

8

Population Distribution and Abundance



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8 Population Distribution and Abundance

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Case Study: From Kelp Forest to Urchin Barren

Waters surrounding the Aleutian Islands have abundant marine life, including the sea otter.



Figure 8.1 Key Players in the Forests of the Deep

Case Study: From Kelp Forest to Urchin Barren

Some of the islands have “kelp forests” in the nearshore waters.

Kelp are brown algae that grow upward from attachments on the sea floor to form dense forest-like stands.

The kelp forests harbor a diverse community of organisms.

Case Study: From Kelp Forest to Urchin Barren

Other islands have “urchin barrens”—abundant sea urchins, very little kelp, and lower species diversity.

The islands do not appear to have different currents, climate, or other physical features that could account for these differences in communities.

Case Study: From Kelp Forest to Urchin Barren

Grazing of kelp by sea urchins could explain the differences.

Two ways of testing this:

- Field studies on many islands show a negative correlation between urchin abundance and kelp cover.

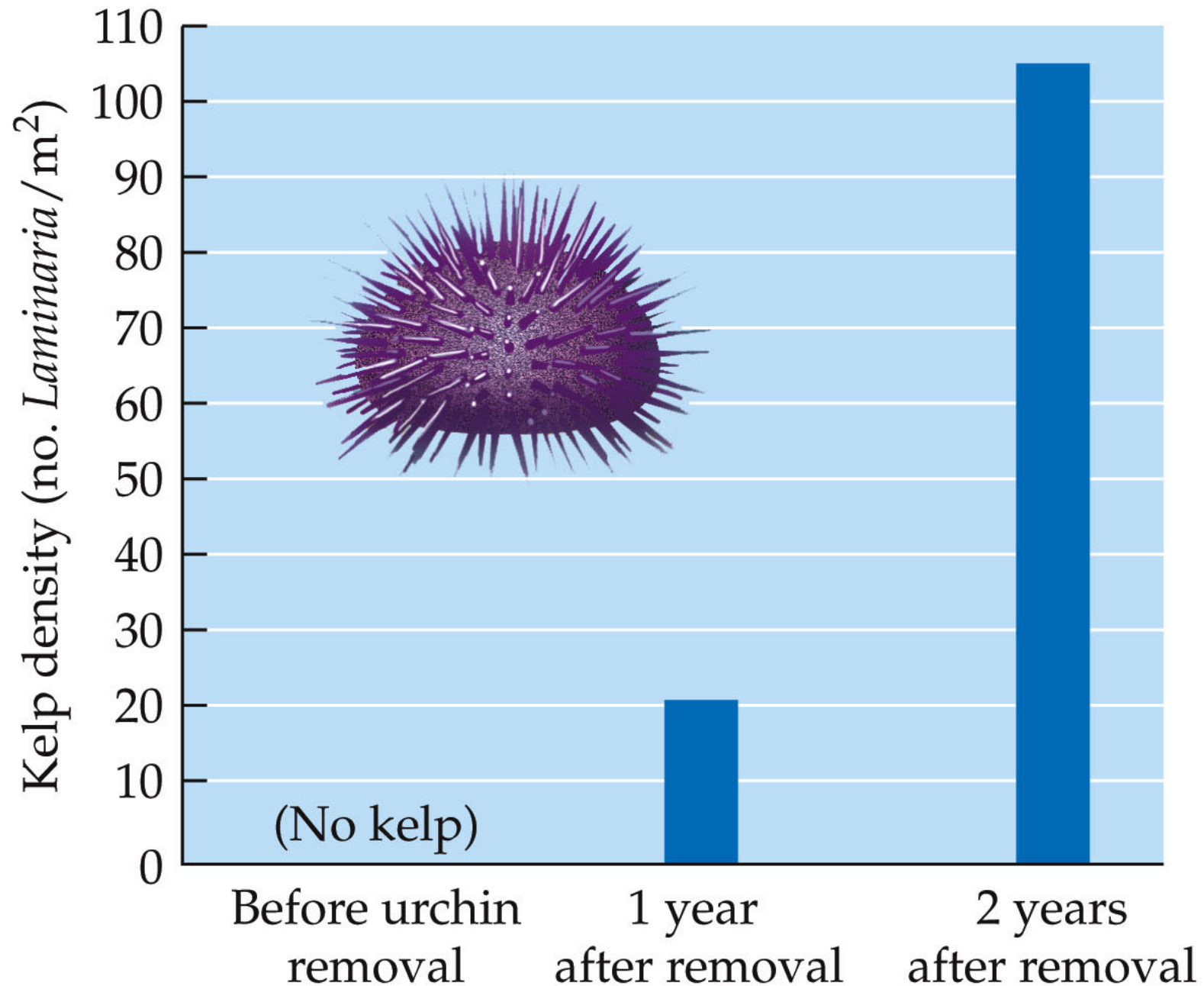
Case Study: From Kelp Forest to Urchin Barren

Experimental studies: Urchins were removed from plots with no kelp. Kelp abundance increased dramatically.

In plots where urchins remained, no kelp grew.

So, presence or absence of urchins determines presence or absence of kelp. What controls the urchins?

Figure 8.2 Do Sea Urchins Limit the Distribution of Kelp Forests?



Distribution: Geographic area over which individuals of a species occur.

Abundance: The number of individuals in a specific area.

Ecologists often wish to understand what factors determine the distribution and abundance of species.

Introduction

Distribution and abundance can change over time and space—populations are dynamic.

Populations of many species are declining; if we wish to protect species, we must understand factors contributing to declines and their underlying causes.

Populations

Concept 8.1: Populations are dynamic entities that vary in size over time and space.

Population: Group of individuals of the same species that live within a particular area and interact with one another.

Abundance can be reported as population **size** (# individuals), or **density** (# individuals per unit area).

Populations

Example:

On a 20-hectare island there are 2,500 lizards.

Population size = 2,500

Population density = 125/hectare

Populations

Sometimes the total area occupied by a population is not known.

It is often difficult to know how far organisms or their gametes can travel.

When the area isn't fully known, an area is delimited based on best available knowledge of the species.

Populations

Abundance can change over time and space. Some species vary more than others.

A 6-year study of 23 species of insects that feed on goldenrod showed that although the sites had similar climatic conditions every year, insect abundances varied greatly.

Figure 8.3 Abundances Are Dynamic (Part 1)

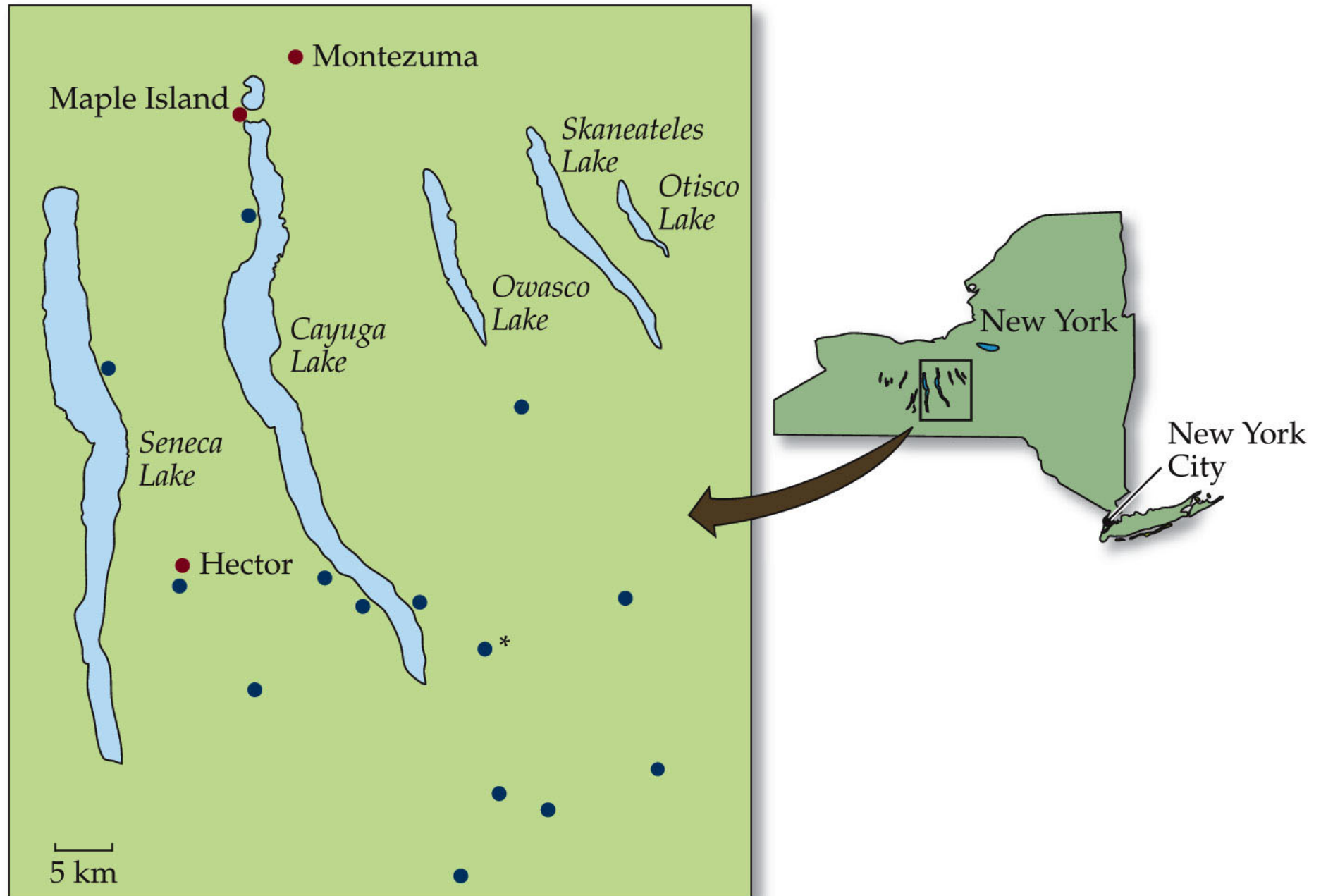
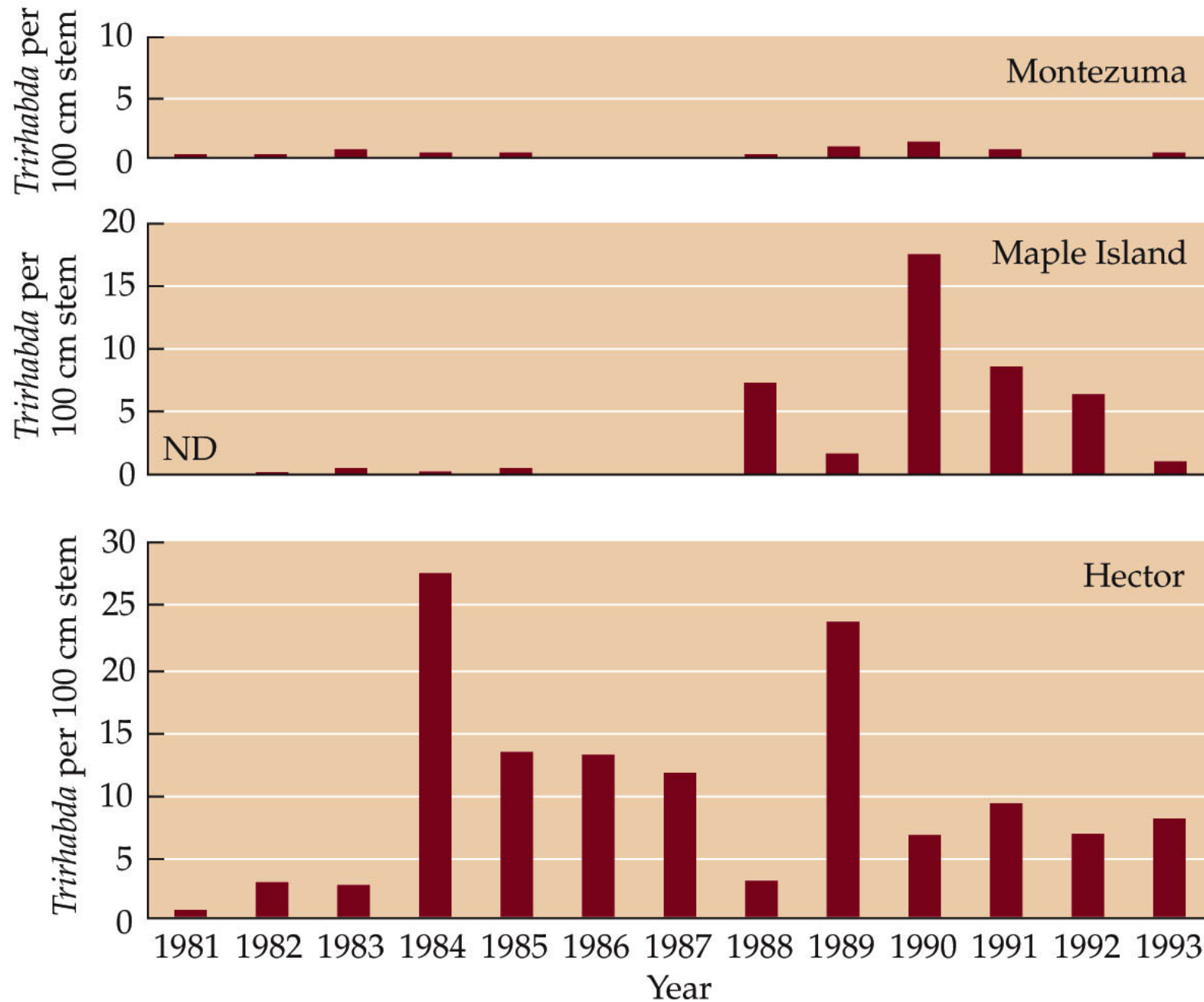


Figure 8.3 Abundances Are Dynamic (Part 2)



Populations

Abundances of some species varied greatly from year to year, while abundance of other species changed little.

Some species also varied in abundance from site to site.

Populations

Species vary in their ability to disperse.

For most plants, dispersal occurs by seed movement. The distance moved can be very small.

Other species, such as whales, can move thousands of kilometers in a year.

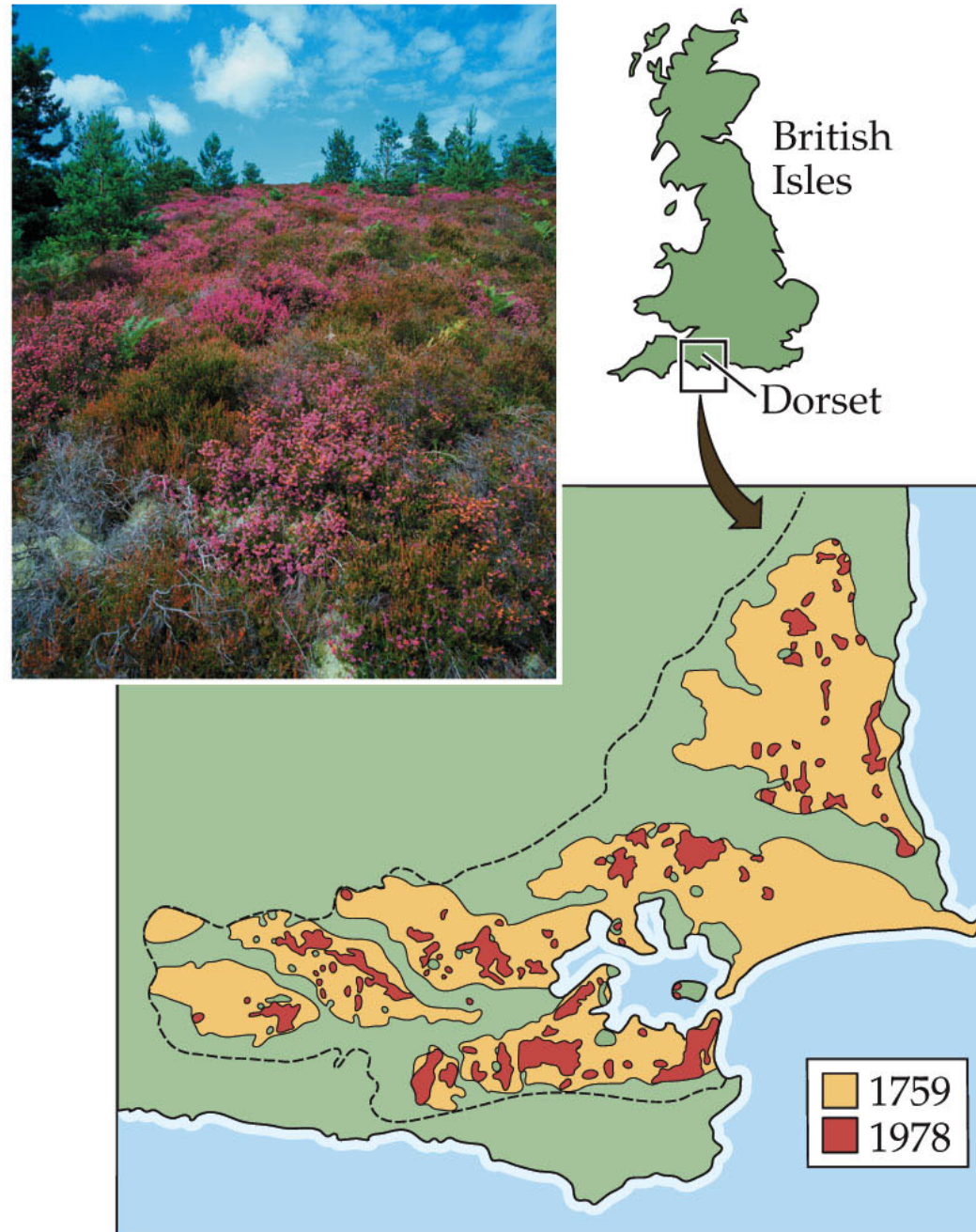
Populations

Populations may exist in patches that are spatially isolated but linked by dispersal.

This can result from physical features of the environment, and from human activities that subdivide populations.

For example, heathlands in England have been fragmented by human development.

Figure 8.4 Fragmentation of Dorset Heathlands



Populations

For some species, it is difficult to determine what an individual is.

Aspen trees can produce clones (genetically identical copies of themselves) by forming new plants from root buds.

A grove of aspens may all be from the same individual.

Figure 8.5 Aspen Groves—One Tree or Many?



Populations

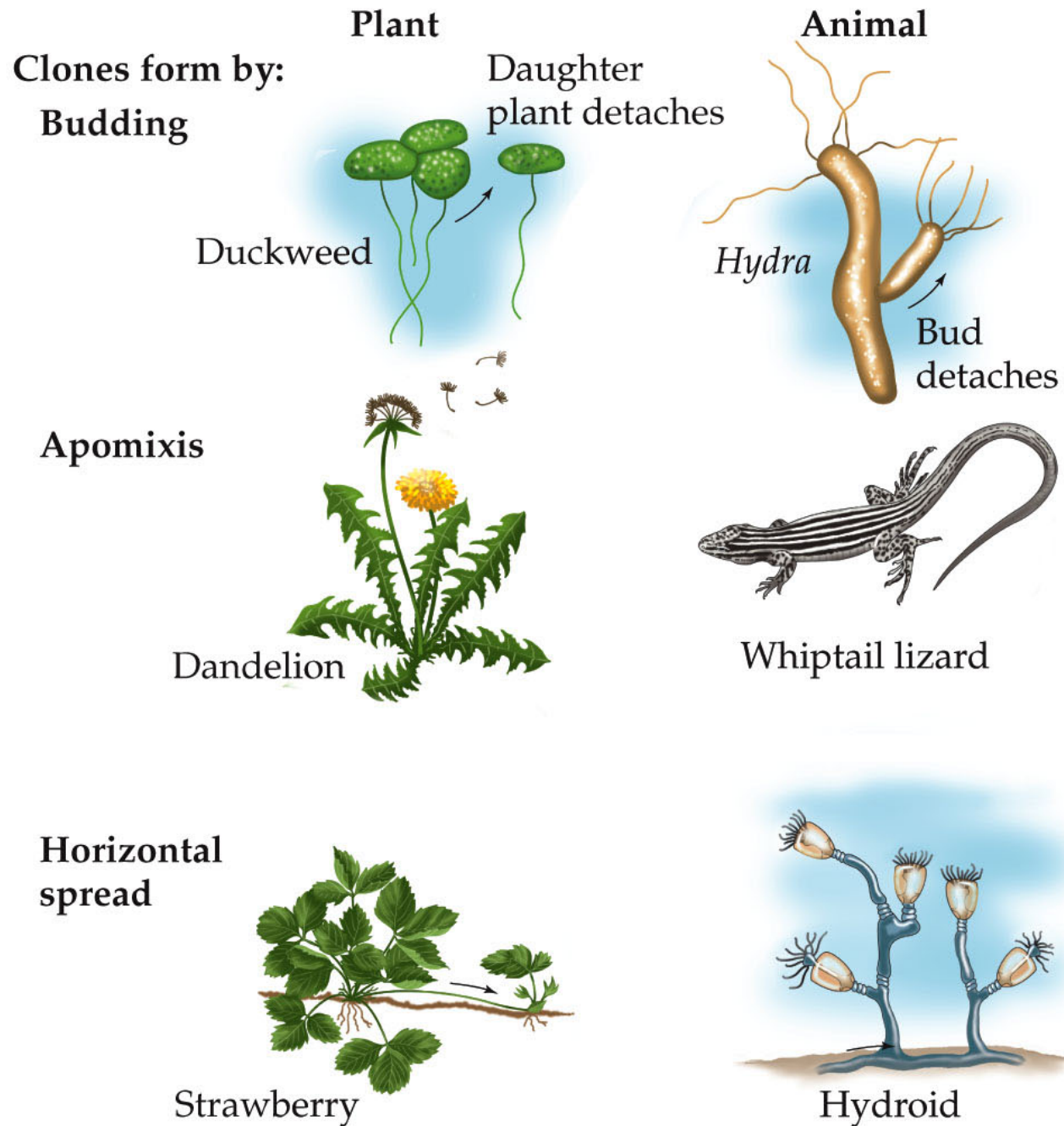
Other plants form clones on horizontal stems or “runners.”

Animals such as corals, bryozoans, and sea anemones can also form clones.

Some insects, fish, frogs, and lizards also produce clones.

How can one count individuals in such a population?

Figure 8.6 Plants and Animals That Form Clones



Populations

Individuals can be defined as products of a single fertilization: The aspen grove would be one individual, a **genet**.

Members of a genet may be independent physiologically, so members of a genet are called **ramets**.

Distribution and Abundance

Concept 8.2: The distributions and abundances of organisms are limited by habitat suitability, historical factors, and dispersal.

Abiotic features of the environment include moisture, temperature, pH, sunlight, nutrients, etc.

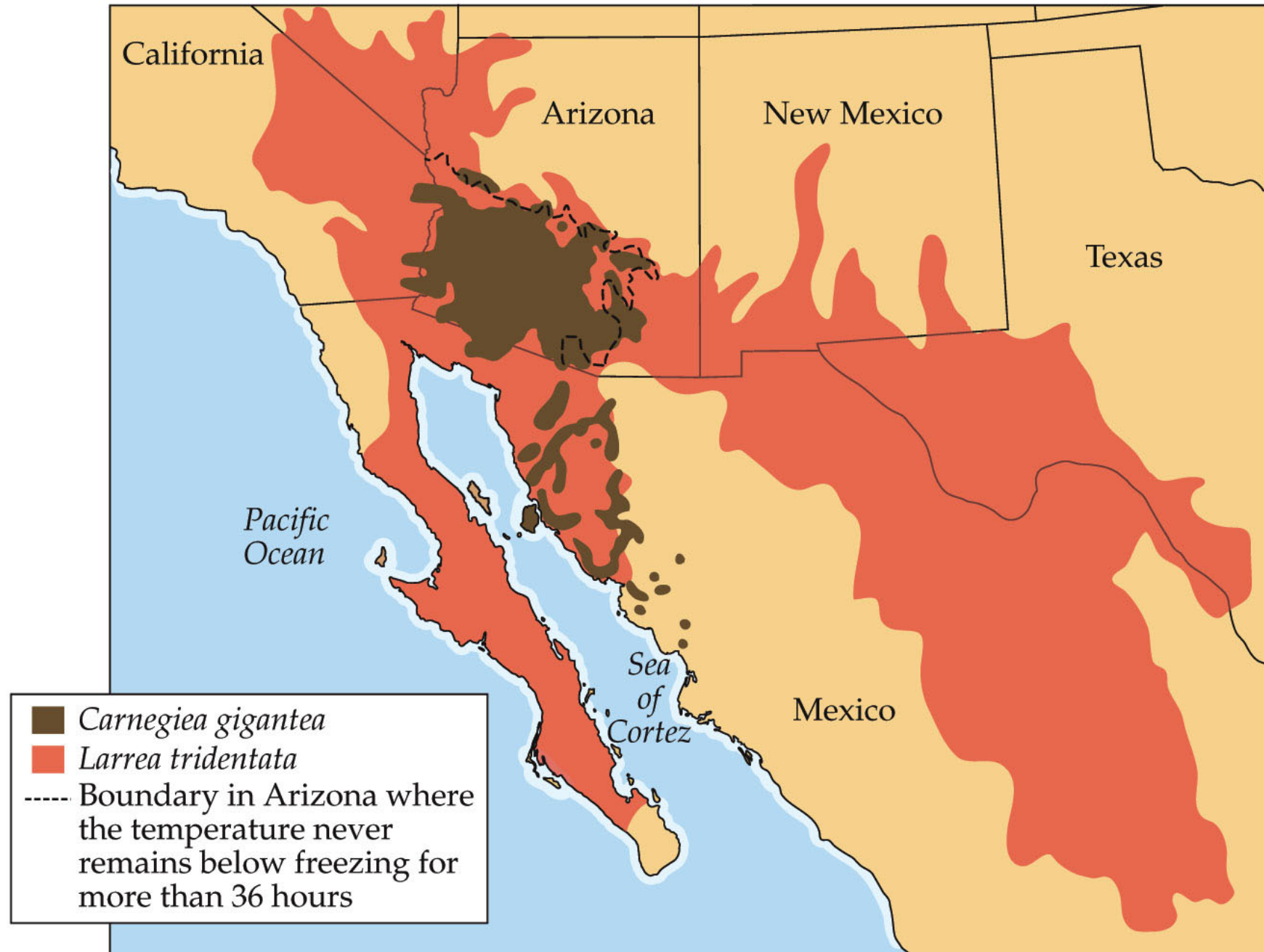
Some species can tolerate broad ranges of physical conditions, others have narrow ranges.

Distribution and Abundance

Creosote bush has a broad range of distribution in North American deserts. It is very tolerant of dry conditions.

Saguaro cactus has a more limited distribution—it can tolerate dry conditions, but not cold temperatures. Its northern limit is the boundary beyond which temperatures can sometimes remain below freezing for at least 36 hours.

Figure 8.7 The Distributions of Two Drought-Tolerant Plants



Distribution and Abundance

Biotic features: Organisms can be affected by herbivores, predators, competitors, parasites and pathogens.

Opuntia stricta, a cactus introduced into Australia, became a pest species, spreading over vast areas.

A moth that feeds on cactus was then released, and distribution and abundance of the cactus has been greatly reduced.

Figure 8.8 Herbivores Can Limit Plant Distributions

(A)



(B)

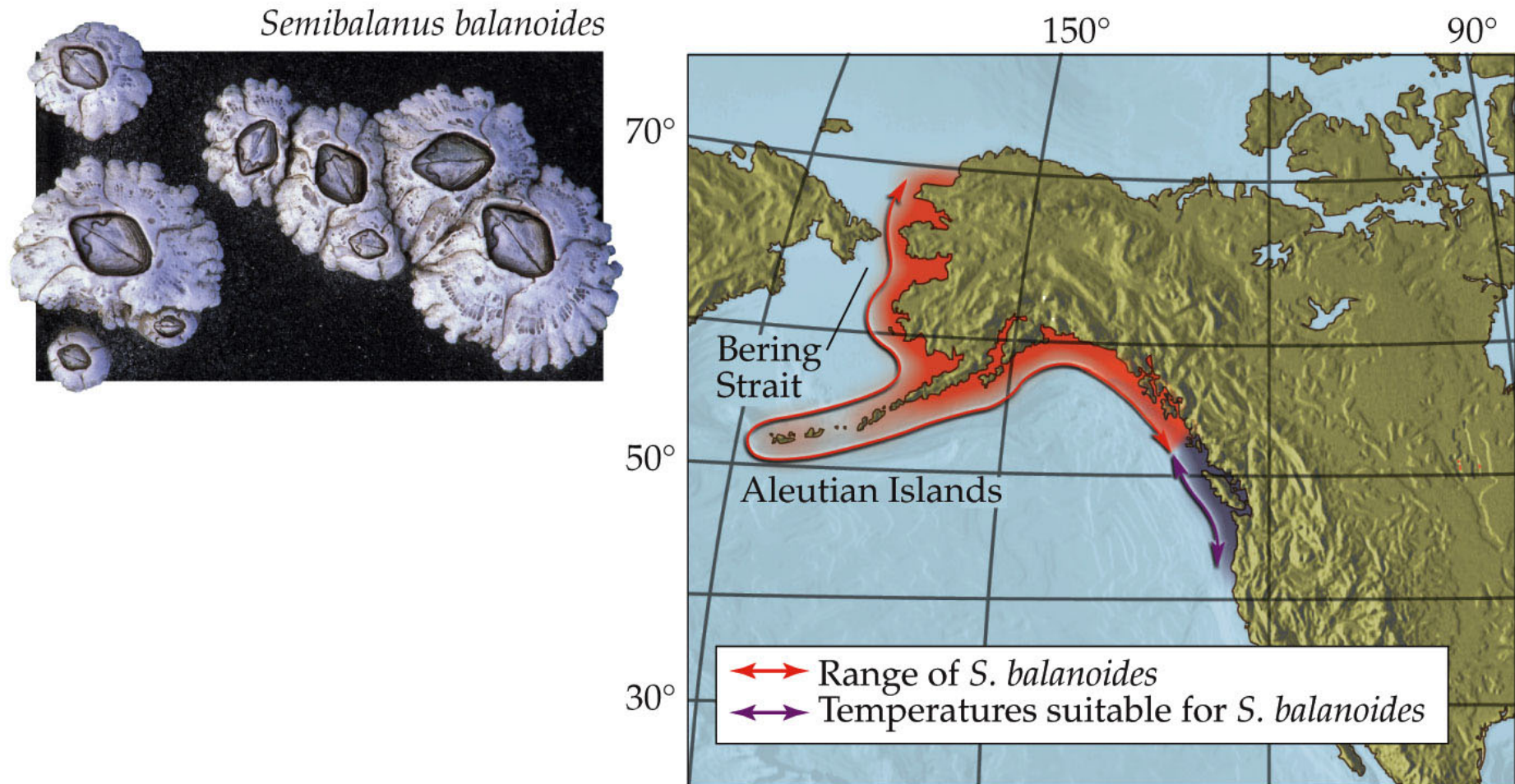


Distribution and Abundance

Abiotic and biotic features of the environment can act together to determine distribution and abundance.

The barnacle *Semibalanus balanoides* is restricted by temperature for survival and reproduction. But competition from other species precludes it from some areas that have suitable temperatures.

Figure 8.9 Joint Effects of Temperature and Competition on Barnacle Distribution



Distribution and Abundance

Some species distributions depend on **disturbance**—events that kill or damage some individuals, creating opportunities for other individuals to grow and reproduce.

For example some species persist only where there are periodic fires.

Distribution and Abundance

Evolutionary history, dispersal abilities, and geologic events all affect the modern distribution of species.

Example: Polar bears evolved from brown bears in the Arctic. They are not found in Antarctica because of an inability to disperse through tropical regions.

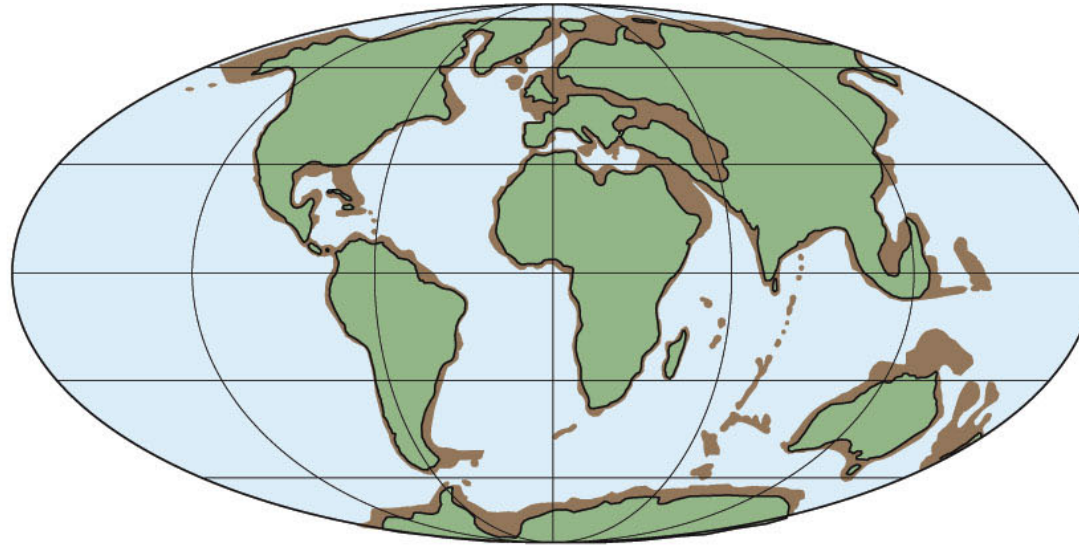
Distribution and Abundance

Continental drift explains the distributions of some species.

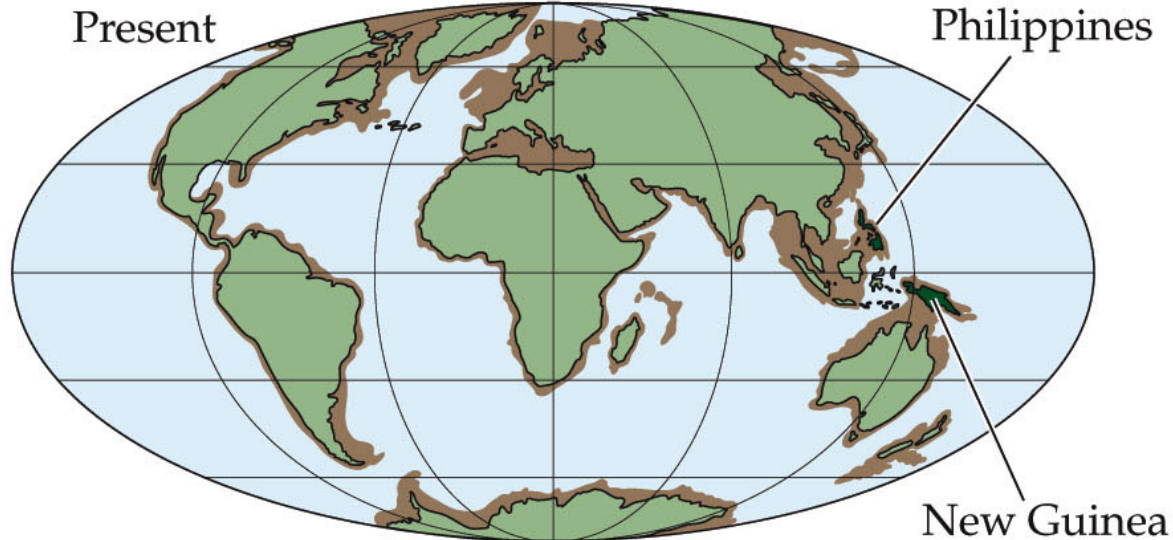
Wallace (1860) observed that animals can vary considerably over very short distances, a phenomenon that could not be explained until continental drift was proposed.

Figure 8.10 Continental Drift Affects the Distribution of Organisms

30 million years before present



Present



Dispersal limitation can prevent species from reaching areas of suitable habitat.

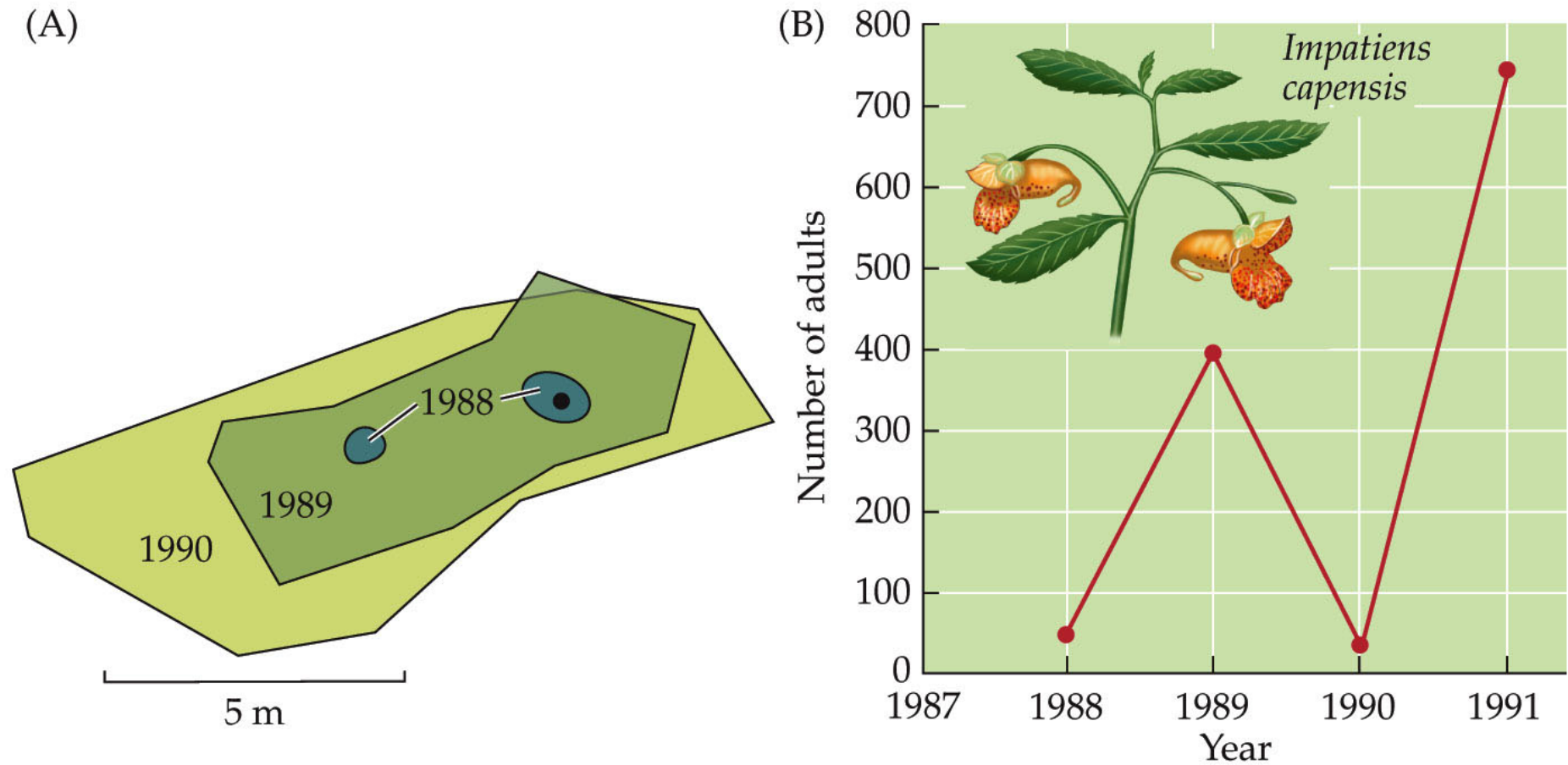
Example: The Hawaiian Islands have only one native mammal, the hoary bat, which was able to fly there.

Distribution and Abundance

In an experimental study of four annual plant species, seeds of each species were placed in 34 unoccupied but apparently suitable sites that were 40 to 600 meters from existing populations.

At three of the 34 test sites, new populations became established, persisted for four generations, and slowly expanded to cover a larger area.

Figure 8.11 Populations Can Expand after Experimental Dispersal



Distribution and Abundance

Dispersal also affects density of populations, and vice-versa.

Many species of aphids produce winged forms (capable of dispersing) in response to crowding.

Distribution and Abundance

Dispersal was studied using desert pupfish in experimental pools (McMahon and Tash 1988).

In “open” pools dispersal was possible, “closed” pools did not allow dispersal.

Open pools had less overcrowding and less mortality, and higher reproductive rates.

Figure 8.12 Desert Pupfish Habitat

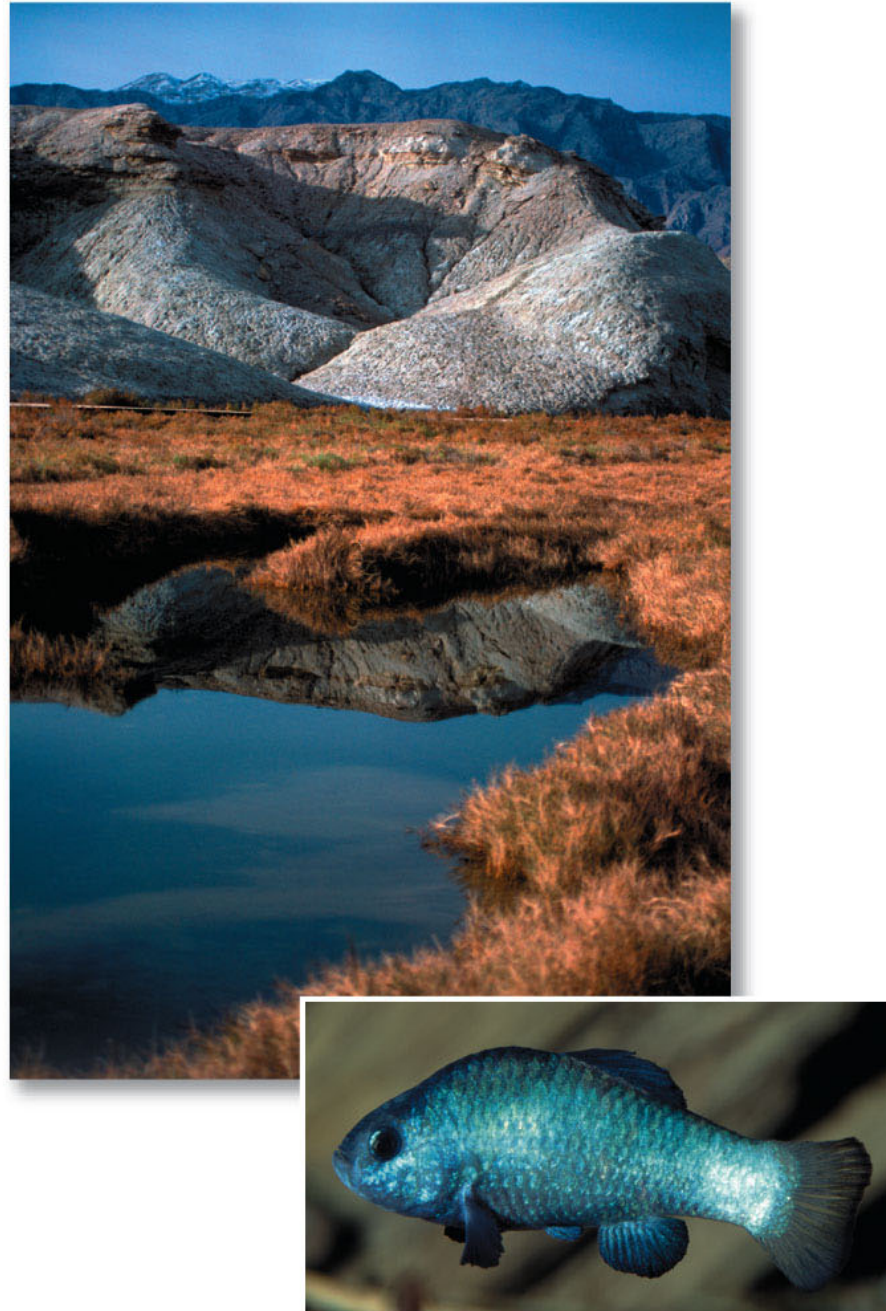


TABLE 8.1				
Effects of Dispersal on Reproduction and Mortality of Desert Pupfish				
	<u>Open Pools</u>		<u>Closed Pools</u>	
	Mean	(SE)	Mean	(SE)
Offspring production per pool				
1982	283	(6.7)	269	(23.4)
1983	117	(60.7)	19	(6.5)
Combined years	350	(56.3)	287	(29.8)
Number mature females per pool in 1983	18	(3.6)	19	(2.6)
Number offspring per female in 1983	7		1	
Total no. dead offspring per pool (1982 and 1983 combined)	36	(11.8)	164	(29.3)
Percentage of offspring that died	10		57	

Source: Data from McMahon and Tash 1988.

Note: Values were measured in artificial pools that were open to dispersal versus artificial pools that were closed to dispersal (there were four pools of each type). Mean values and the associated standard error (SE) of the mean are given. The SE of the mean provides a measure of how much the data varied from one pool to the next (see **Web Stats Review**).

Distribution and Abundance

Dispersal may play a similar role in natural populations of desert pupfish. Following heavy rains, the small pools are connected by temporary streams.

Dispersal is risky for fish that live in desert pools, but these experiments suggest that dispersal may provide a fish with a greater chance for survival and reproduction.

Geographic Range

Concept 8.3: Many species have a patchy distribution of populations across their geographic range.

There is much variation in the size of **geographic ranges**—the entire geographic region over which a species is found.

Geographic Range

Devil's Hole pupfish lives in a single desert pool (7 × 3 m across and 15 m deep).

Many tropical plants have a small geographic range. In 1978, 90 new species were discovered on a single mountain ridge in Ecuador, each species was restricted to that ridge.

Geographic Range

Other species, such as the coyote, have very large geographic ranges.

Some species are found on several continents.

Few species are found on all continents except humans, Norway rats, and the bacterium *E. coli*.

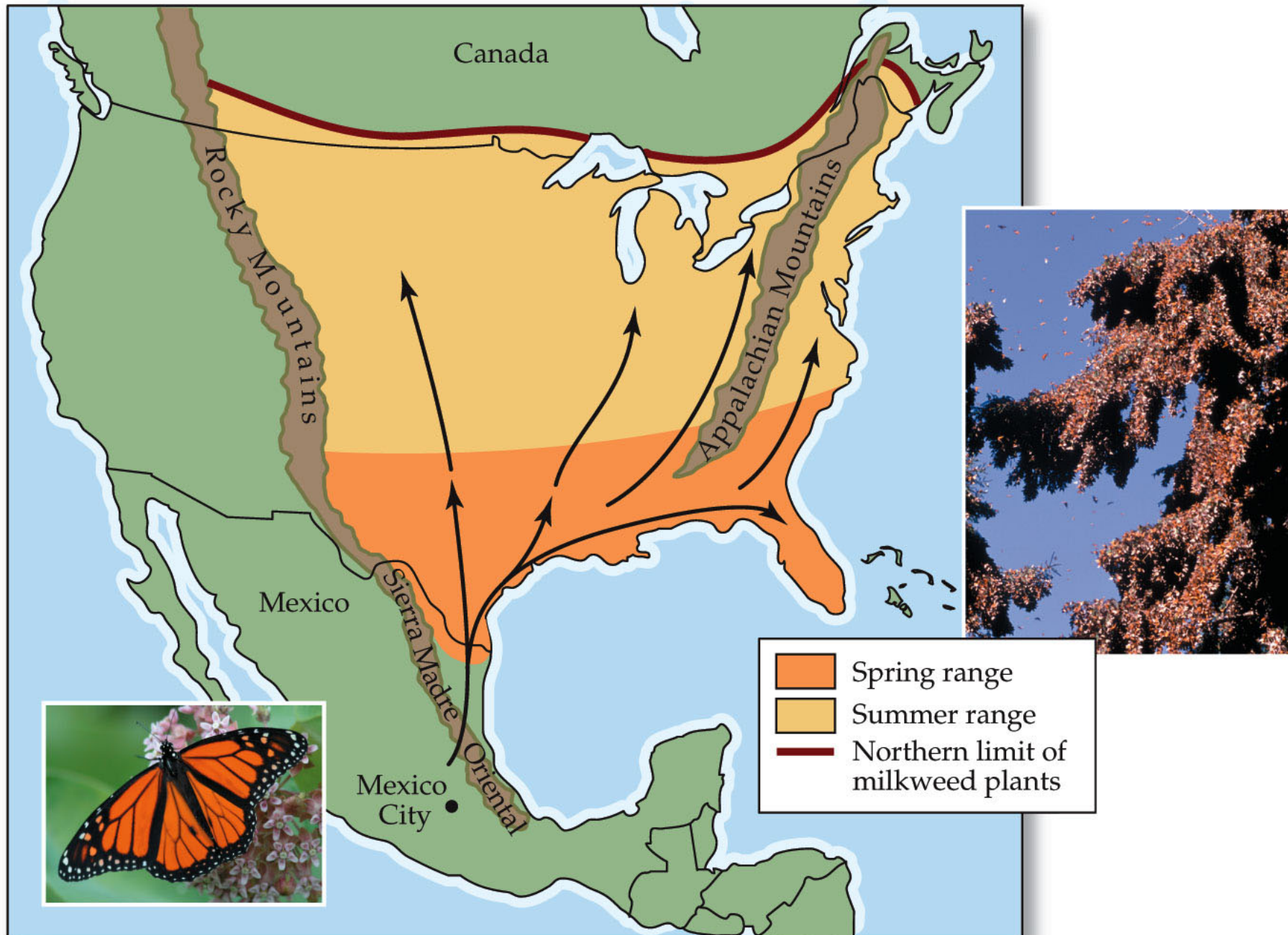
Geographic Range

Geographic range includes areas a species occupies during all life stages.

Some species, such as monarch butterflies, migrate long distances between summer and winter habitats.

For some species, it is difficult to find all the life stages and the ranges they inhabit.

Figure 8.13 Monarch Migrations



Geographic Range

Many species have patchy distributions because not all habitat within the range is suitable.

This can operate at different spatial scales.

At large scales, climate may dictate locations of populations. At small scales, soils, topography, other species, etc. can determine patchiness.

Geographic Range

Patchiness at different scales is illustrated by the shrub *Clematis fremontii* var. *riehlii*.

It is restricted to areas of dry, rocky soil with few trees, called barrens or glades.

The glades occur on outcrops of limestone on south- or west-facing slopes.

Figure 8.14 Populations Often Have a Patchy Distribution (Part 1)

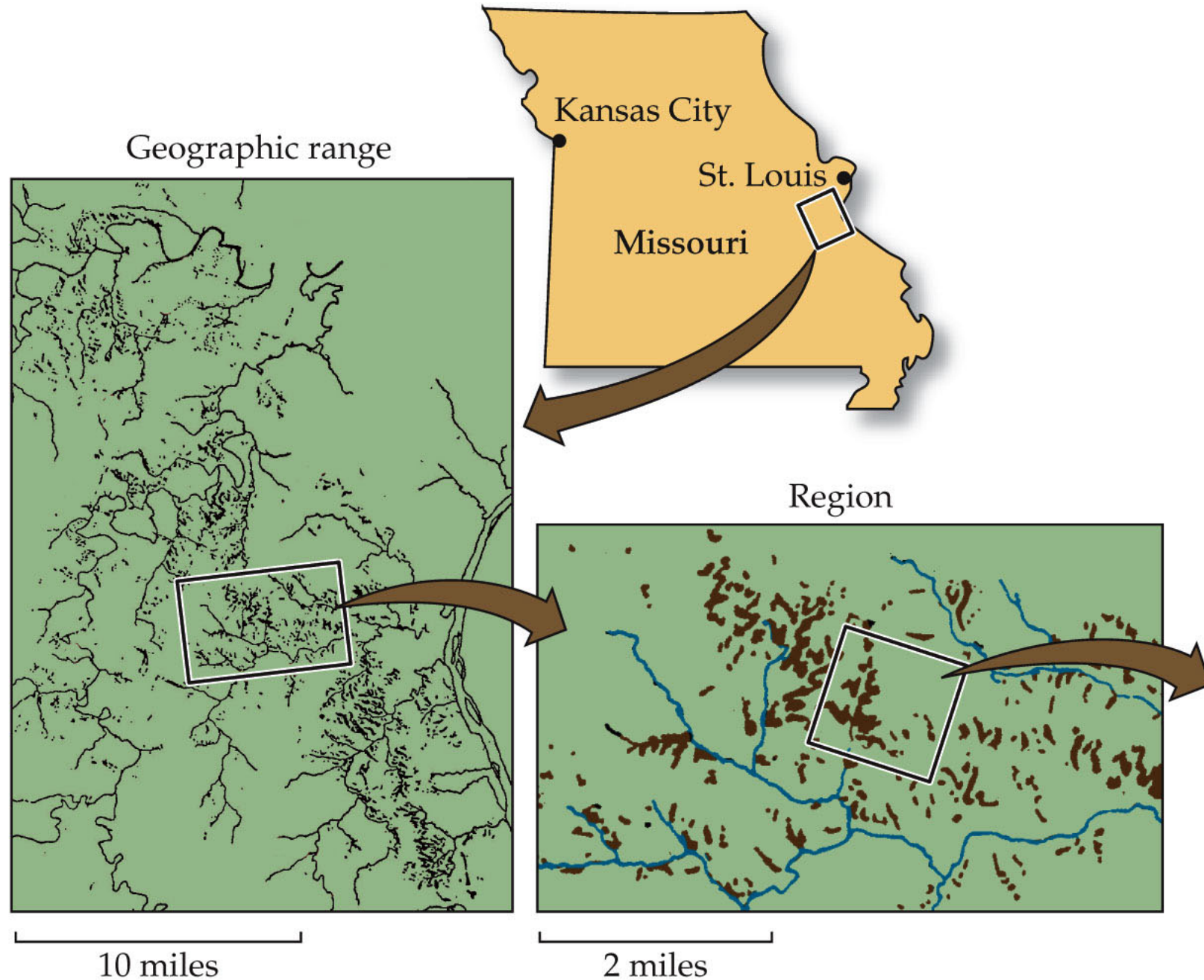
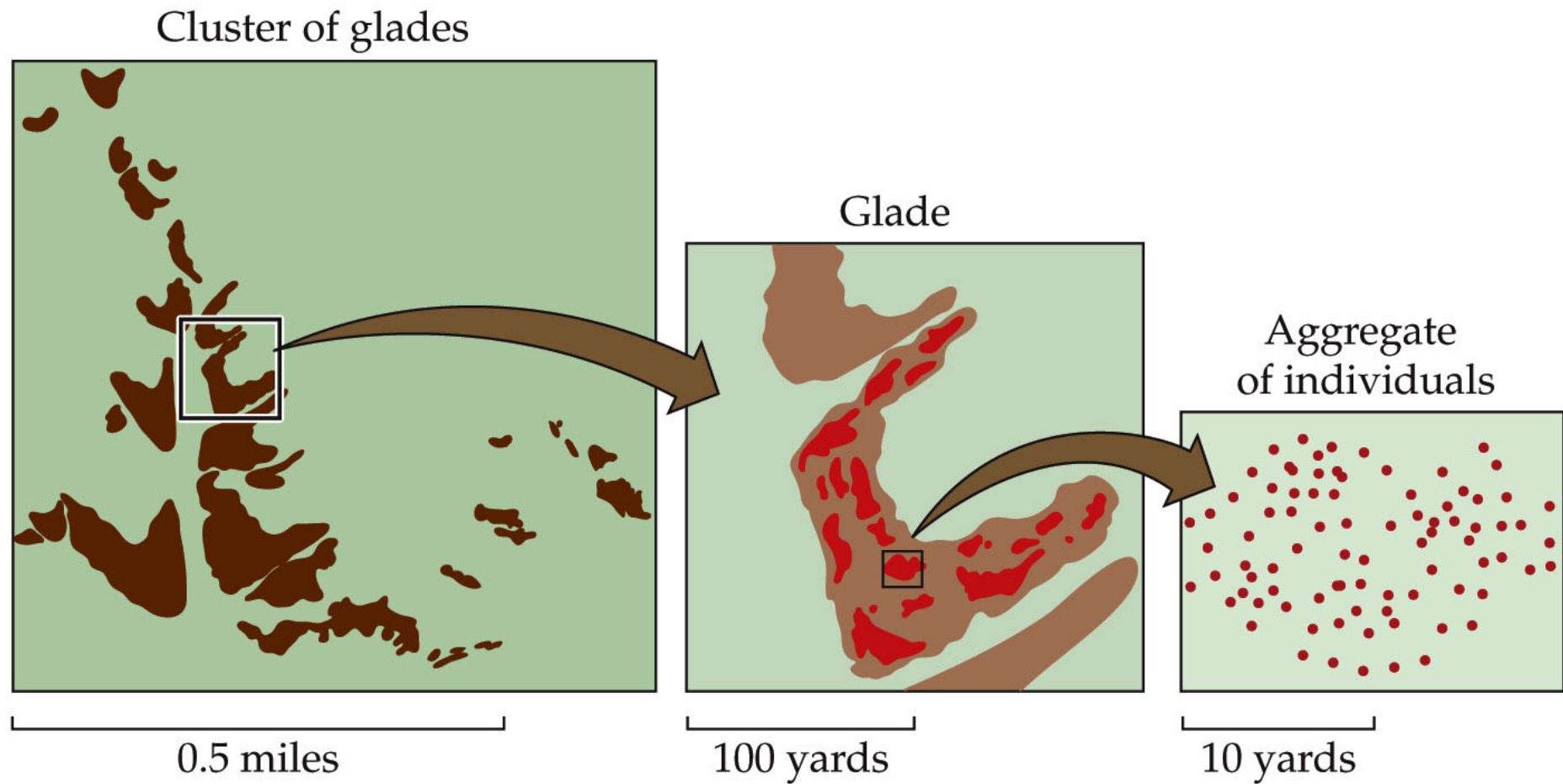


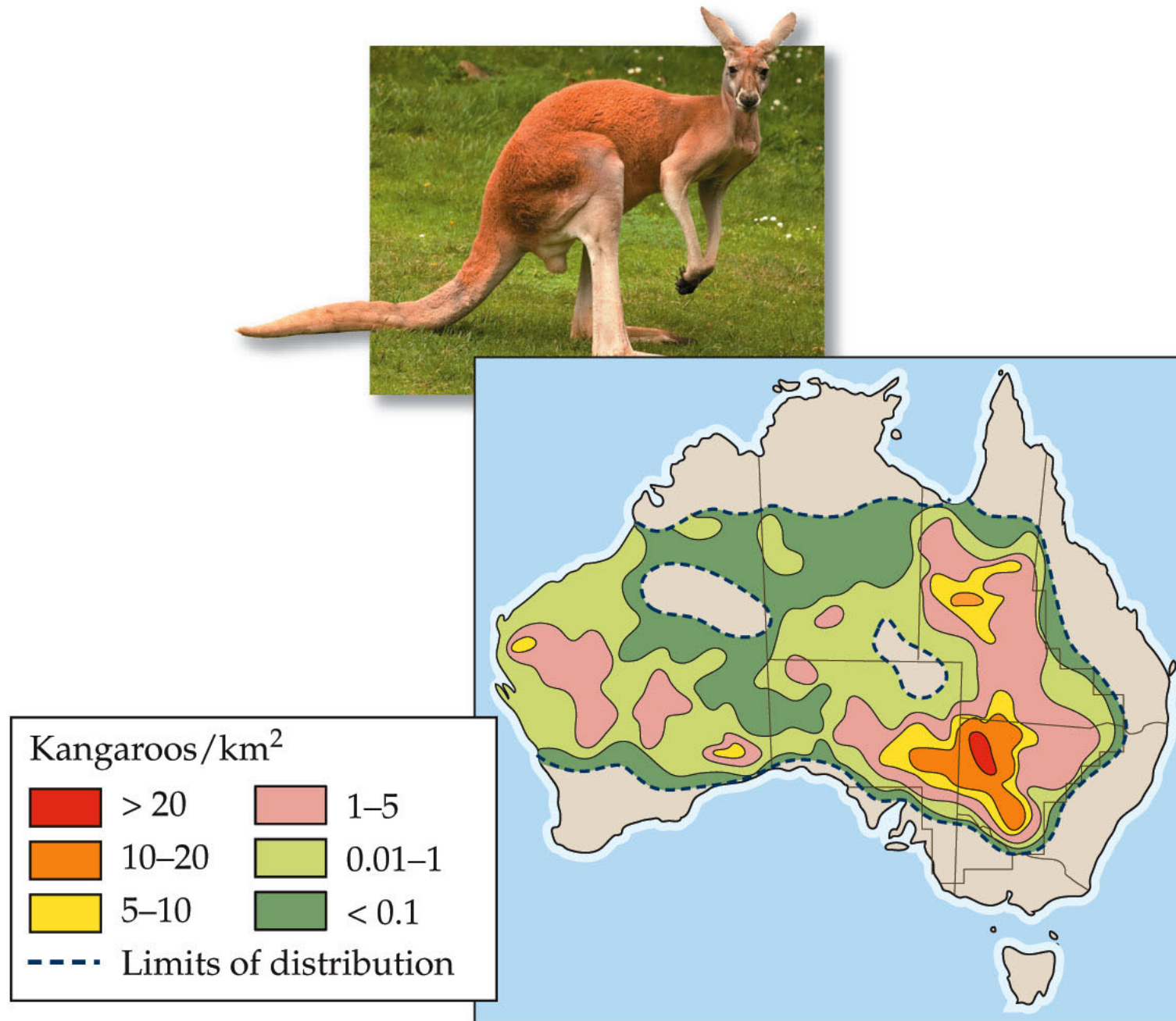
Figure 8.14 Populations Often Have a Patchy Distribution (Part 2)



Geographic Range

Density of red kangaroos varies throughout their range in Australia, including areas of high density, and areas where they are absent.

Figure 8.15 Abundance Varies Throughout a Species' Geographic Range



Geographic Range

In some cases, population density is greatest in the center of the range, decreasing toward the boundaries.

This is true for many North American species, including plants, intertidal invertebrates, and terrestrial vertebrates.

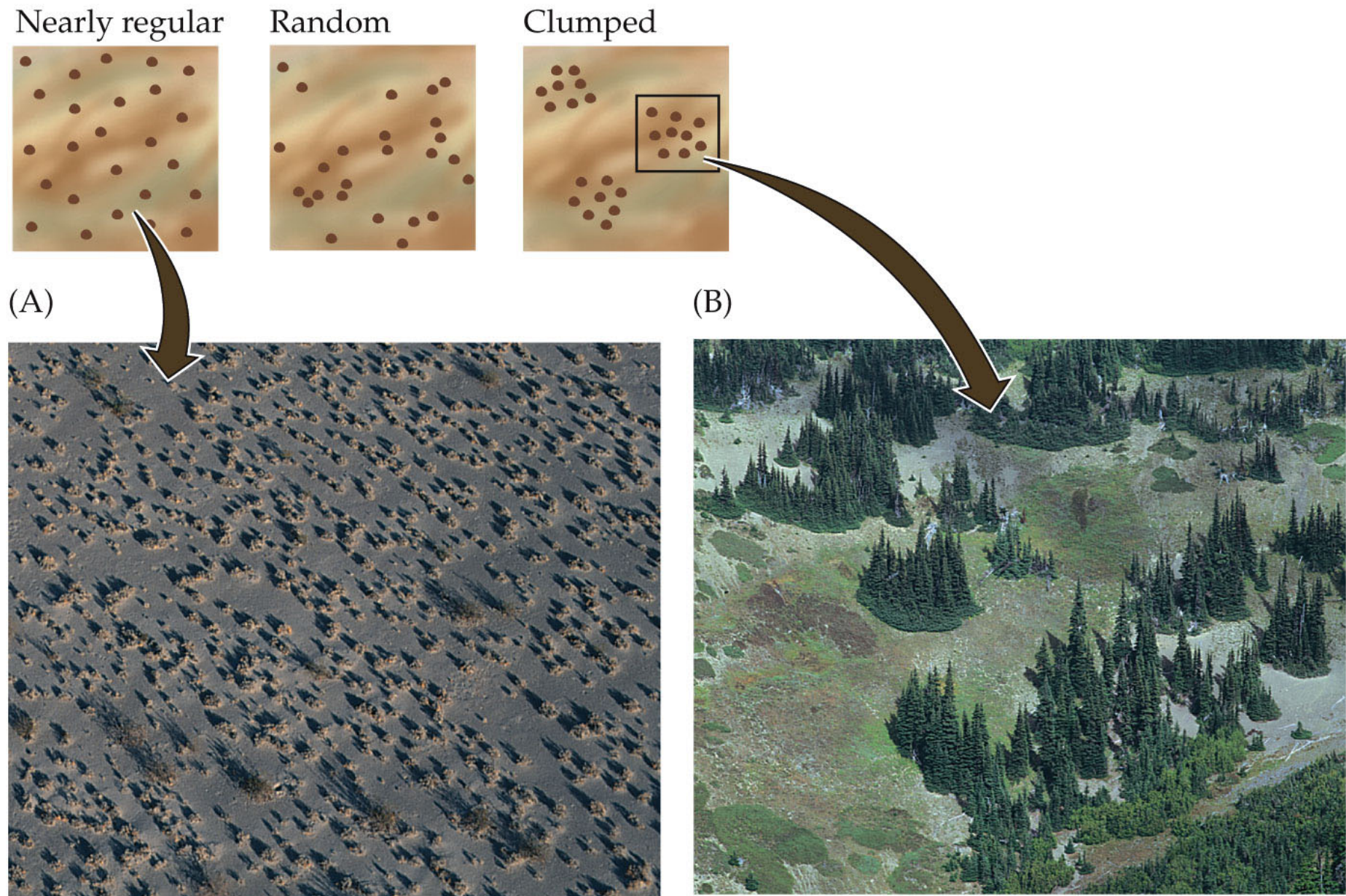
Dispersion within Populations

Concept 8.4: The dispersion of individuals within a population depends on the location of essential resources, dispersal, and behavioral interactions.

Dispersion is the spatial arrangement of individuals within a population:

- Regular—individuals are evenly spaced.
- Random—individuals scattered randomly.
- Clumped—the most common pattern.

Figure 8.16 Dispersion of Individuals within Populations



Dispersion within Populations

Dispersion patterns often result from the distribution of resources.

Random or clumped dispersion can also result from dispersal (e.g. short dispersal distances cause individuals to clump together).

Dispersion within Populations

Interactions among individuals can also influence dispersion.

Individuals may repel or attract others.
Examples of both can be seen in
Seychelles warblers.

The warblers are territorial, which results in a regular dispersion.

Dispersion within Populations

Some of the territories provide better resources than others.

In high quality territories, cooperative breeding occurs—young birds postpone breeding and instead help their parents raise more offspring.

The high quality sites attract birds and can result in clumped dispersions.

Dispersion within Populations

Cooperative breeding is advantageous when high-quality territories are scarce. A young bird will survive and produce more offspring over its lifetime if it stays to help the parents, and delays breeding.

If high-quality territories are abundant, cooperative breeding is not favored.

Figure 8.17 Territorial Behavior Affects Dispersion within Populations (Part 1)

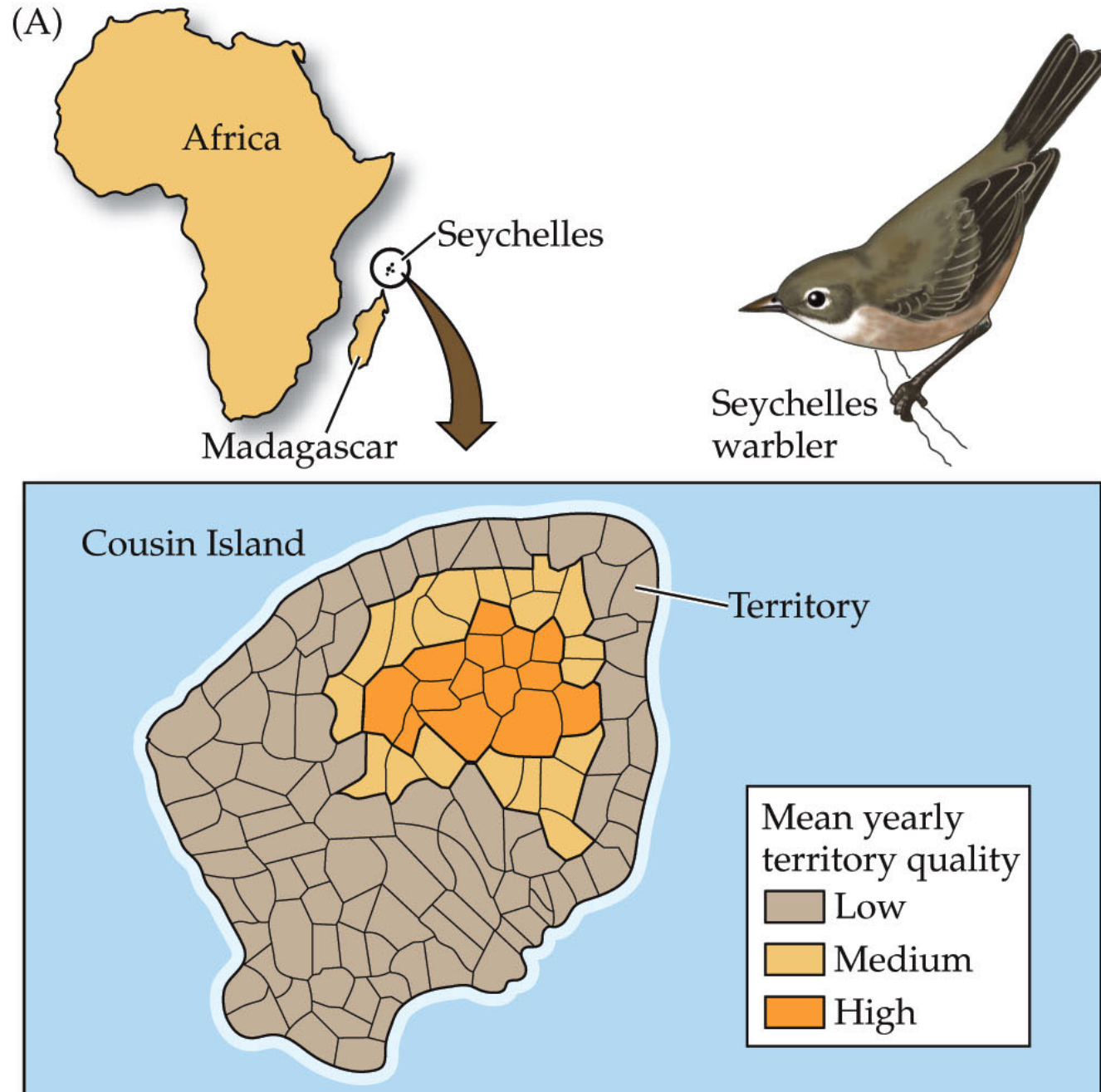
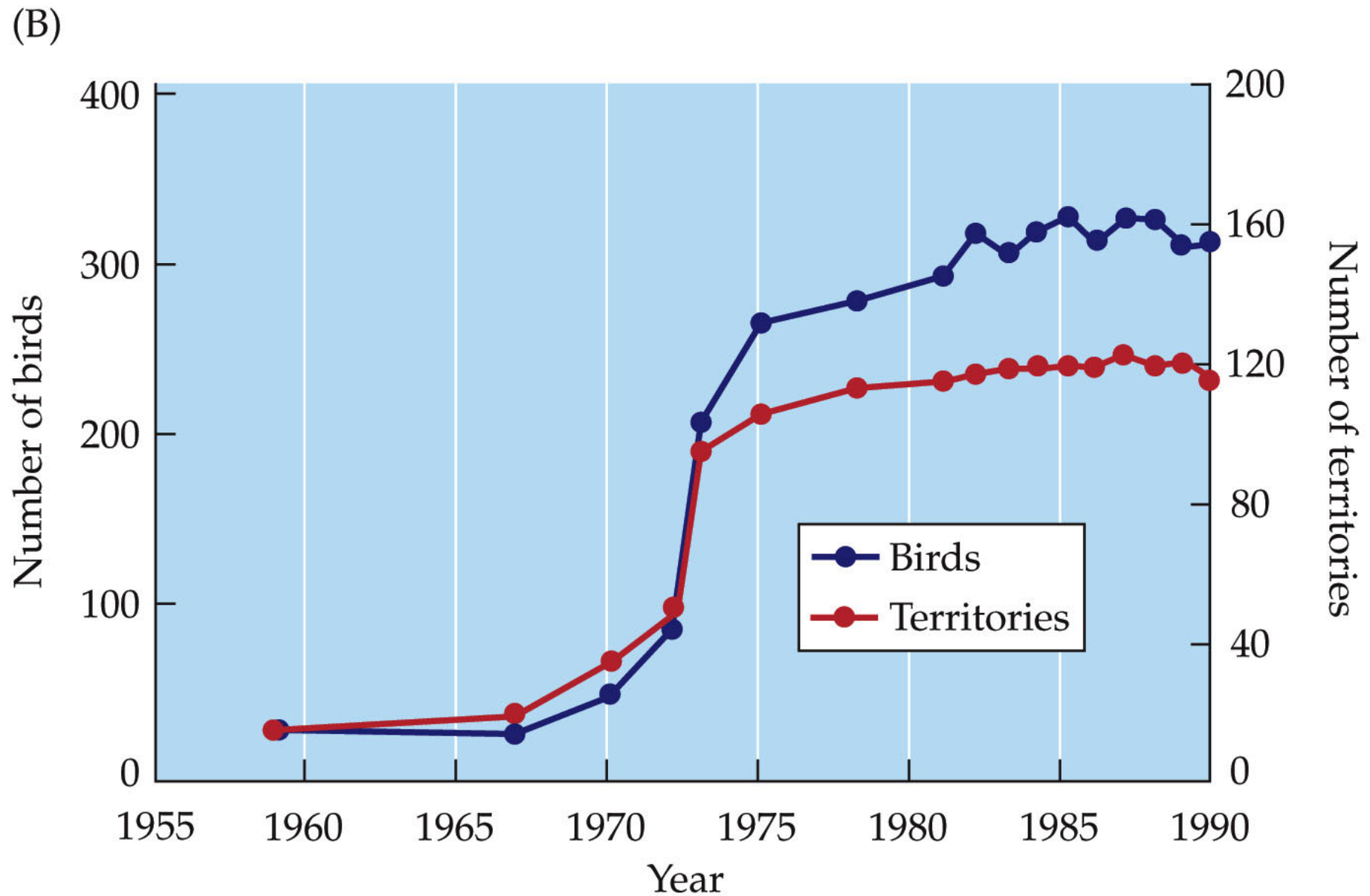


Figure 8.17 Territorial Behavior Affects Dispersion within Populations (Part 2)



Estimating Abundances and Distributions

Concept 8.5: Population abundances and distributions can be estimated with area-based counts, mark–recapture methods, and niche modeling.

Complete counts of individual organisms in a population are often difficult or impossible.

Several methods are used to estimate the actual or **absolute population size**.

Estimating Abundances and Distributions

Area-based counts are used to estimate abundance of immobile organisms.

Quadrats are sampling areas (or volumes) of specific size, such as 1 m².

Individuals are counted in several quadrats; the counts are used to estimate population size.

Figure 8.18 Estimating Absolute Population Size

(A)



(B)



Estimating Abundances and Distributions

Example:

40, 10, 70, 80, and 50 chinch bugs are counted in five 10 cm × 10 cm (0.01 m²) quadrats.

$$\frac{(40 + 10 + 70 + 80 + 50) / 5}{0.01} = 5000/\text{m}^2$$

Estimating Abundances and Distributions

Quadrats should be representative of the entire area covered by the population.

As many quadrats as possible are used.

Quadrat locations are selected at random or on a regularly spaced grid.

Estimating Abundances and Distributions

Mark–recapture methods are used for mobile organisms.

A subset of individuals is captured and marked or tagged in some way, then released.

At a later date, individuals are captured again, and the ratio of marked to unmarked individuals is used to estimate population size.

Estimating Abundances and Distributions

Example: 23 butterflies are captured and marked (M).

Several days later, 15 are captured (C), 4 of them marked (R for recaptured).

To estimate total population size (N):

$$M / N = R / C \quad \text{or} \quad N = (M \times C) / R$$

$$N = (23 \times 15) / 4 = 86$$

Estimating Abundances and Distributions

Sometimes the available data can only provide an index of population size that is related to actual population size in unknown ways.

For example number of cougar tracks in an area, or number of fish caught per unit of effort.

Estimating Abundances and Distributions

These data can be compared from one time period to another, allowing an estimate of **relative population size**.

Interpretation is tricky (e.g. the number of cougar tracks is related to population density, but also activity levels of individuals).

Estimating Abundances and Distributions

Long-term ecological data sets can contribute to solving applied problems.

Outbreak of a new disease in 1993 in New Mexico was caused by a new strain of hantavirus, which was carried by the deer mouse.

The CDC turned to ecologists that studied deer mouse populations.

Estimating Abundances and Distributions

Deer mouse specimens from 1979 to 1992 carried the virus. Why did the outbreak occur in 1993?

Data on deer mice had been collected at Sevilleta National Wildlife Refuge since 1989.

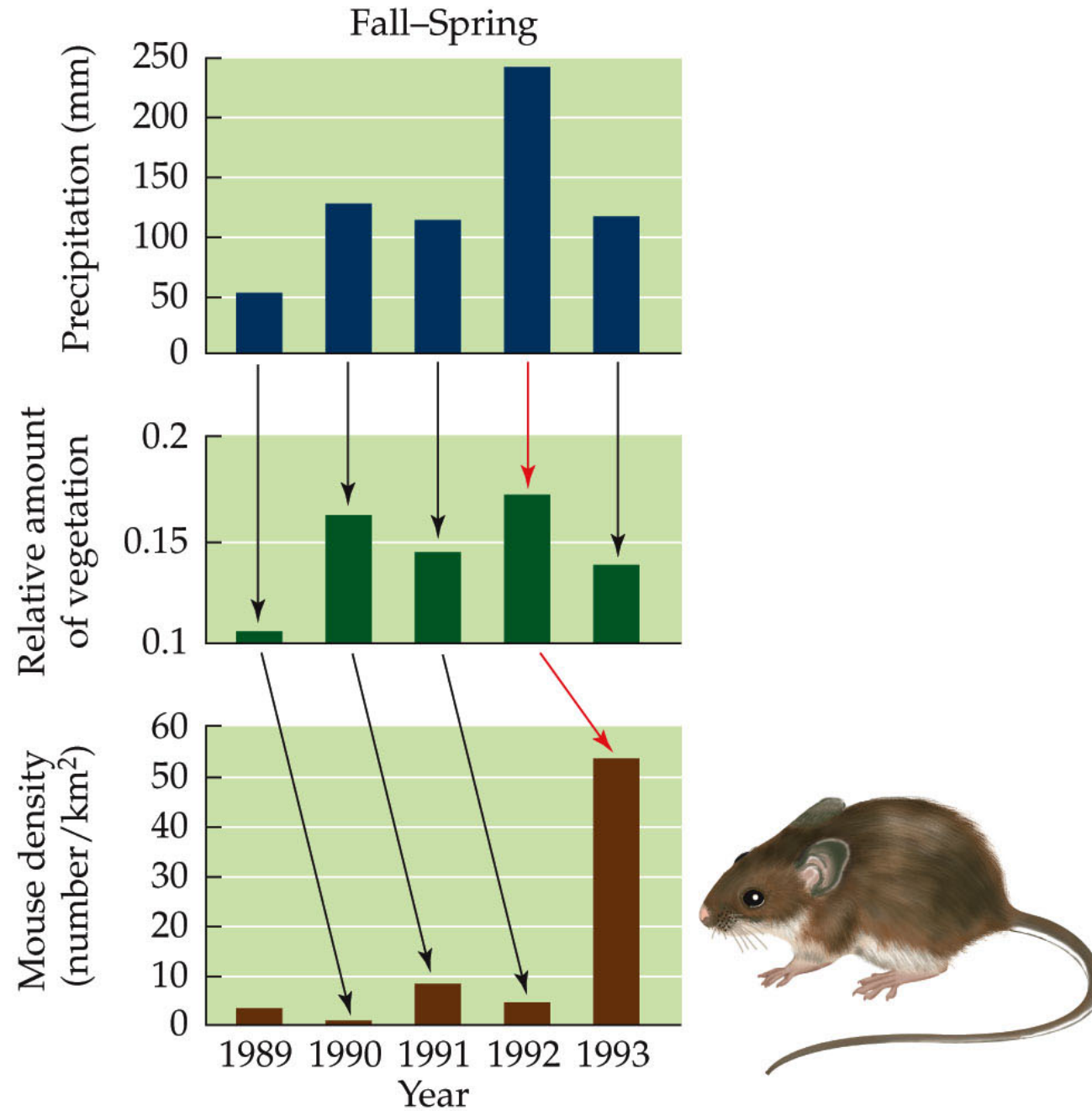
Densities of several species had increased 3- to 20-fold between 1992 and 1993.

Estimating Abundances and Distributions

Precipitation data and satellite photos showed that high rainfall led to more plant growth, which provided seeds, etc. for rodents.

High mouse densities increased the chances of them coming in contact with humans.

Figure 8.19 Causing the Outbreak? From Rain to Plants to Mice



Estimating Abundances and Distributions

Ecologists often wish to predict the future distribution of a species, such as a pest species or disease carrier.

Species distributions may also change with global warming.

Estimating Abundances and Distributions

The **ecological niche**: The physical and biological conditions that a species needs to grow, survive, and reproduce.

A **niche model** is a predictive tool that models the environmental conditions occupied by a species based on the conditions at localities it is known to occupy.

Estimating Abundances and Distributions

A niche model was developed for chameleons in Madagascar.

Data on plant cover, temperature, precipitation, topography, and hydrology were recorded for $1 \times 1 \text{ km}^2$ “grid cells.”

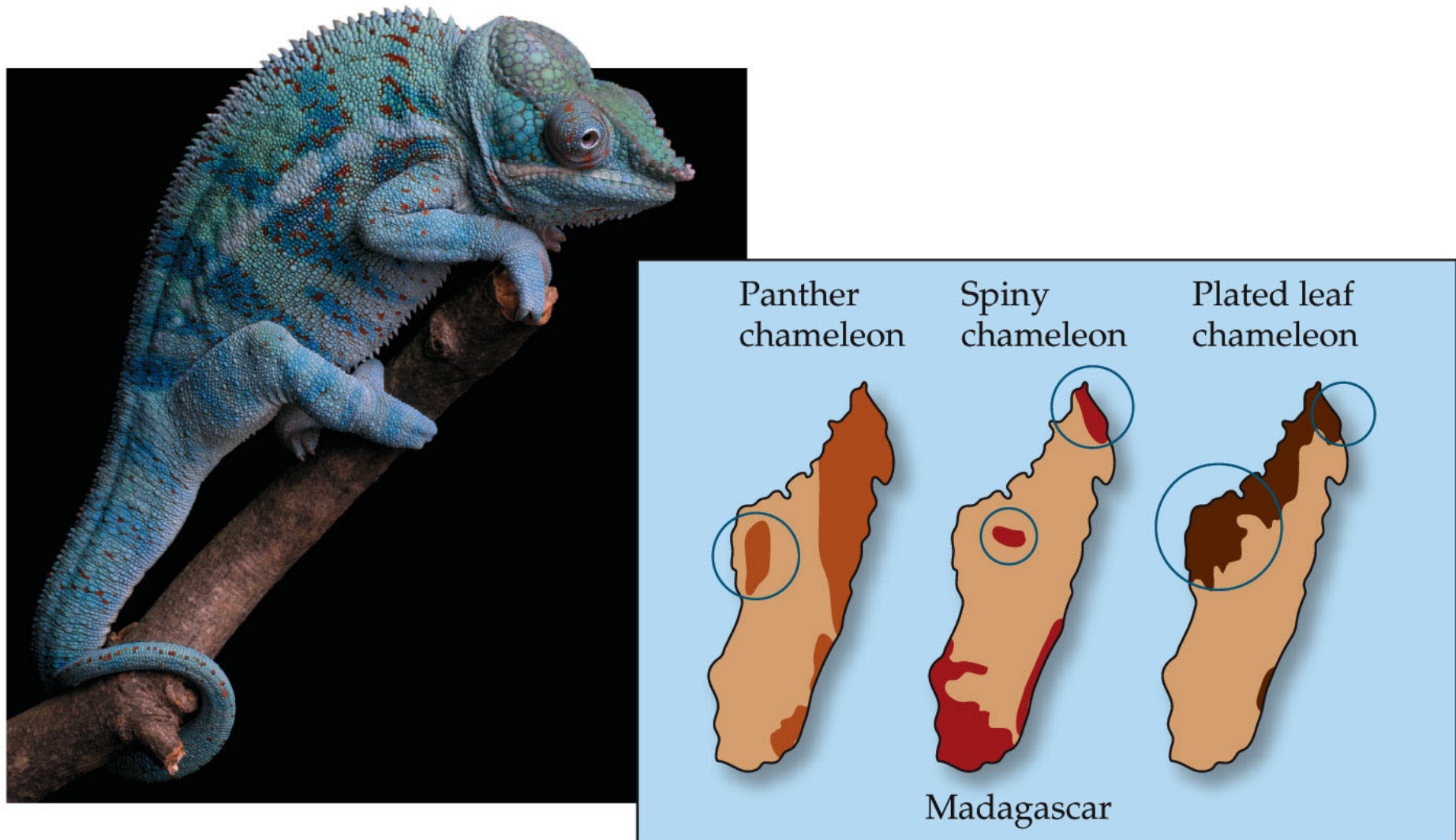
For each species, the investigators developed “habitat rules” that described the environmental conditions where each species was most likely to be found.

Estimating Abundances and Distributions

Habitat rules were developed from environmental data in grid cells where a species was known to occur.

Accurate habitat rules were determined by a computer program using GARP (Genetic Algorithm for Rule-set Prediction).

Figure 8.20 Predicted Distributions of Madagascar Chameleons



Estimating Abundances and Distributions

GARP works by changing habitat rules in a way that mimics the occurrence of genetic mutations and natural selection.

Predictions of species occurrences can then be made based on environmental conditions.

Estimating Abundances and Distributions

Accuracy of predictions was tested using chameleon location data that had not been entered into the program.

The rules correctly predicted where chameleons would be found 75%–85% of the time.

Estimating Abundances and Distributions

An “error” in the predictions was also investigated:

For some areas, the program predicted that two or more species would be found, but in which none of the species were known to occur.

When researchers surveyed two of these areas, seven previously unknown chameleon species were discovered.

Case Study Revisited: From Kelp Forest to Urchin Barren

Do sea urchins starve after kelp forests have disappeared?

Urchins are able to survive on other foods —other algae, benthic diatoms, and **detritus** (recently dead or partly-decomposed organisms).

They can also reduce their metabolic rate, reabsorb sex organs, and absorb dissolved nutrients directly from seawater.

Case Study Revisited: From Kelp Forest to Urchin Barren

Sea otters have a high metabolic rate and can consume large numbers of sea urchins.

Aleutian Islands that have sea otters have few sea urchins, leading to the hypothesis that sea otters control population size of urchins.

Case Study Revisited: From Kelp Forest to Urchin Barren

To test this, Estes and Duggins (1995) compared sites with and without otters.

They also studied sites newly colonized by sea otters: Within 2 years, urchins virtually disappeared, and kelp densities increased dramatically.

Figure 8.21 The Effect of Otters on Urchins and Kelp (Part 1)

(A) Southern Alaska

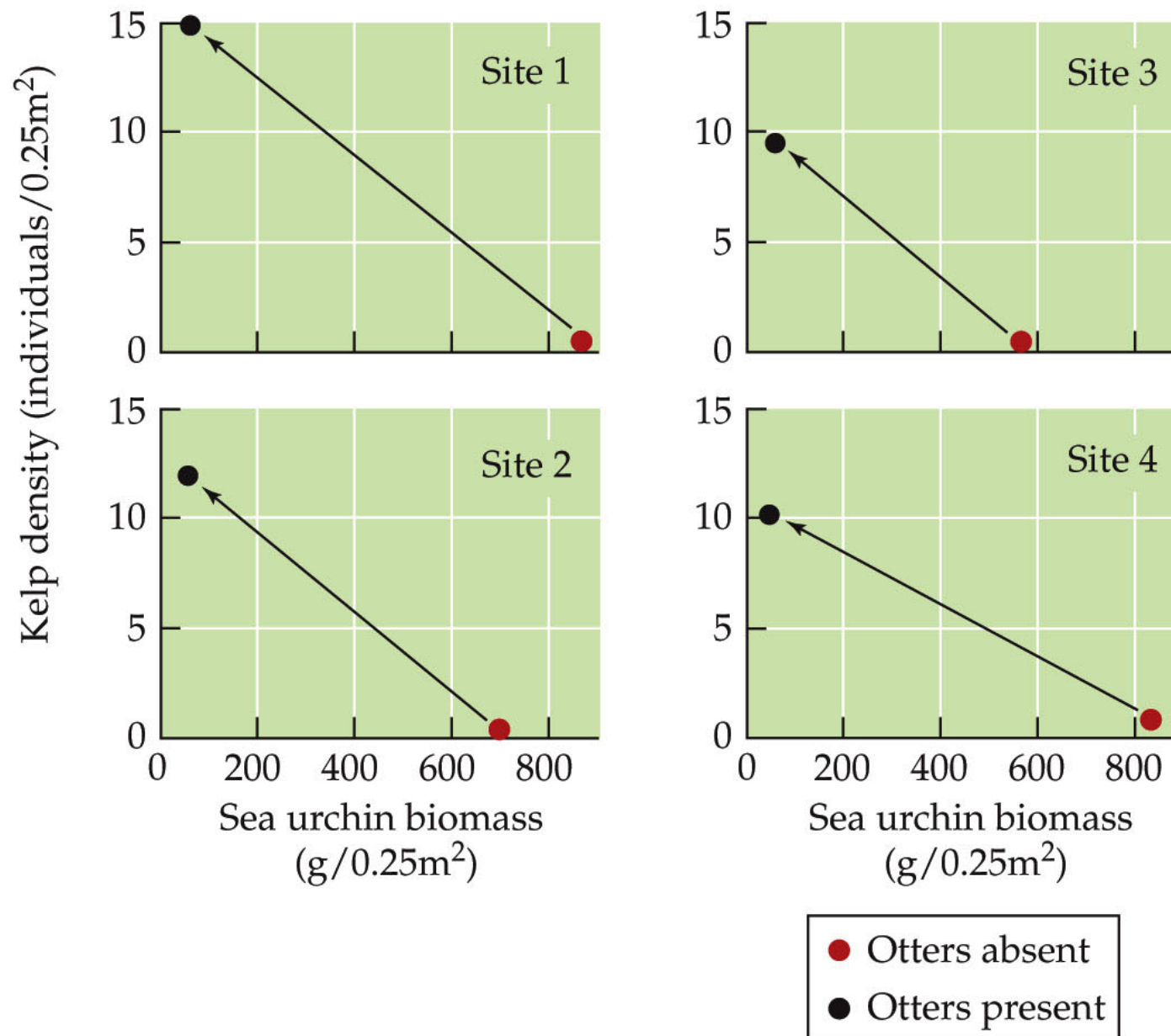
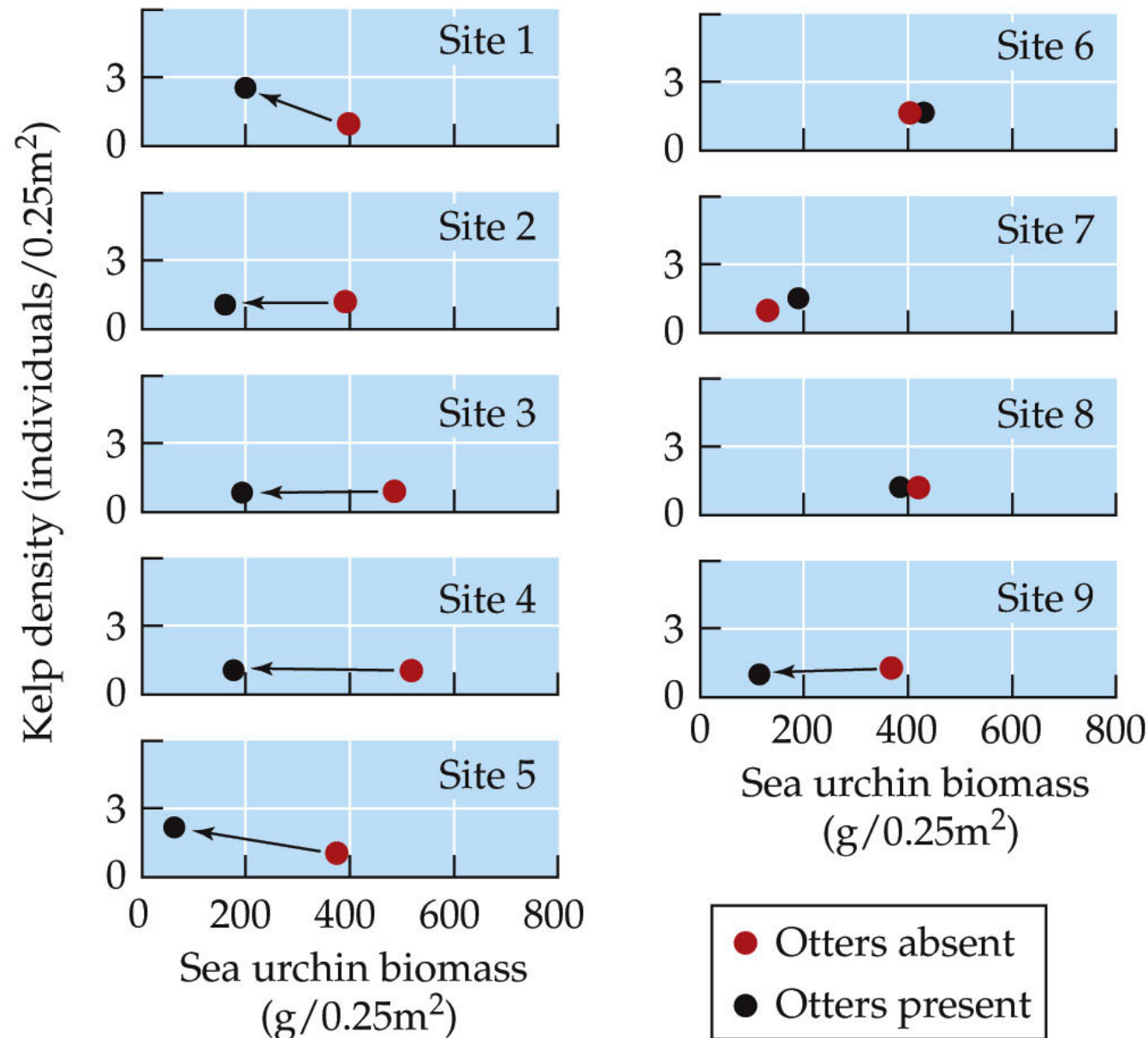


Figure 8.21 The Effect of Otters on Urchins and Kelp (Part 1)

(B) Aleutian Islands



Case Study Revisited: From Kelp Forest to Urchin Barren

Historically, sea otters were abundant throughout the North Pacific, but were hunted to near extinction for furs.

By 1911, only scattered colonies survived.

By the 1970s, otter populations had begun to recover, but declined again in the 1990s.

Case Study Revisited: From Kelp Forest to Urchin Barren

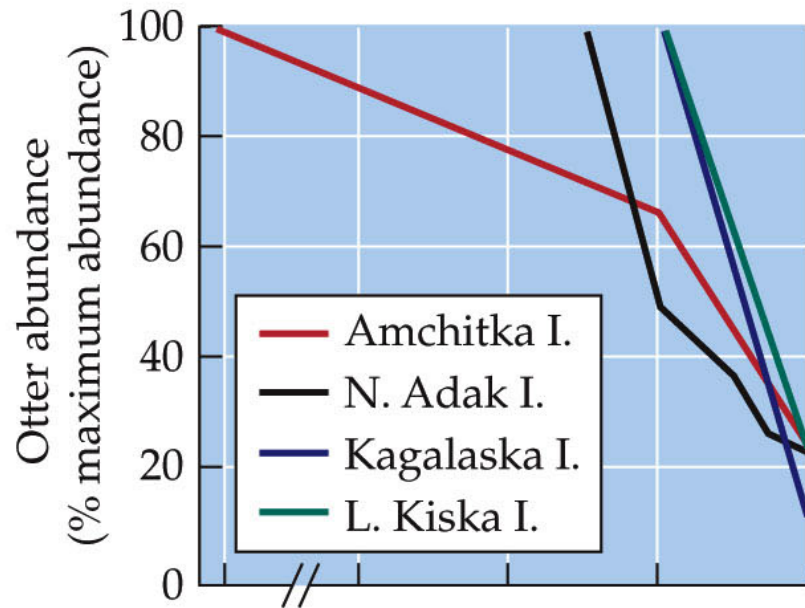
The recent sea otter decline may be due to predation by killer whales.

It is unclear why killer whales began to consume more sea otters, perhaps it is because preferred prey (large whales, then seals, sea lions) became more scarce.

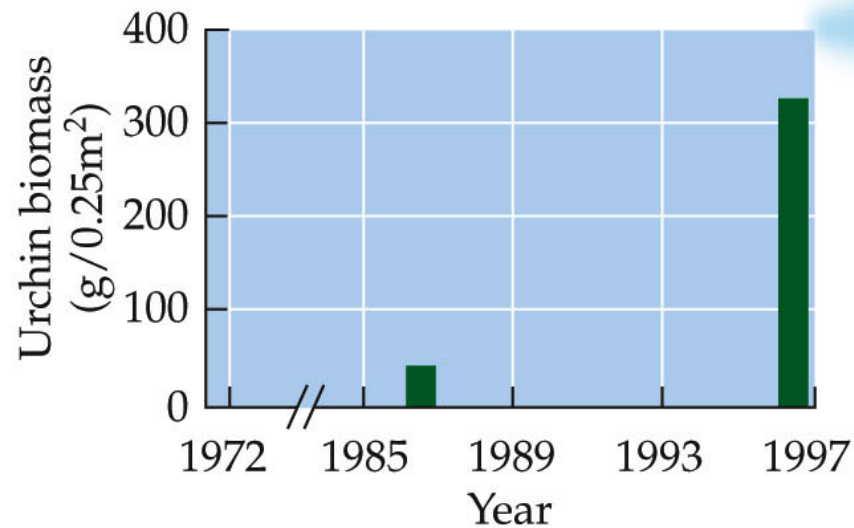
But declines of seal populations could be due to other factors as well.

Figure 8.22 Orca Predation on Otters May Have Led to Kelp Decline (Part 1)

(A) Sea otter abundance



(B) Sea urchin biomass



Pre-1990

Late 1990s



Killer whale

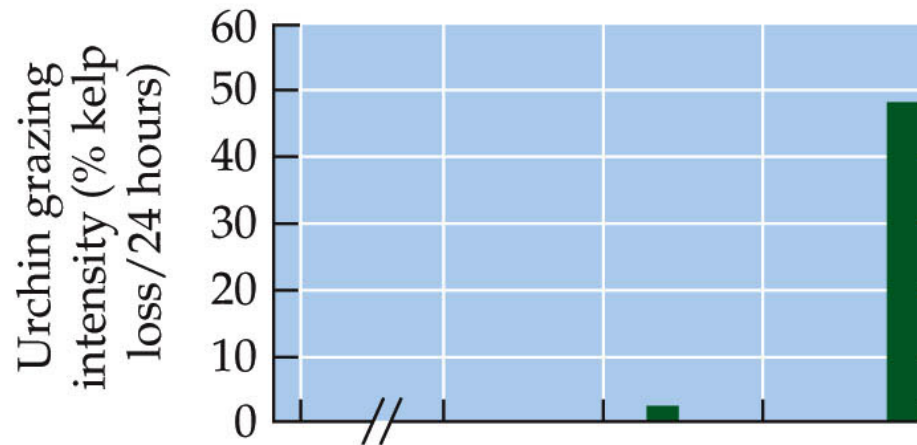


Sea otter

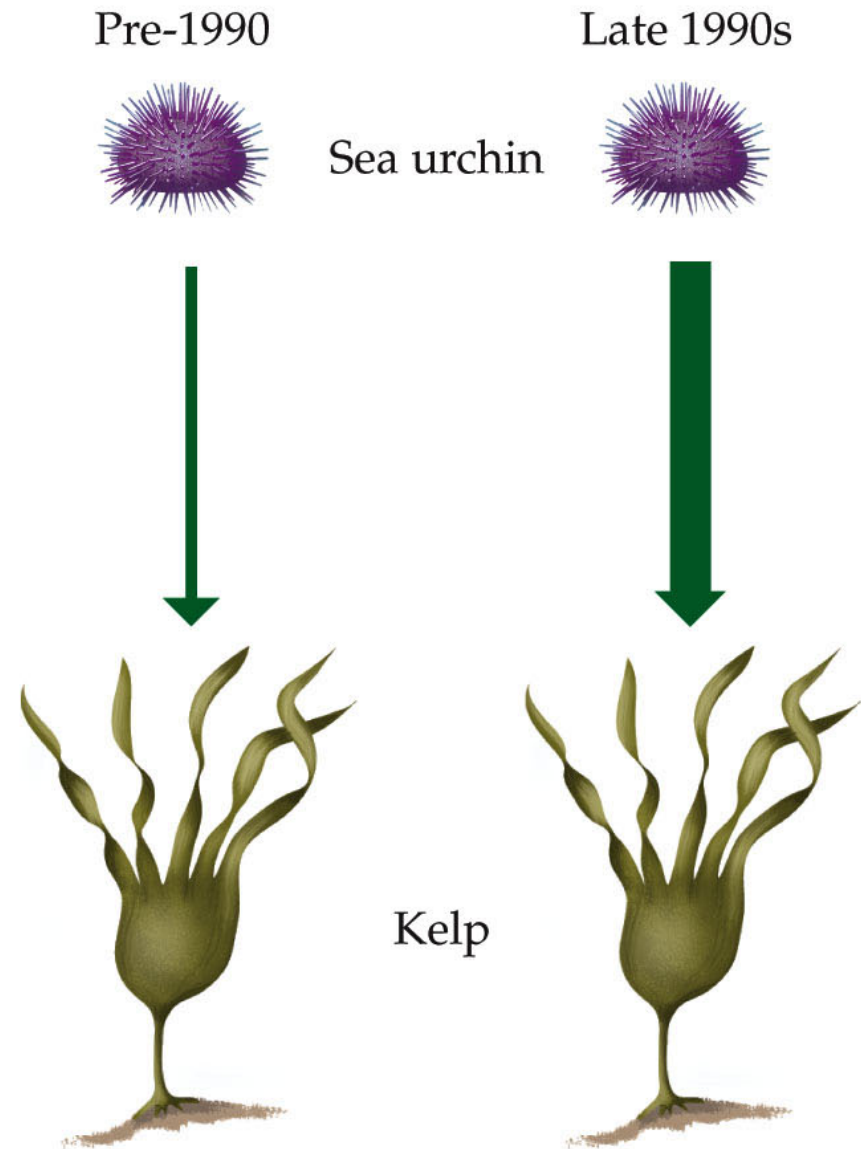
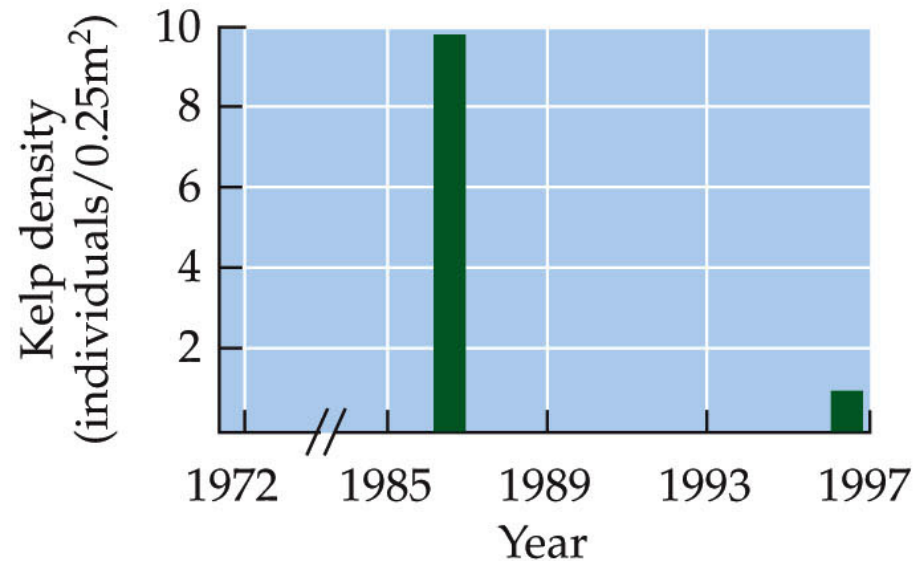


Figure 8.22 Orca Predation on Otters May Have Led to Kelp Decline (Part 2)

(C) Grazing intensity



(D) Total kelp density



Connections in Nature: From Urchins to Ecosystems

Kelp forests have strong effects on nearshore ecosystems.

They are very productive, rivaling tropical rainforests for biomass production.

The tips of the kelp fronds are constantly eroding, creating floating detritus which is food for many organisms.

Connections in Nature: From Urchins to Ecosystems

Experiments using carbon-13 labeled sugars show that kelp provides food for a wide range of species (Duggins et al. 1989).

Kelp forests also serve as nurseries for the young of many species and as havens from predators for adults.

Connections in Nature: From Urchins to Ecosystems

Kelp forests protect shores from wave action, reducing turbulence in the intertidal zones.

This can increase sedimentation, which harms filter-feeders.

But barnacles and mussels are more abundant in deeper waters when kelp is present.

Connections in Nature: From Urchins to Ecosystems

Because kelp has such an important impact on nearshore ecosystems, the effects of sea urchins, otters, humans, and perhaps killer whales can have significant impacts on these ecosystems.

The possible connection to killer whales also illustrates the potential for ecosystems to be connected across huge spatial and temporal scales.