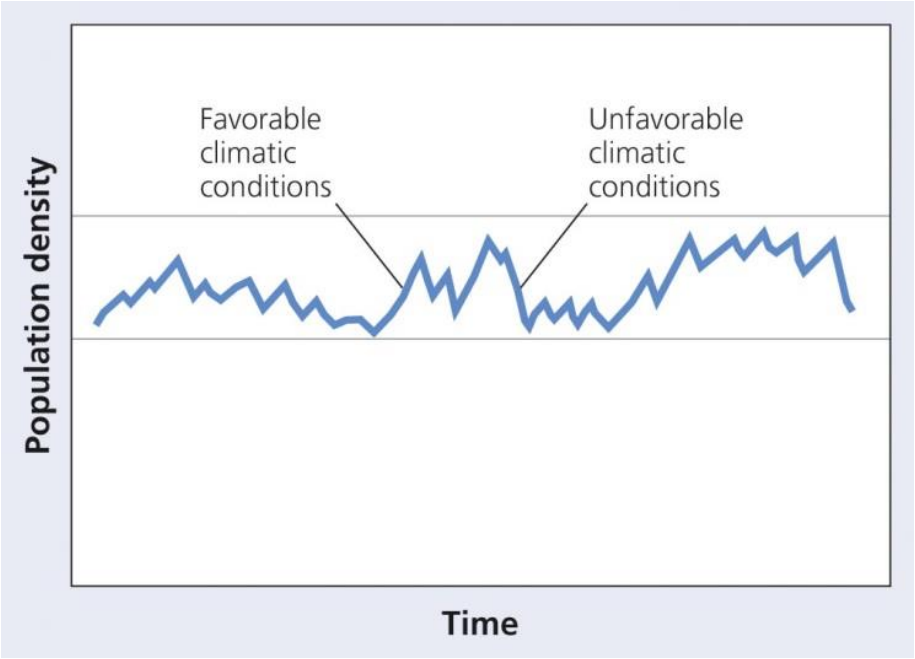
Take Home Points

- No population can grow indefinitely.
- Several important regulatory factors comprise paired mechanisms that limit growth.
  - Biotic and abiotic factors
  - Top-down and bottom-up factors
  - Density-dependent and density-independent factors

 Copyright © 2015 Oxford University Press

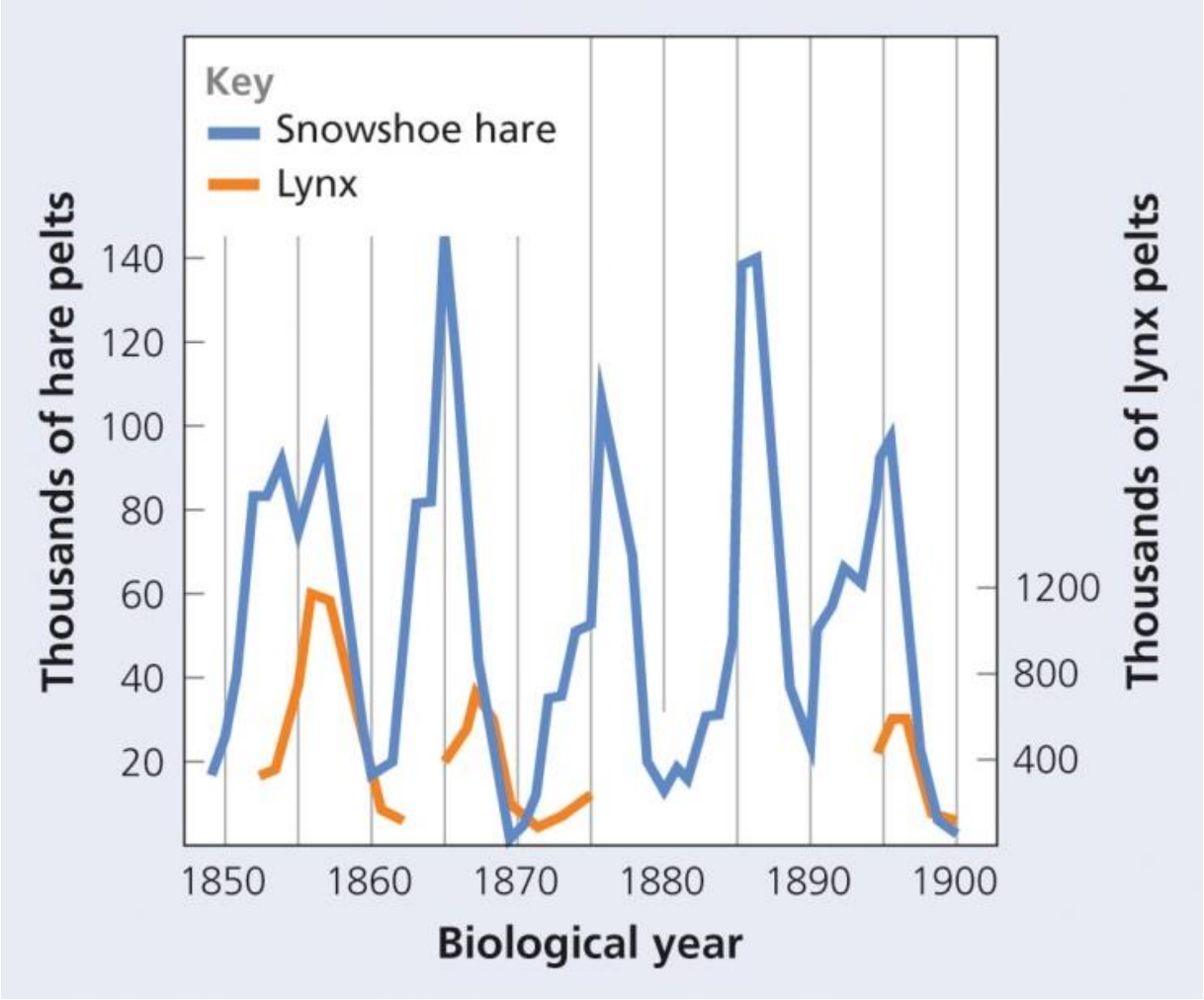
Population Stability

- Stable population fluctuates within relatively narrow limits.
- Achieved by the sum of both density dependent and density independent regulatory factors.
- The population may be stable but not at equilibrium.



 Copyright © 2015 Oxford University Press

Density-Dependent Control Does Not Always Result in Stability



 Copyright © 2015 Oxford University Press

Can Populations Achieve Stability by Internal Control Processes?

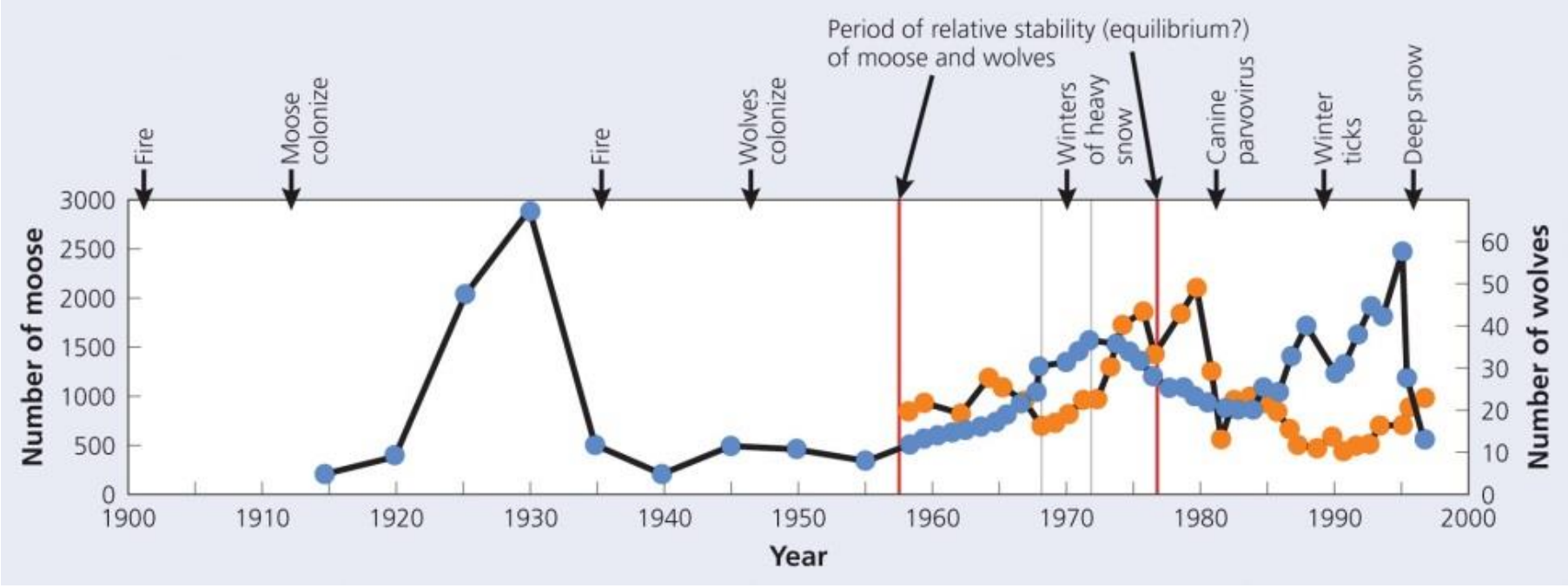
- Self-regulation requires that internal mechanisms affect the components of the basic equation

$$r = (b + i) - (d + e)$$

in a density-dependent fashion.

 Copyright © 2015 Oxford University Press

Interactions Among the Population Control Factors



Moose population on Isle Royale

Orange – wolves; blue – moose.

 Copyright © 2015 Oxford University Press

Take Home Points

- All populations fluctuate to varying degrees. Population stability is usually short-lived.
- Density-dependent factors tend to limit the degree of population fluctuation but do not necessarily lead to stability.
- Most populations are regulated by a number of interacting factors.
- Over time, the importance of regulatory factors may change. Therefore:
  - Long-term studies are important for understanding the process of population regulation.
  - It is not likely that any single factor will regulate a population.

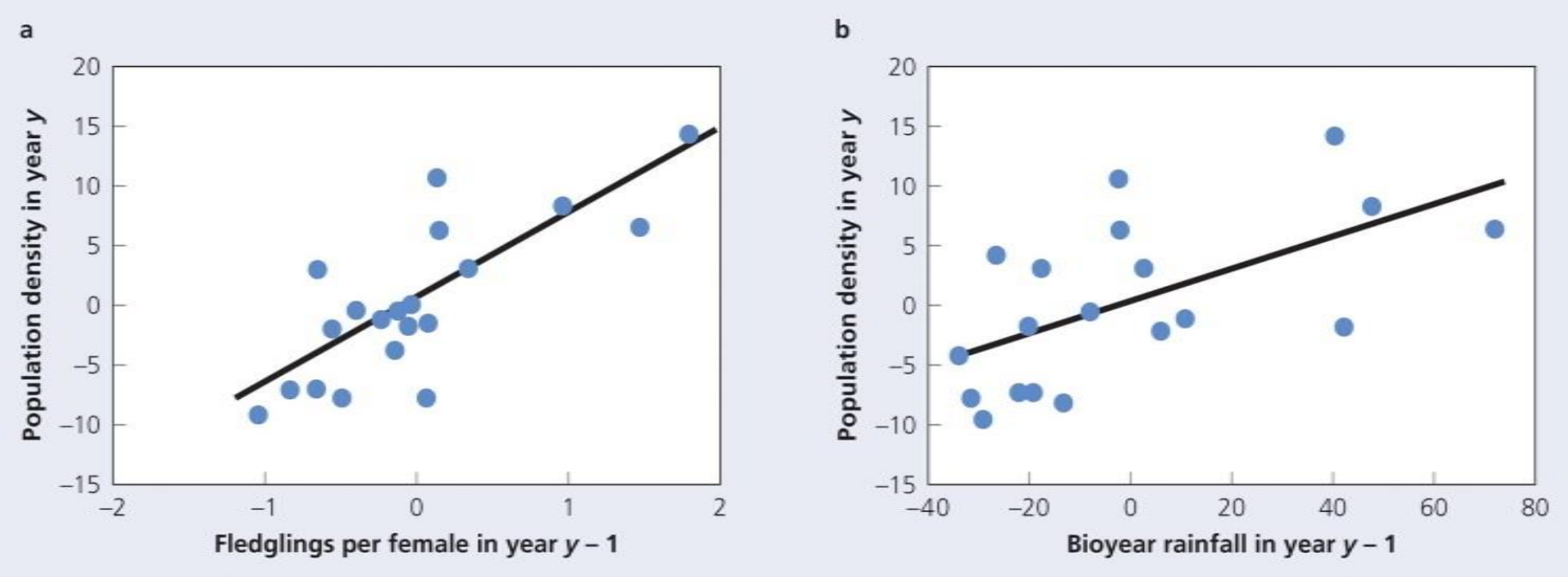
 Copyright © 2015 Oxford University Press

Long-Term Studies of Song Sparrow Population Dynamics

- **Question:** How do density-independent and density-dependent forces interact to determine the size of a song sparrow population?
- **Hypothesis:** Abiotic factors are the main factor determining population size.
- **Prediction:** Reproduction should correlate positively with precipitation; mortality should decrease with precipitation.

 Copyright © 2015 Oxford University Press

Long-Term Studies of Song Sparrow Population Dynamics

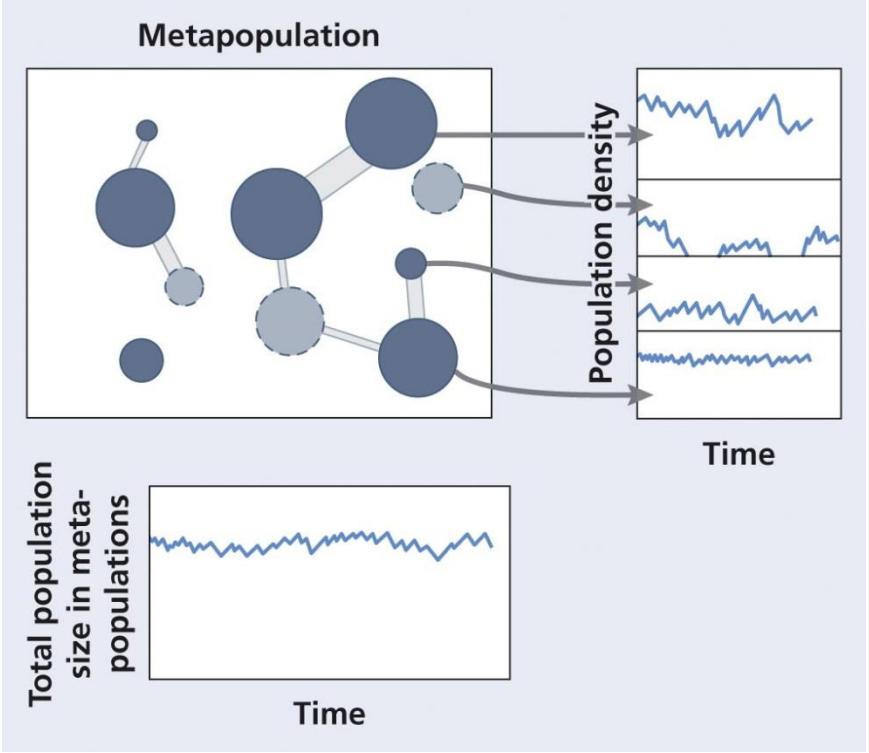


- The number of fledglings per female was positively correlated the total rainfall in the period July to the following June.
- i.e., density-independent and density-dependent factors interact.

 Copyright © 2015 Oxford University Press

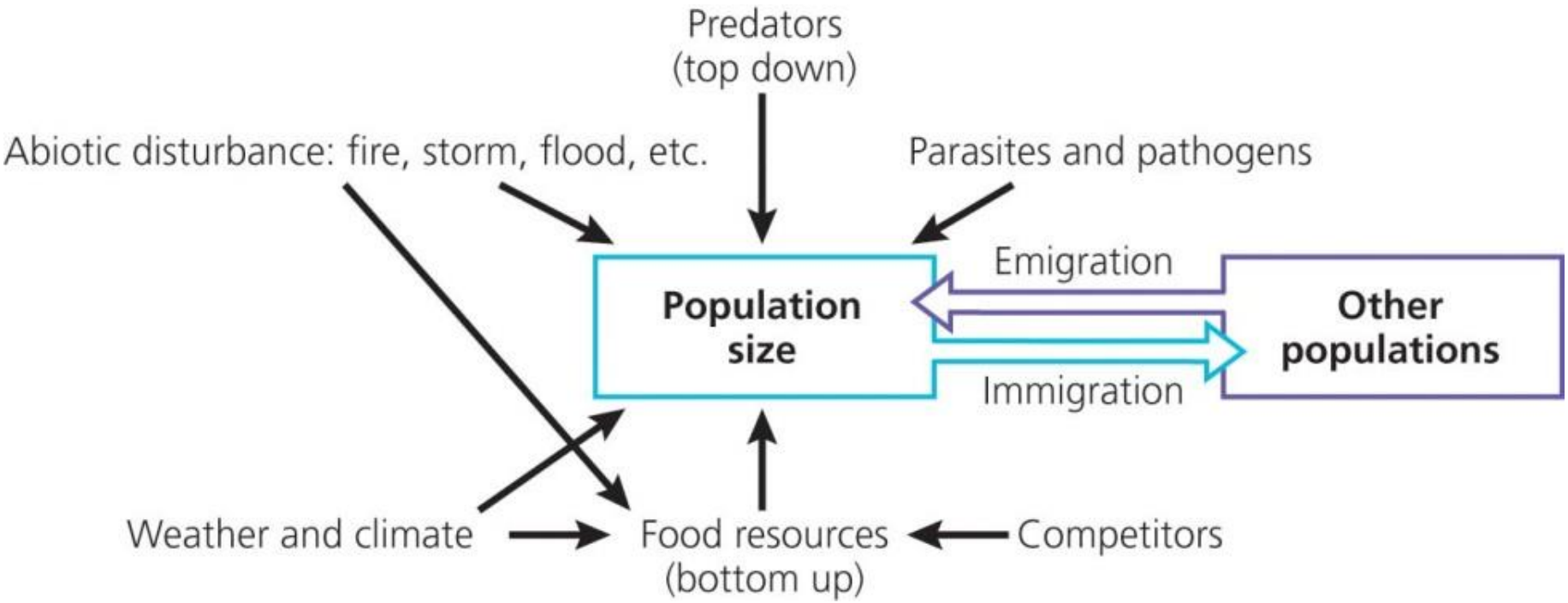
Metapopulation

- A group of populations in a landscape composed of habitat of varying quality and linked by migration.
- Any given habitat patch is vulnerable to extinction.
- The metapopulation is comparatively stable because it is composed of a set of populations that fluctuate independently.



 Copyright © 2015 Oxford University Press

A General Conceptual Model of Population Regulation and Control



 Copyright © 2015 Oxford University Press

Take Home Points

- Regulatory factors vary over space. Thus, populations are spatial mosaics of different regulatory processes.
- The metapopulation concept incorporates this spatial variation.
- The populations that comprise a metapopulation fluctuate and are regulated independently. However, they are potentially connected by dispersal among populations.

 Copyright © 2015 Oxford University Press