Part 6 Community Ecology

Chap.26 The Concept of the Community

Chap.27 Structure of the community

Chap.29 Biodiversity

- 26.1 The community is the association of populations.
- 26.2 Is there a natural unit at the community level of ecological organization?
- 26.3 Ecotones occur at sharp physical boundaries or where habitat-dominating growth forms change.
- 26.4 The structure of natural communities may be described in relation to ecological continua.

- 26.5 The historical record reveals both change and continuity in communities.
- 26.6 Evolutionary history may leave a distinctive imprint on community organization.
- 26.7 The characteristics of the community emerge from a hierarchy of processes over scales of time and space.

Definition of a community

- Community is the associations of plants and animals occurring in a particular locality and dominated by one or more prominent species or by some physical characteristic.
- An assemblage is a taxonomically related group that occurs in the same geographic area.

Definition of a guild

- A group of populations that uses a suite of resource in the same manner. Such groups are called guilds.
- The members of a guild occur in the same area, in which case the group is referred to as a local guild.

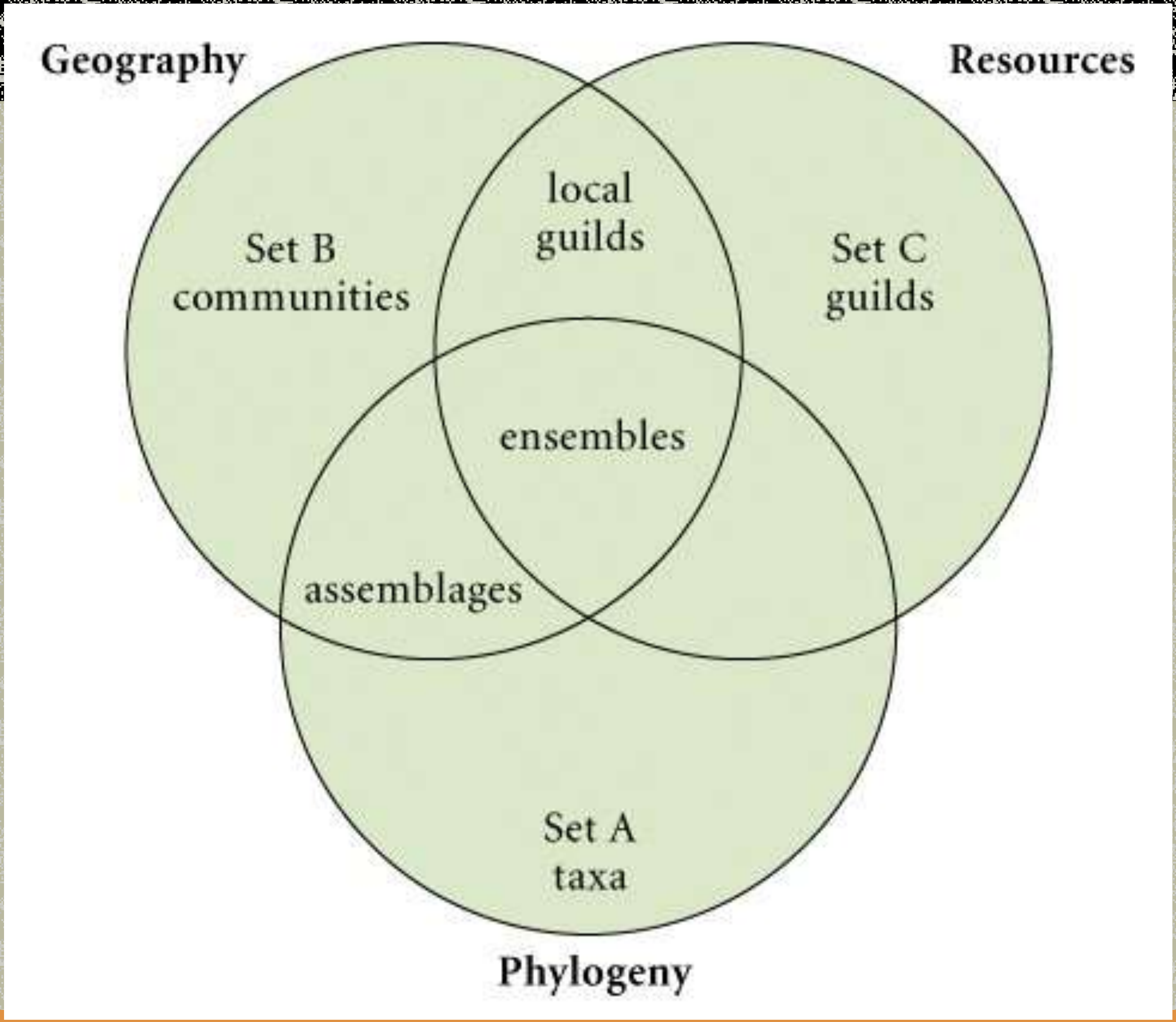


Fig. 26-1 Relationships among the various terms used to describe groups of organisms.

Community

- Community structure
- community function
- species richness
- closed community (Clement's concept)
- open community (Gleason's concept)

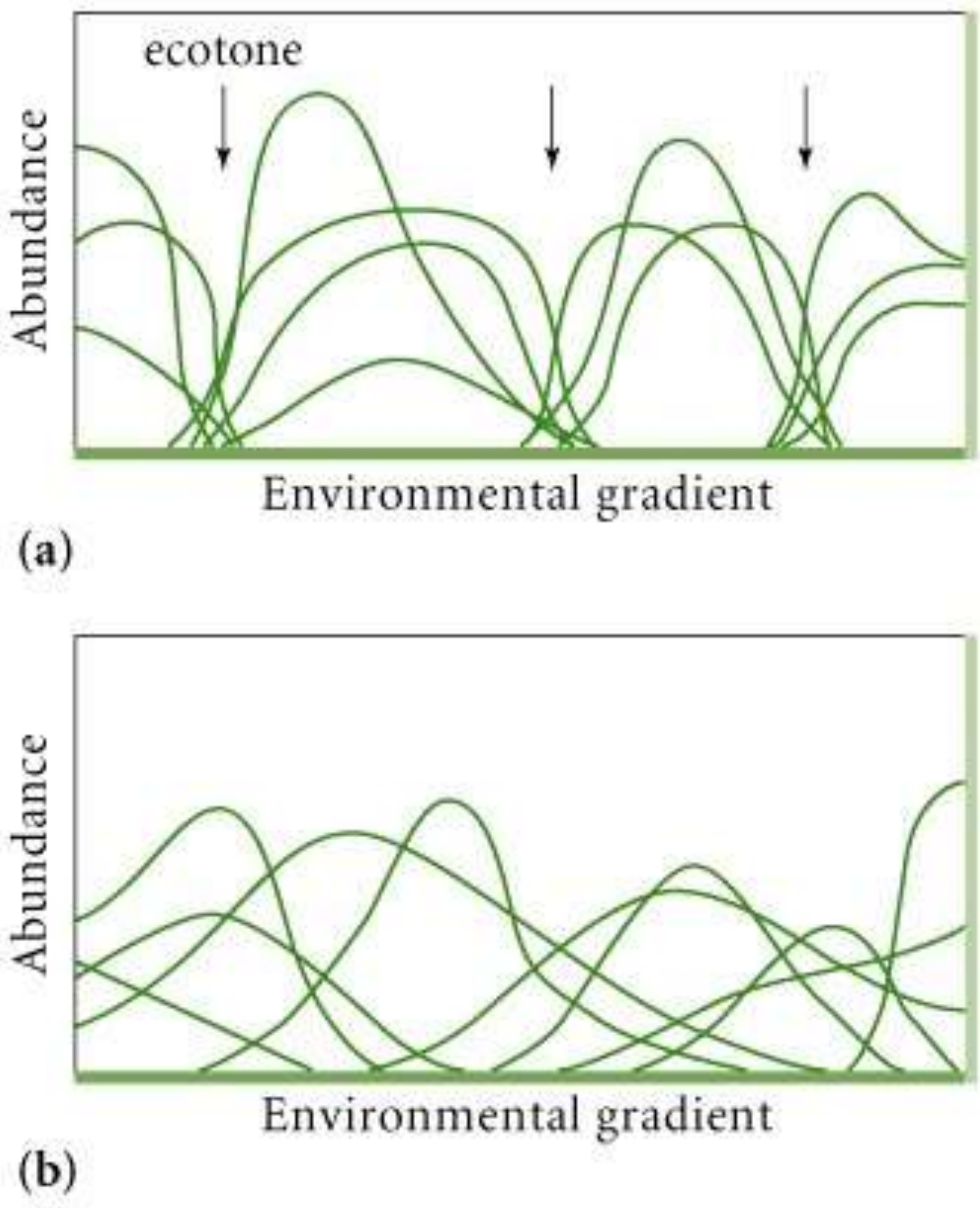


Fig. 26.3 Hypothetical distributions of species according to two concepts of communities. (a) closed communities (b) open communities

- ecotone

Fig. 26-4 A sharp community boundary (ecotone) with an abrupt change in the physical properties of adjacent habitats.

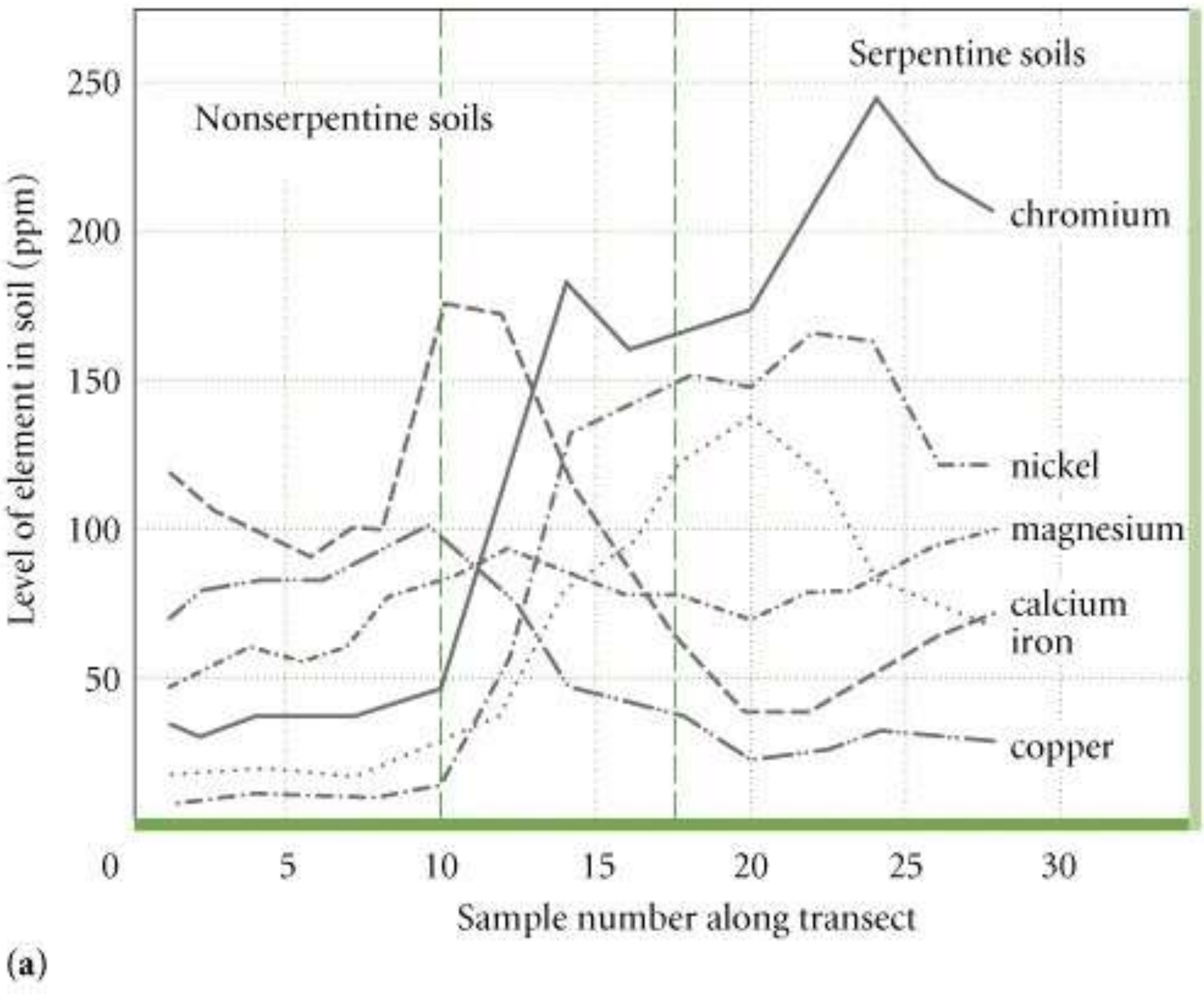


Fig. 26-5 An ecotone resulting from soil conditions. (a) changes in the concentration of elements in the soil.

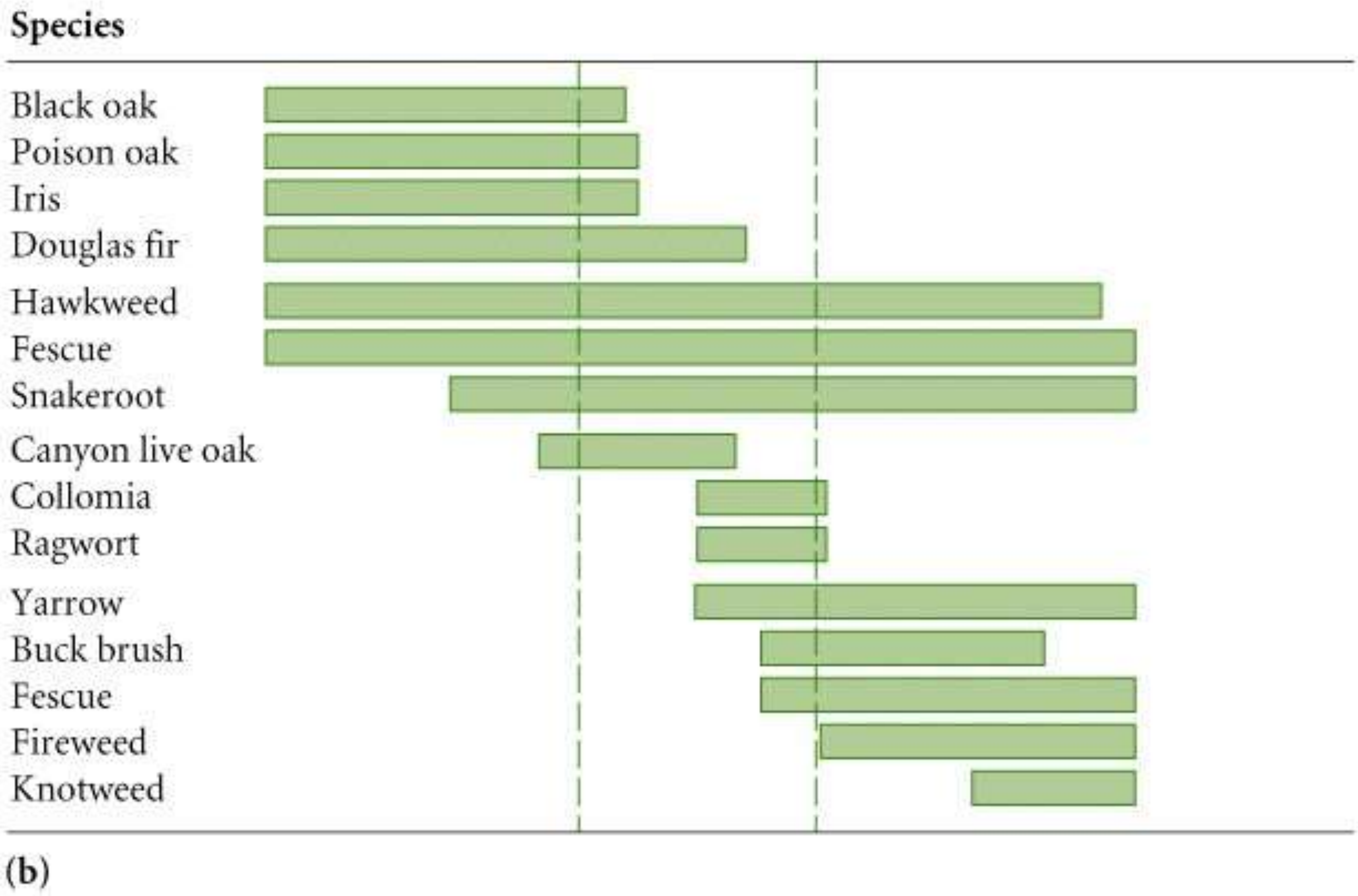


Fig. 26-5 An ecotone resulting from soil conditions.
(b) replacement of plant species across the boundary between nonserpentine and serpentine soils.

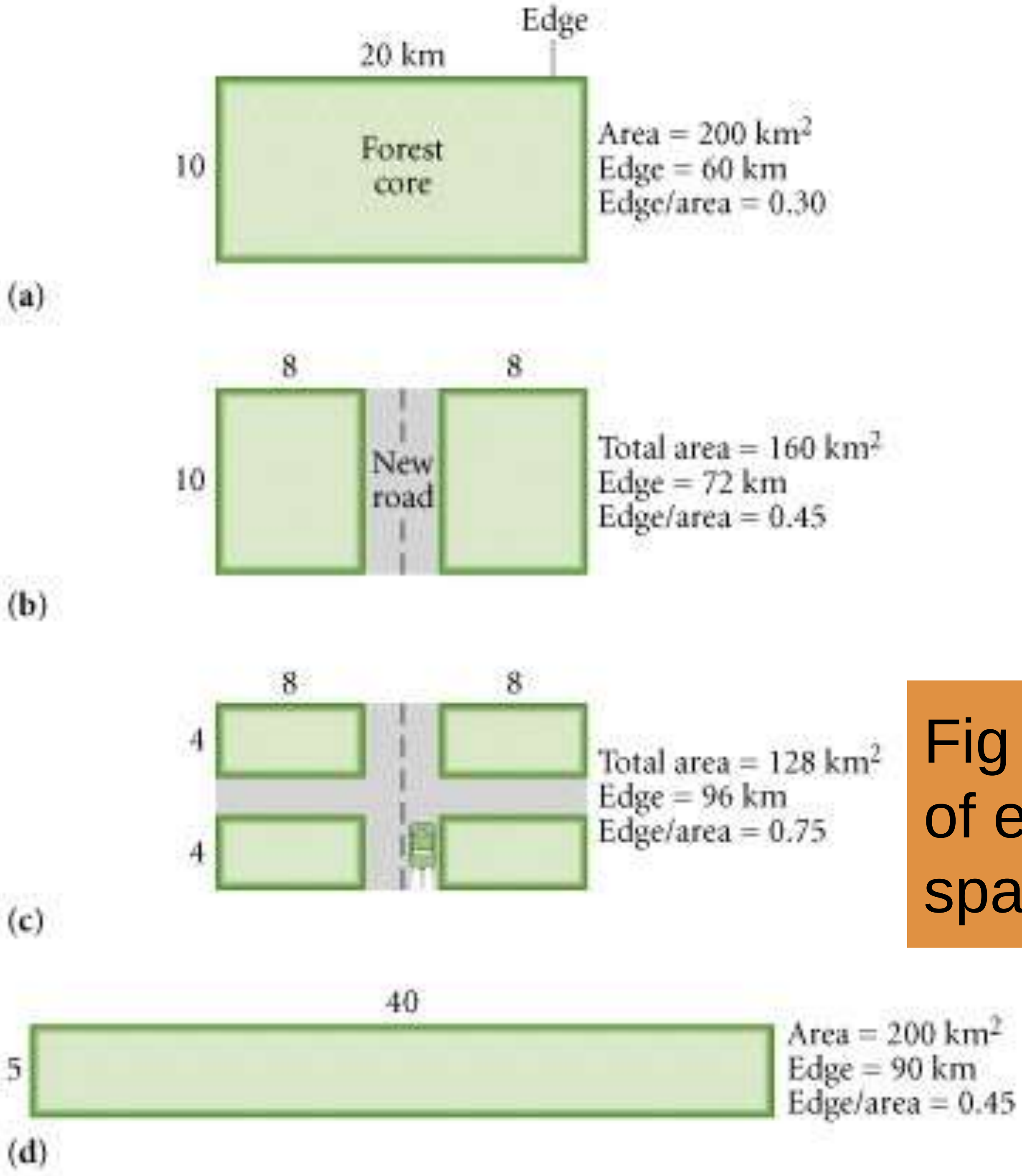
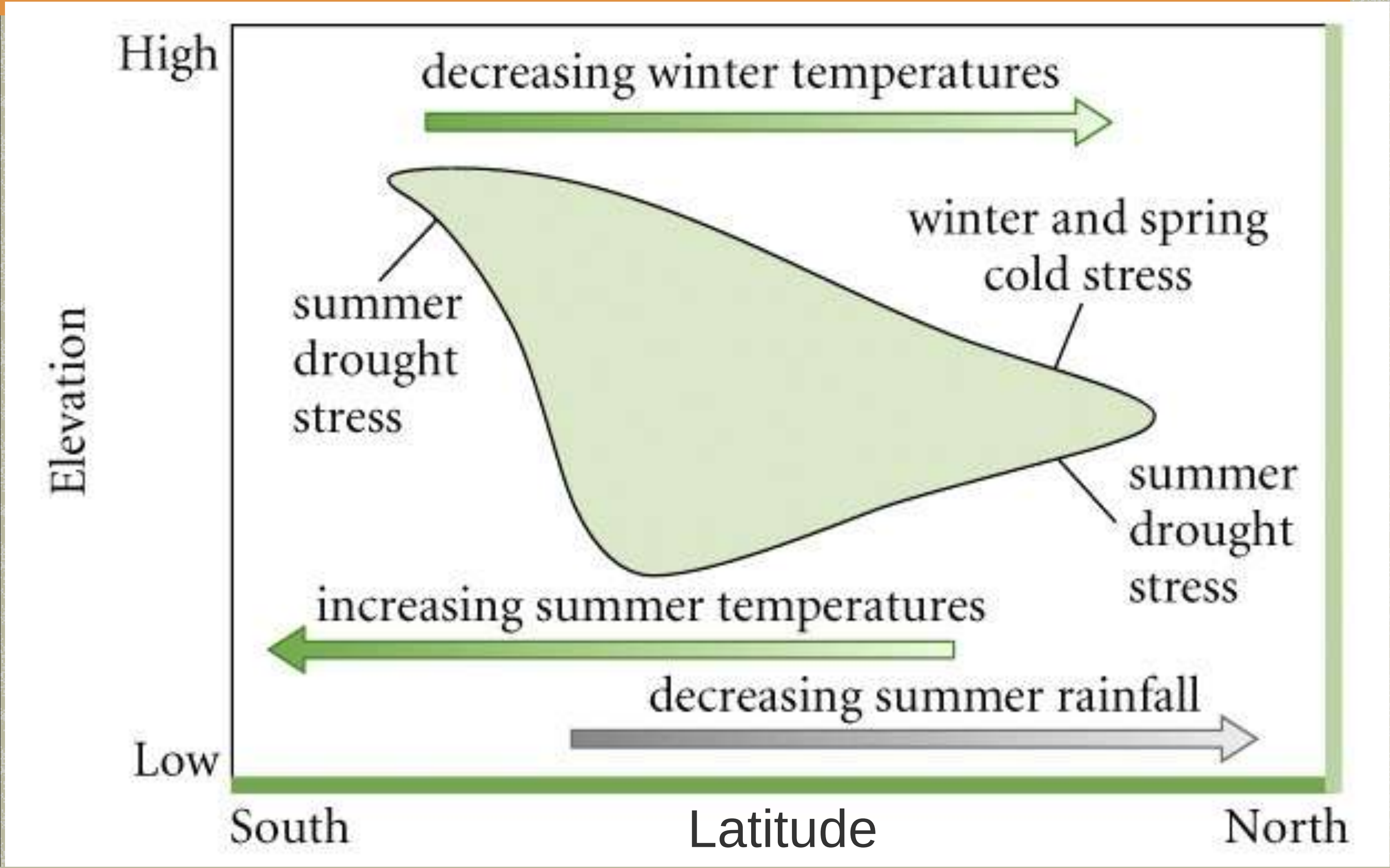


Fig 26-6 The amount of edge and interior space changes.

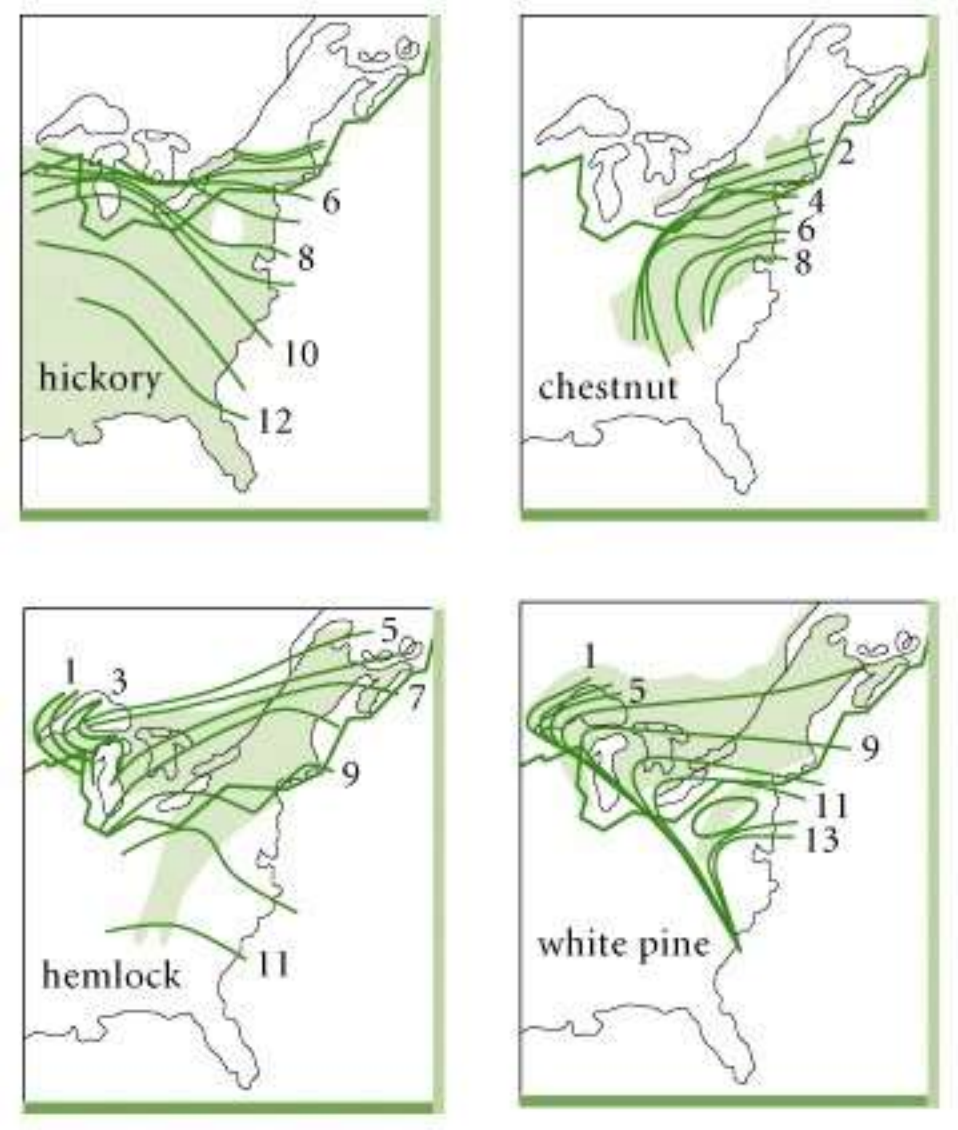
26.4 The structure of natural communities may be described in relation to ecological continua.



- Fig. 26-8 gradients of temperature and moisture within elevational and latitudinal space.

26.5 The historical record reveals both change and continuity in communities.

- Fig. 26-13 Migration of four species from Peistocene refuges to their present distributions following the retreat of the glaciers.
- Numbers indicate thousands of years before the present.



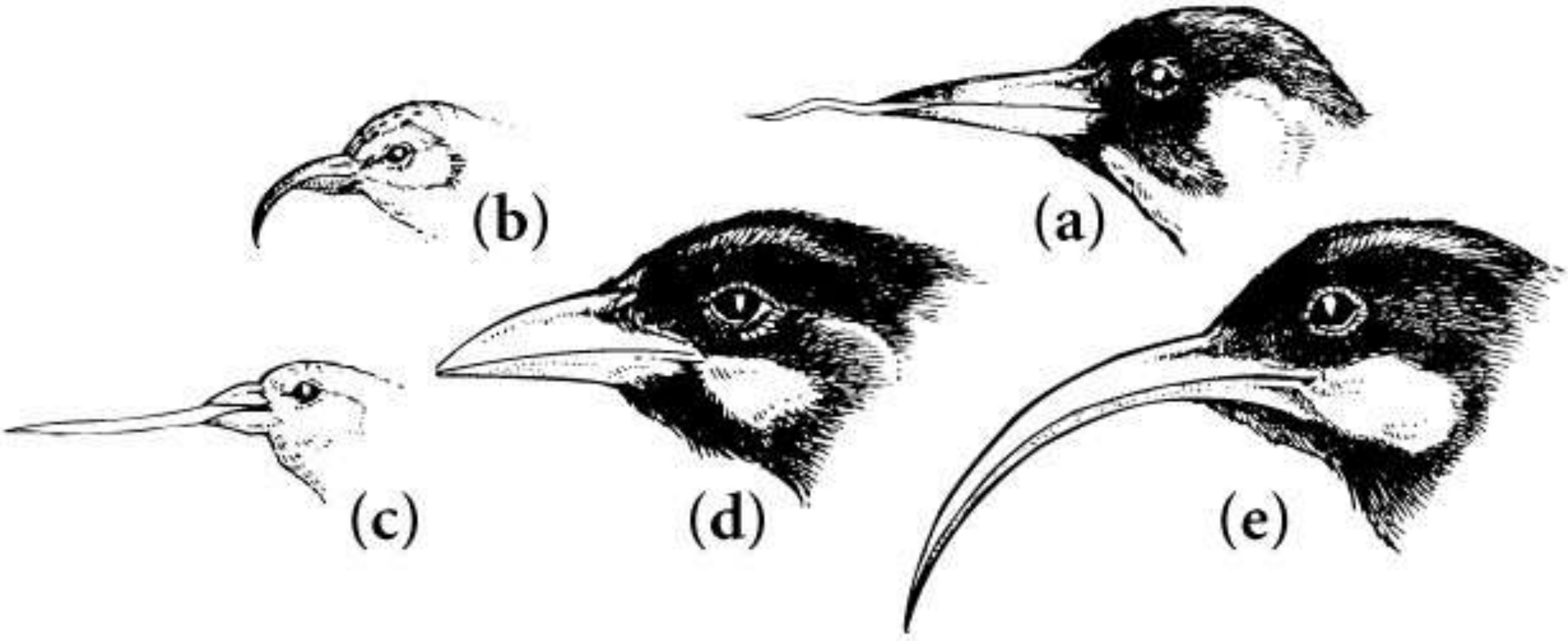


Fig. 26-15 Unrelated birds that have become adapted to extract insects from wood

(a) European green woodpecker

(b) Hawaiian honeycreeper

(c) Galapagos woodpecker-finch

(d) New Zealand huia(now extinct) male

(e) New Zealand huia female

26.6 Evolutionary history may leave a distinctive imprint on community organization.

- Fig. 26-16 Morphological convergence among unrelated African(left) and Neotropical (right) rain forest mammals.

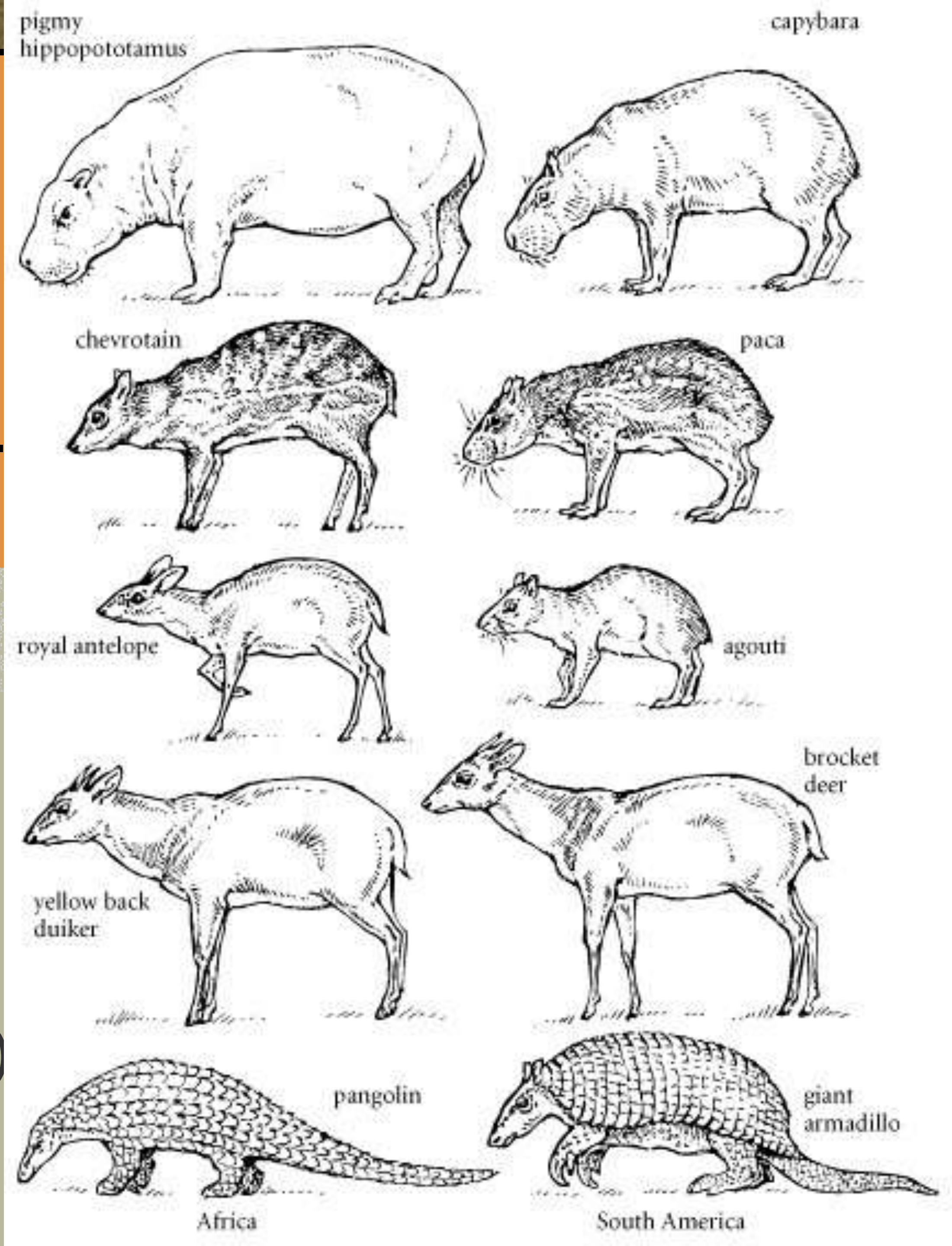


Fig.26-17 Mangrove vegetation in an estuary

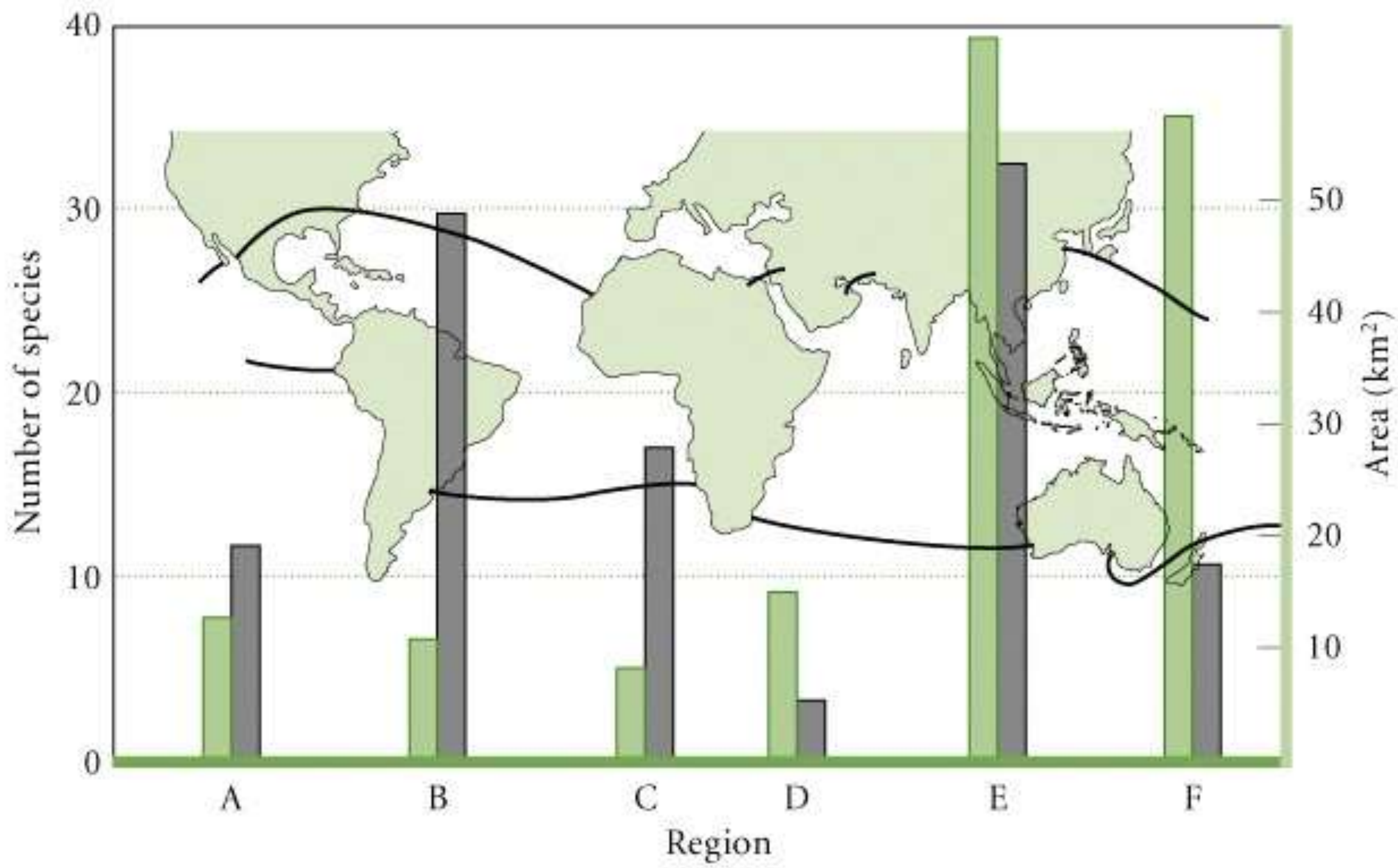


Fig. 26-18 Bars show the area extent of mangrove habitat (gray) and numbers of species mangrove trees and shrubs (green).

26.7 The characteristics of the community emerge from a hierarchy of processes over scales of time and space.

- A community is a single point of reference in time and space from which population and evolutionary influence emanates.
- Several kinds of processes are important, each with a different characteristic scale of time and space.
- Although ecology has traditionally focused upon local contemporary systems, it clearly must expand its concept to embrace global and historical processes.

Chap.27
Structure of the community

- 27.1 Understanding community structure requires that we adopt multiple perspectives.
- 27.2 Lists of species provided the first descriptions of biological communities.
- 27.3 The relative abundance of species is a measure of community structure.
- 27.4 Diversity indices incorporate species richness and species abundance.

- 27.5 The number of species encountered increases in direct proportion to the area sampled.
- 27.6 Food web analysis is used to reveal community structure.
- 27.8 The analysis of interaction food webs has roots in theoretical and experimental ecology.
- 27.9 Indirect interactions are important features of community structure.
- 27.10 Analysis of interaction food webs requires experimentation based on theory.

27.1 Understanding community structure requires that we adopt multiple perspectives.

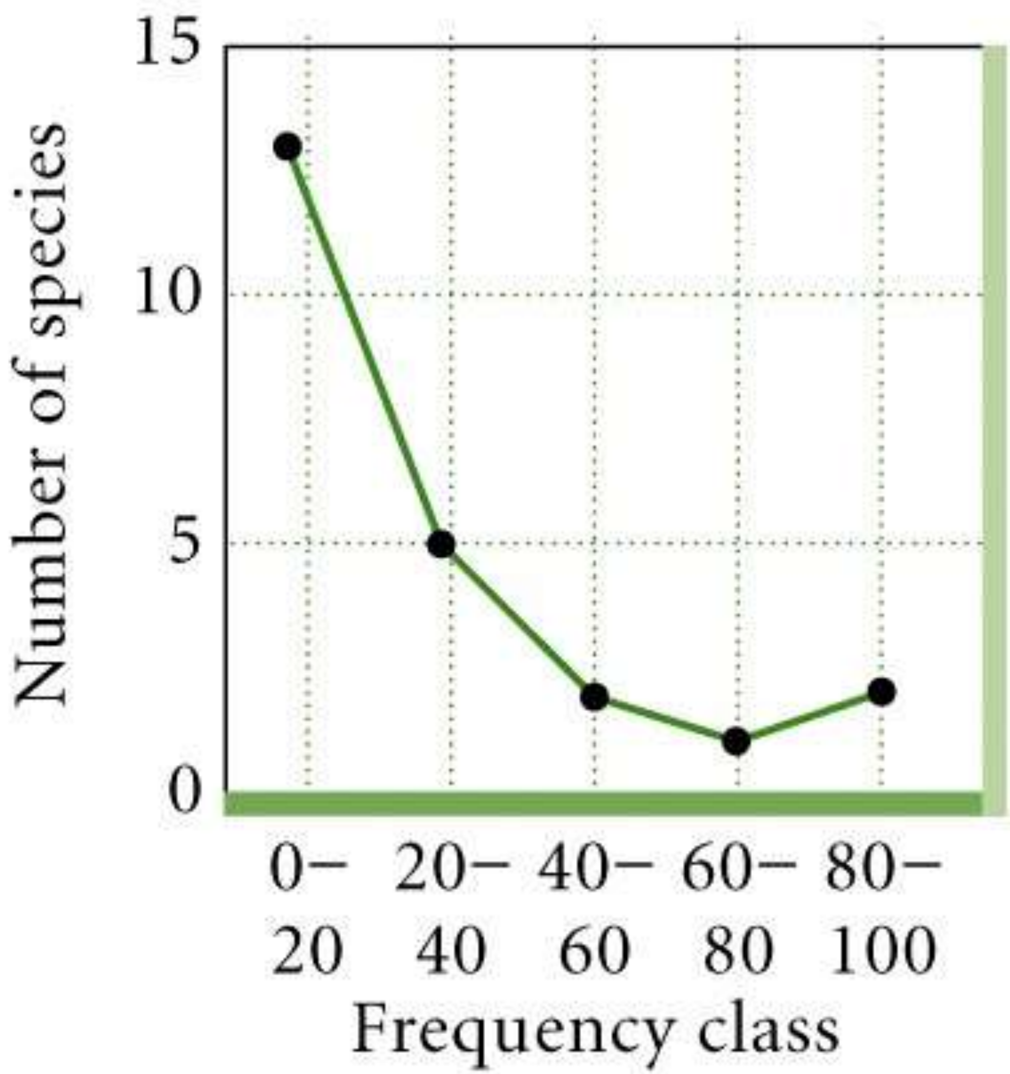
- 1. We may address patterns within a small area of relatively uniform habitat.
- 2. We addresses patterns of distribution over large areas containing a variety of habitats.
- 3. We may also view communities from two temporal perspectives.
  - (1) speciation (新種的產生) (species richness)
  - (2) historical events that may affect the structure of a community.

27.2 Lists of species provided the first descriptions of biological communities.

- During the latter part of the nineteenth century, European naturalists turned their attention from describing new species to characterizing local floras according to their species composition.
- The study, called floristic analysis or phytosociology, led directly to the functional concept of the community.

27.3 The relative abundance of species is a measure of community structure.

- Fig. 27-1 Number of species of plants in a peat bog, in each of five frequency classes, based on the percentages of twenty-five 0.1 m^2 sampling areas occupied.



27.4 Diversity indices incorporate species richness and species abundance.

- Communities differ in their numbers of species(species richness) and in the relative abundance of those species (species evenness), a feature that is referred to as species diversity.
- Simpson's index $D = 1 / \sum p_i^2$
- Shannon-Weaver index
  - $H = - \sum p_i \log_e p_i$

$\sum p_i^2 = 0.25+0.25=0.50$
D= 1/0.5 =2

$\sum p_i^2 = 0.04+0.04+0.04 + 0.04 + 0.04 =0.20$
D= 1/0.2 = 5

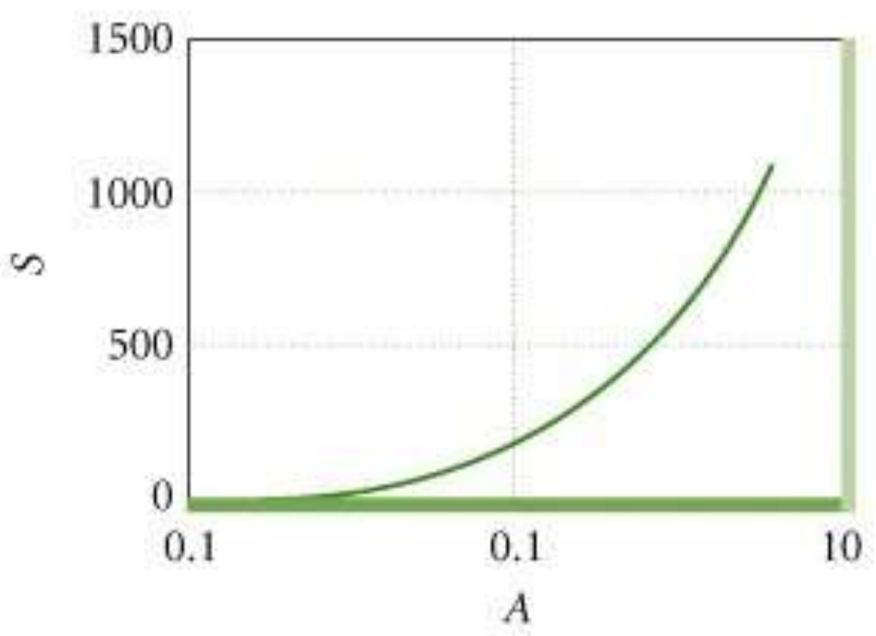
- Simpson's index
  - $D= 1 / \sum p_i^2$
- Shannon-Weaver index
  - $H = - \sum p_i \log_e p_i$

TABLE 27-2 Comparison of the Simpson and Shannon-Weaver diversity indices for three communities having different relative abundance and species richness values

	n	p_i	p_i^2	$-p_i \ln p_i$
Community A (species richness = 5)				
Species 1	10	0.50	0.25	0.35
Species 2	10	0.50	0.25	0.35
Species 3	0	0.00	0.00	0.00
Species 4	0	0.00	0.00	0.00
Species 5	0	0.00	0.00	0.00
Simpson's index, *D*	2			
Shannon-Weaver index, *H*	0.69			
Community B (species richness = 5, high evenness)				
Species 1	4	0.20	0.04	0.32
Species 2	4	0.20	0.04	0.32
Species 3	4	0.20	0.04	0.32
Species 4	4	0.20	0.04	0.32
Species 5	4	0.20	0.04	0.32
Simpson's index, *D*	5			
Shannon-Weaver index, *H*	1.61			
Community C (species richness = 5, low evenness)				
Species 1	18	0.80	0.64	0.18
Species 2	1	0.05	0.00	0.15
Species 3	1	0.05	0.00	0.15
Species 4	1	0.05	0.00	0.15
Species 5	1	0.05	0.00	0.15
Simpson's index, *D*	1.54			
Shannon-Weaver index, *H*	0.78			

27.5 The number of species encountered increases in direct proportion to the area sampled.

- Species-area relationship
  - S(species richness) = cA^z
  - $\log S = \log c + z \log A$



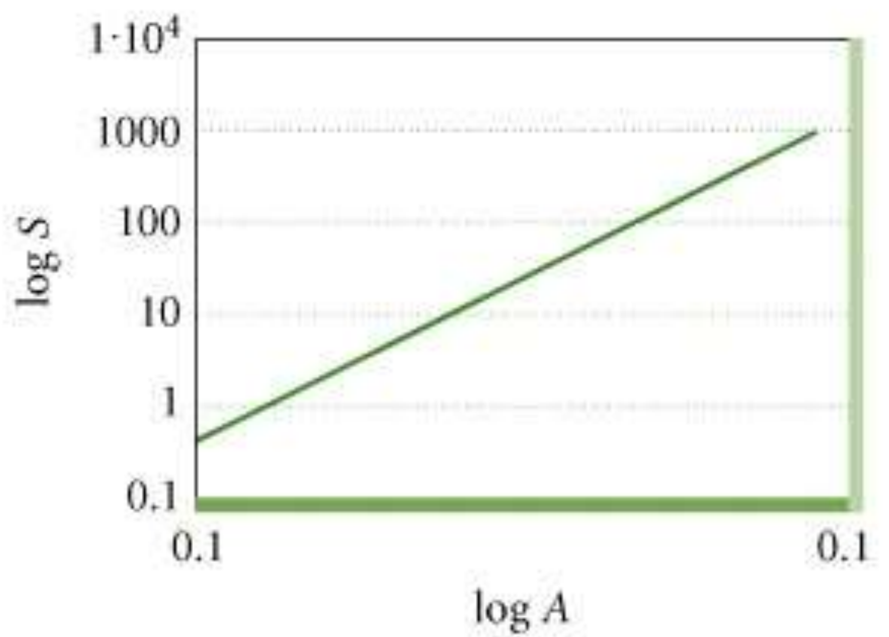
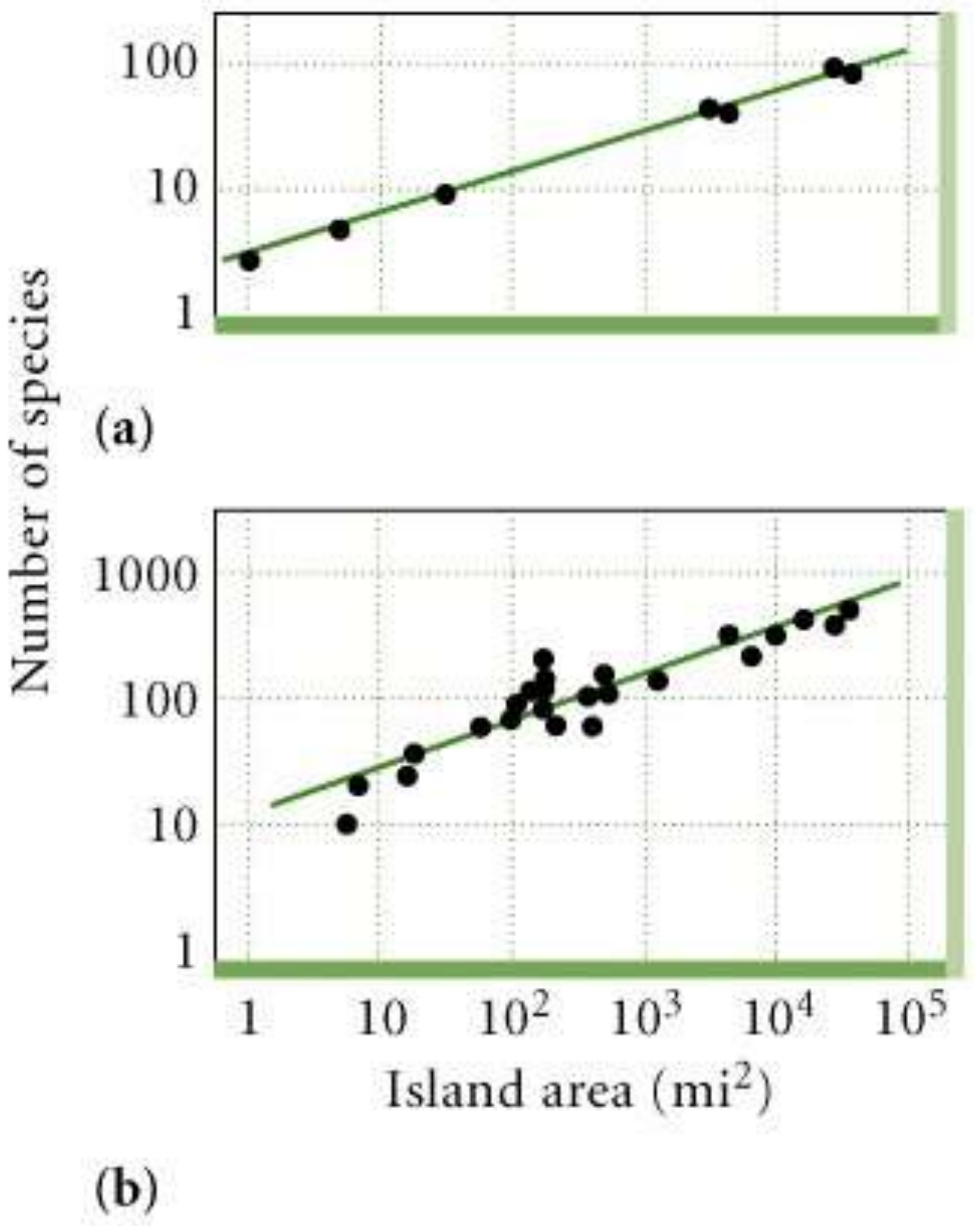


Fig. 27.11

Fig. 27-12 Species-area curves
(a) for amphibians and reptiles in the West Indies and
(b) for birds in the Sunda Islands, Malaysia.



Mechanisms of species-Area relationships

- equilibrium hypothesis
- disturbance hypothesis
- habitat diversity hypothesis
- passive sampling hypothesis (larger area represent bigger targets for immigration)
- geographic distribution hypothesis

Chap.29 Biodiversity

- Biodiversity may be viewed at the ecosystem level, so-called ecosystem diversity, which encompasses the great variety of habitat types and biomes.
- These different levels of diversity describe a hierarchy from the individual and population levels of genetic variation, through community levels to the ecosystem level.

Chap.29 Biodiversity

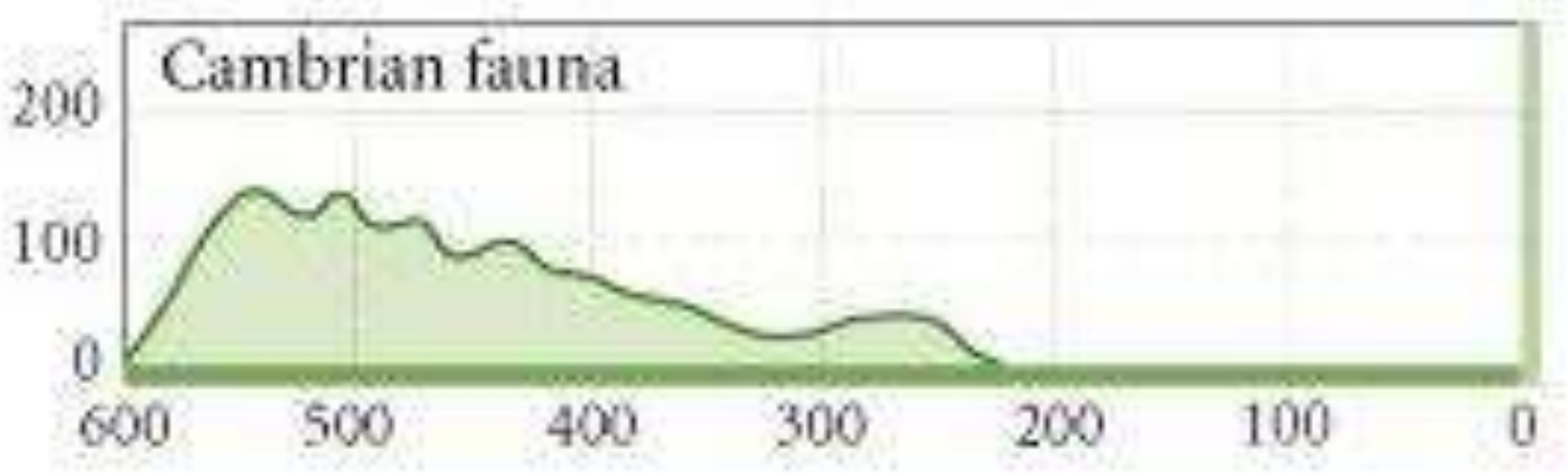
- 29.1 A number of general patterns of species diversity have been observed.
- 29.2 Contemporary thinking about community organization reconciles the regional/historical and local/ deterministic views of regulation of diversity.
- 29.3 The number of species on islands depends on immigration and extinction rates.

- 29.4 Are species produced more rapidly in the tropics than at higher latitudes?
- 29.5 The time hypothesis suggests that older habitats are more diverse.
- 29.6 Niche theory(職位理論) provides the framework for the theory of regulation of species diversity.
- 29.7 Species diversity increases with primary production in some cases.
- 29.8 Environmental and life history variation may affect species diversity.

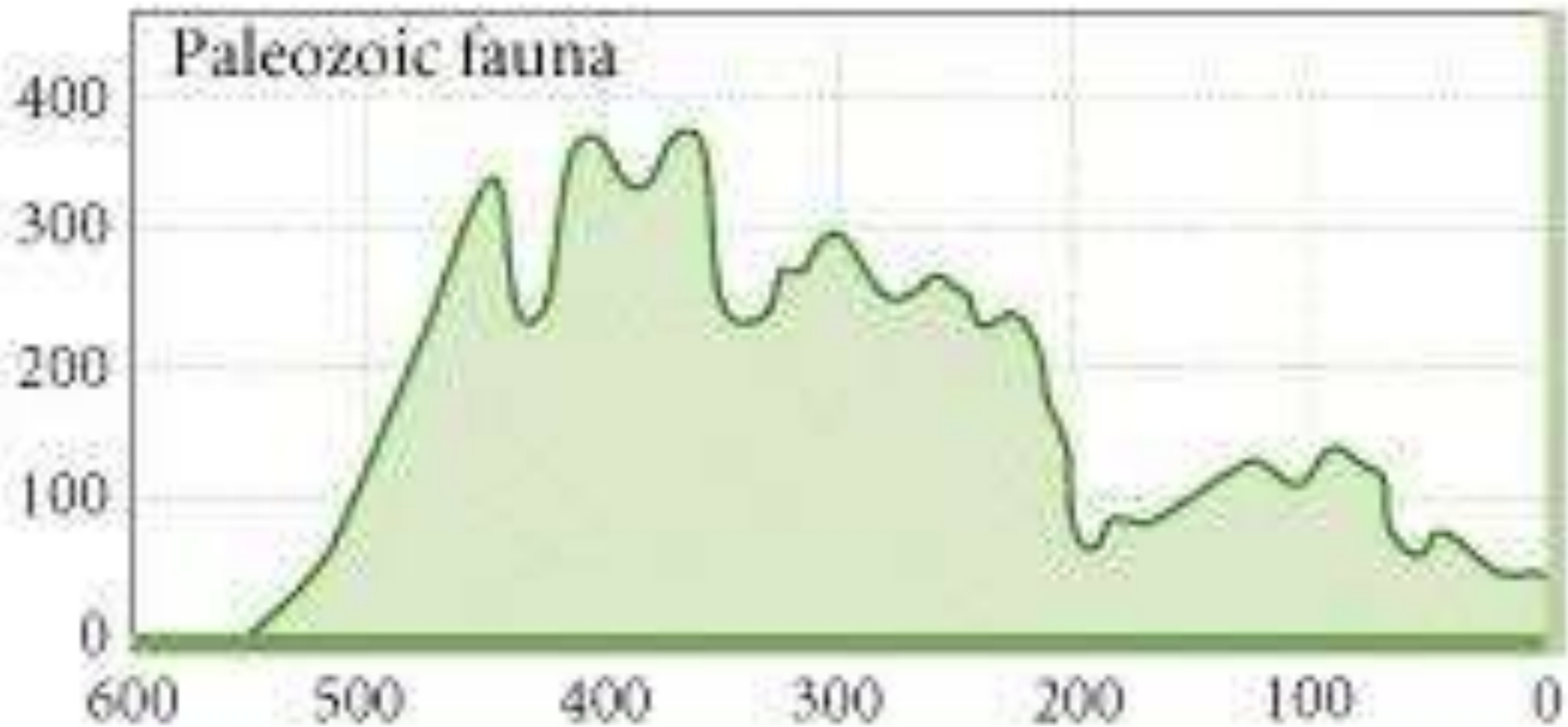
Chap.29 Biodiversity

- 29.9 The activities of predators and herbivores may affect species diversity.
- 29.10 Can reduced competition explain high diversity?
- 29.11 Disturbance may affect species diversity.
- 29.12 Do communities reveal evidence of competition between species?

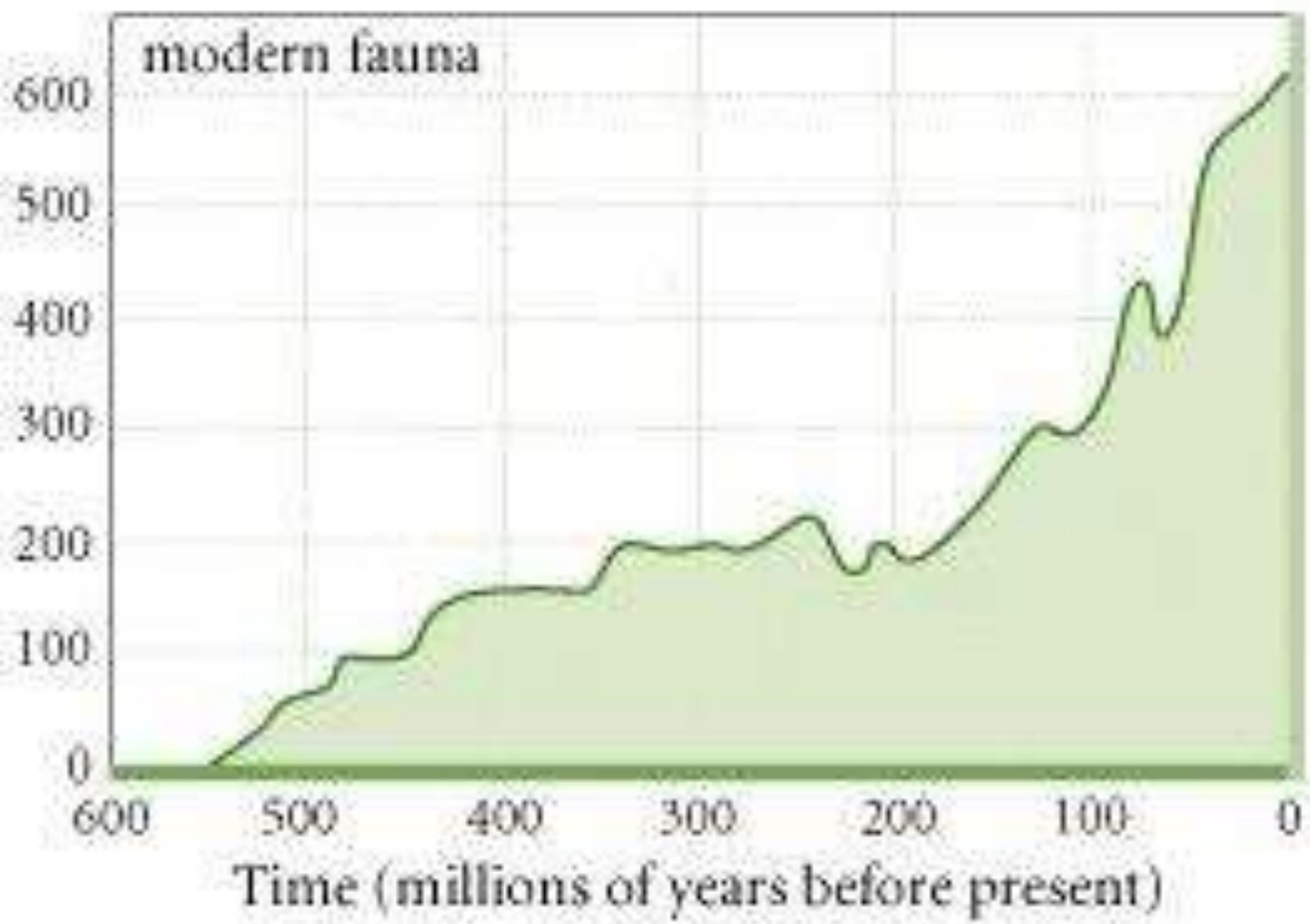
29.1 A number of general patterns of species diversity have been observed.



- Diversity in geologic time.
- Fig. 29-1a Number of families of organisms that arose during the Cambrian period



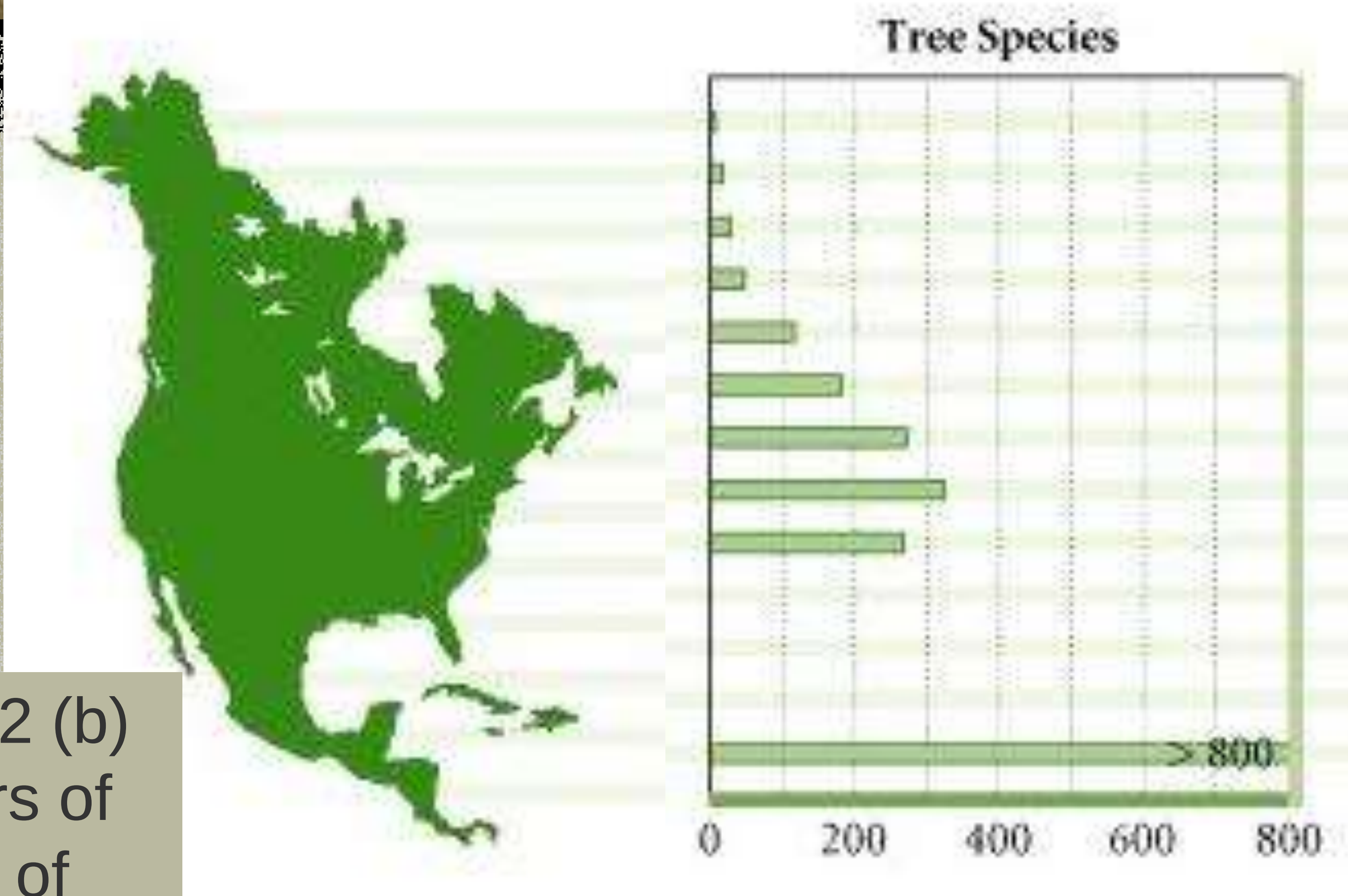
- Fig. 29-1b Number of families of organisms that arose during the Paleozoic period



- Fig. 29-1b Number of families of organisms that arose during the modern period

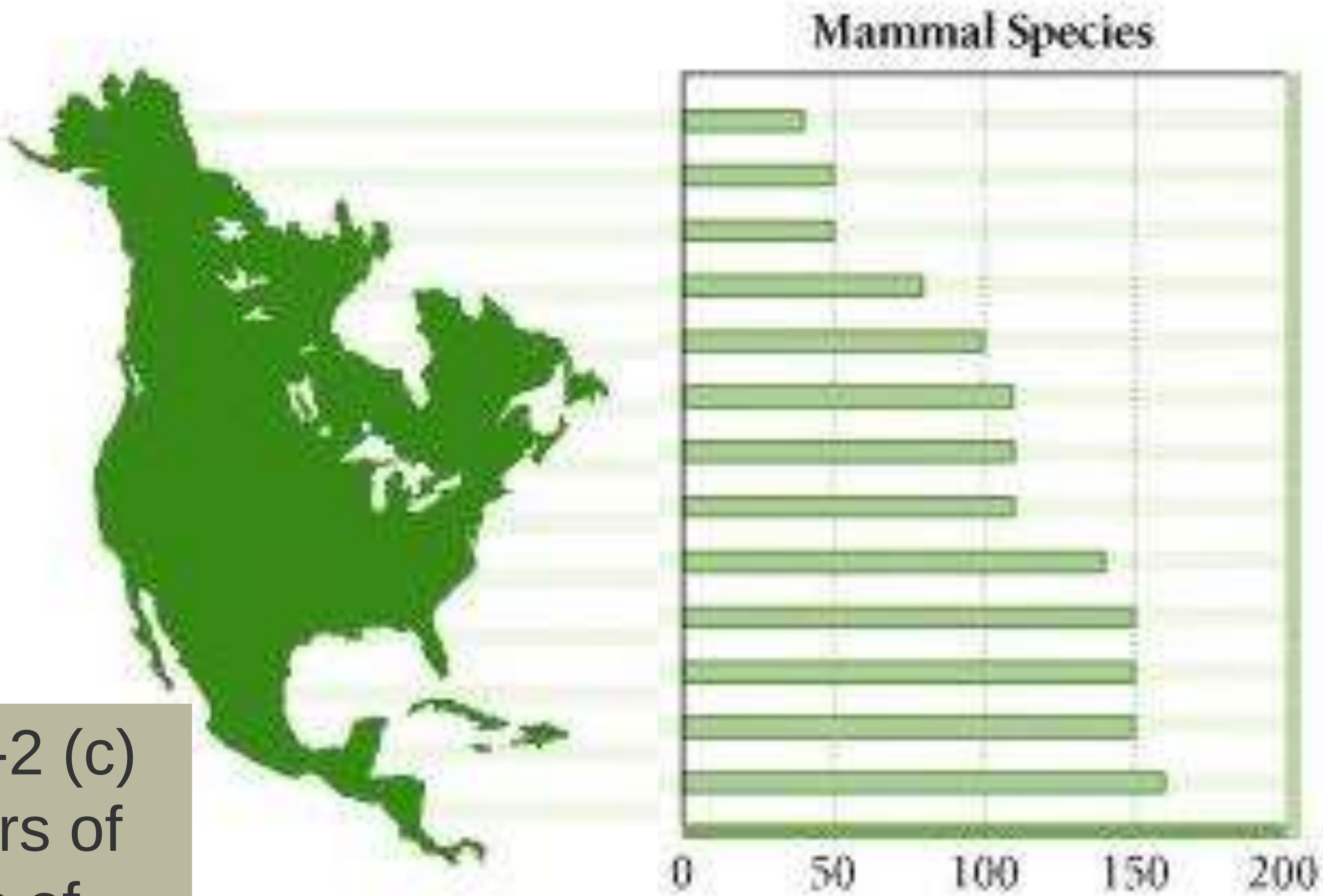
Latitudinal gradients of diversity

- Fig. 29-2 (a) Numbers of species of breeding birds by latitude.



- Fig. 29-2 (b) Numbers of species of breeding trees by latitude.

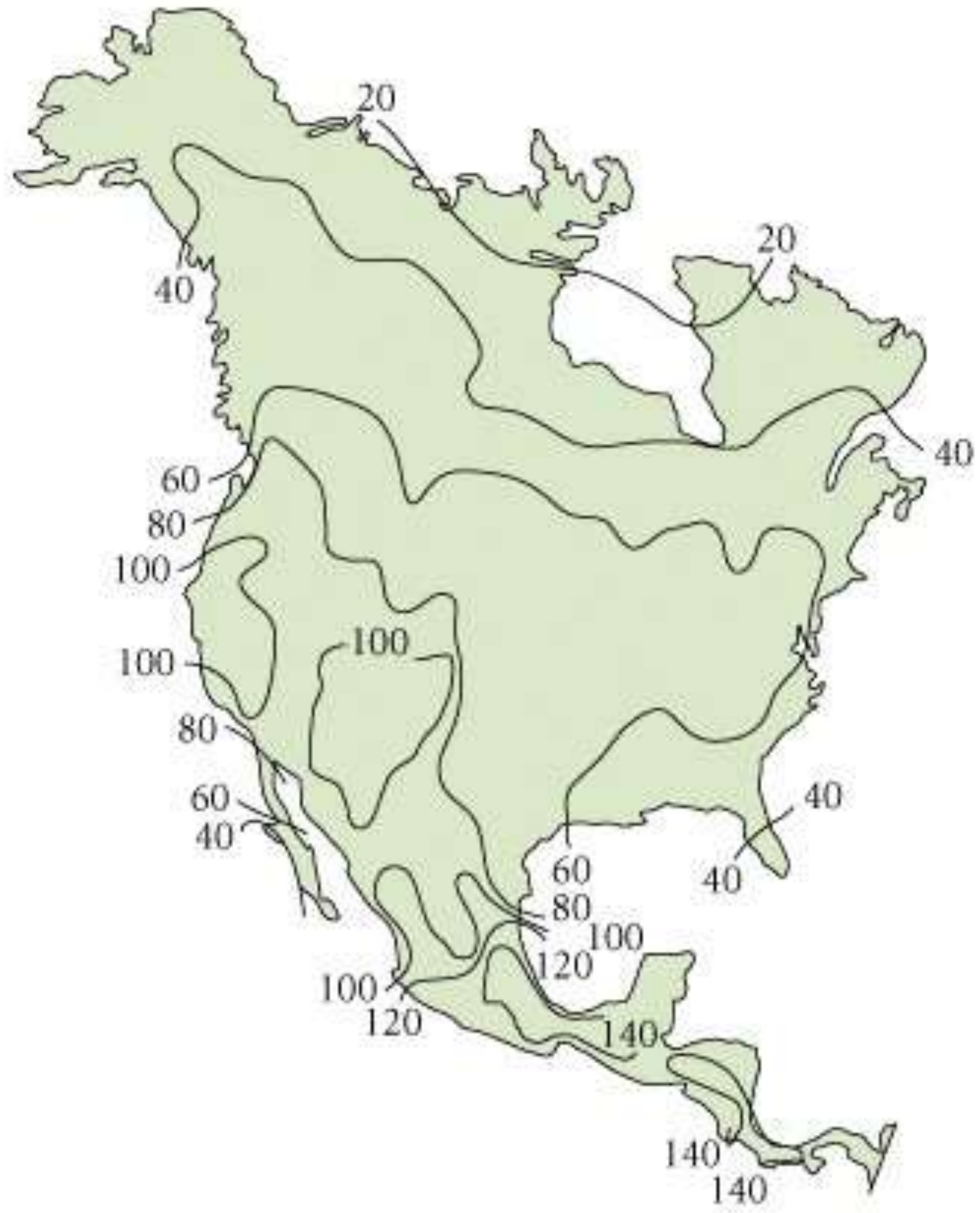
Latitudinal gradients of diversity



- Fig. 29-2 (c) Numbers of species of breeding mammals by latitude.

Latitudinal gradients of diversity

Fig. 29-4 Species diversity contours for mammals in 150-square-mile blocks in continental North America.



29.2 Contemporary thinking about community organization reconciles the regional/historical and local/ deterministic views of regulation of diversity.

- Ecologists viewed species diversity as a regional phenomenon representing outcome of historical events. (regional/historical view)
- Ecologists ask questions about how population interactions such as predation and competition affect species diversity. (local/ deterministic view)

Local and Regional components of diversity

- Local and regional factors are expressed n different components of species diversity, two of which are alpha(or local)diversity, and gamma(or regional) diversity.
- Ecologists refer to the difference in species from one habitat to the next as beta diversity.

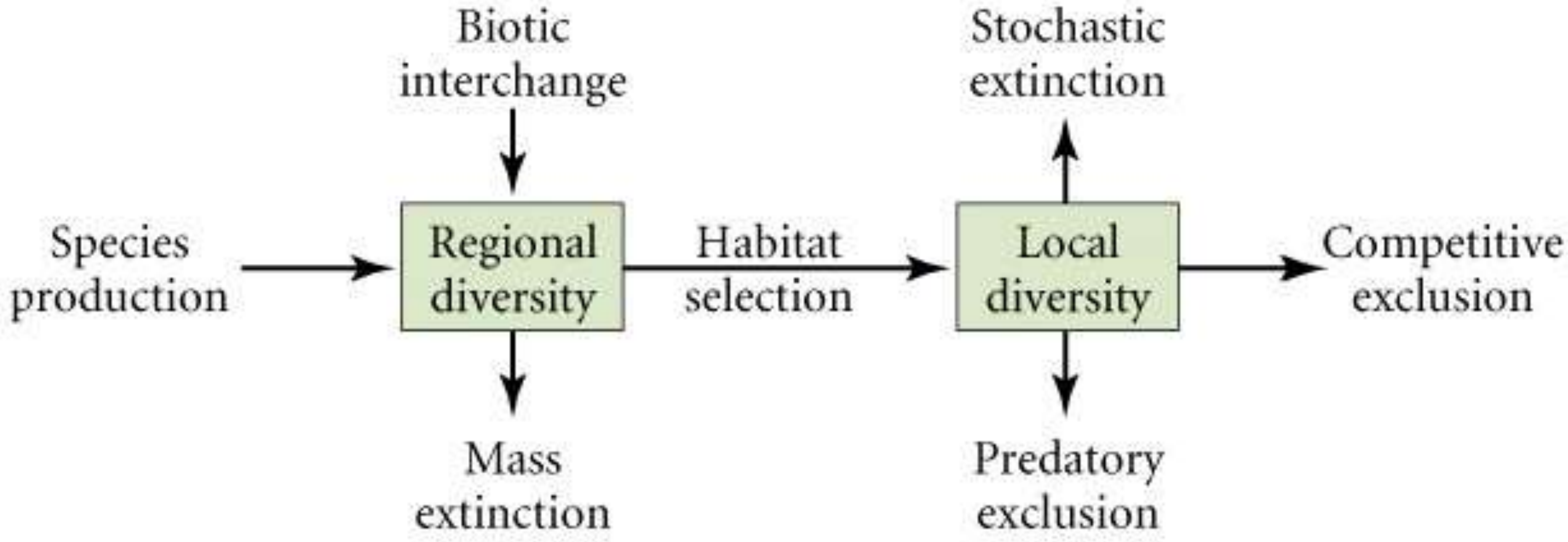


Fig. 29-5 Factors affecting regional and local species diversity. Numbers of species are increased at the regional level by speciation and immigration. Habitat selection connects regional and local diversity.

Fig. 29.6 Relationship between alpha, gamma, and bets (turnover) diversity.
(a) The diversity in each habitat(alpha) is the same for all four habitats)
(b) Alpha diversity is 2 for one habitat and 1 for the other three.
(c) Average alpha diversity =0.5
(d) alpha diversity=3.

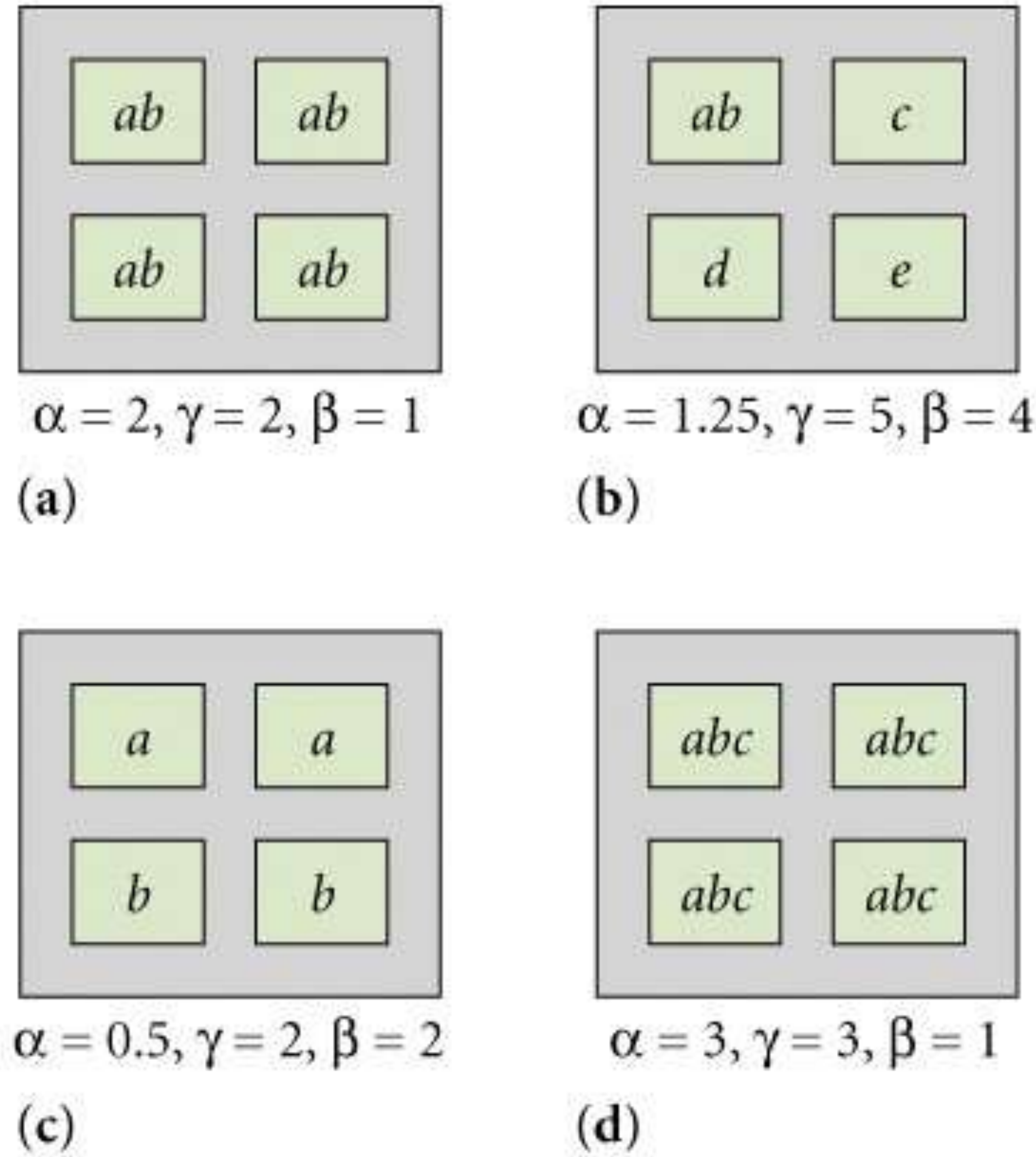


TABLE 29-1 Relative abundances and habitat distributions of resident land birds in seven tropical localities within the Caribbean basin

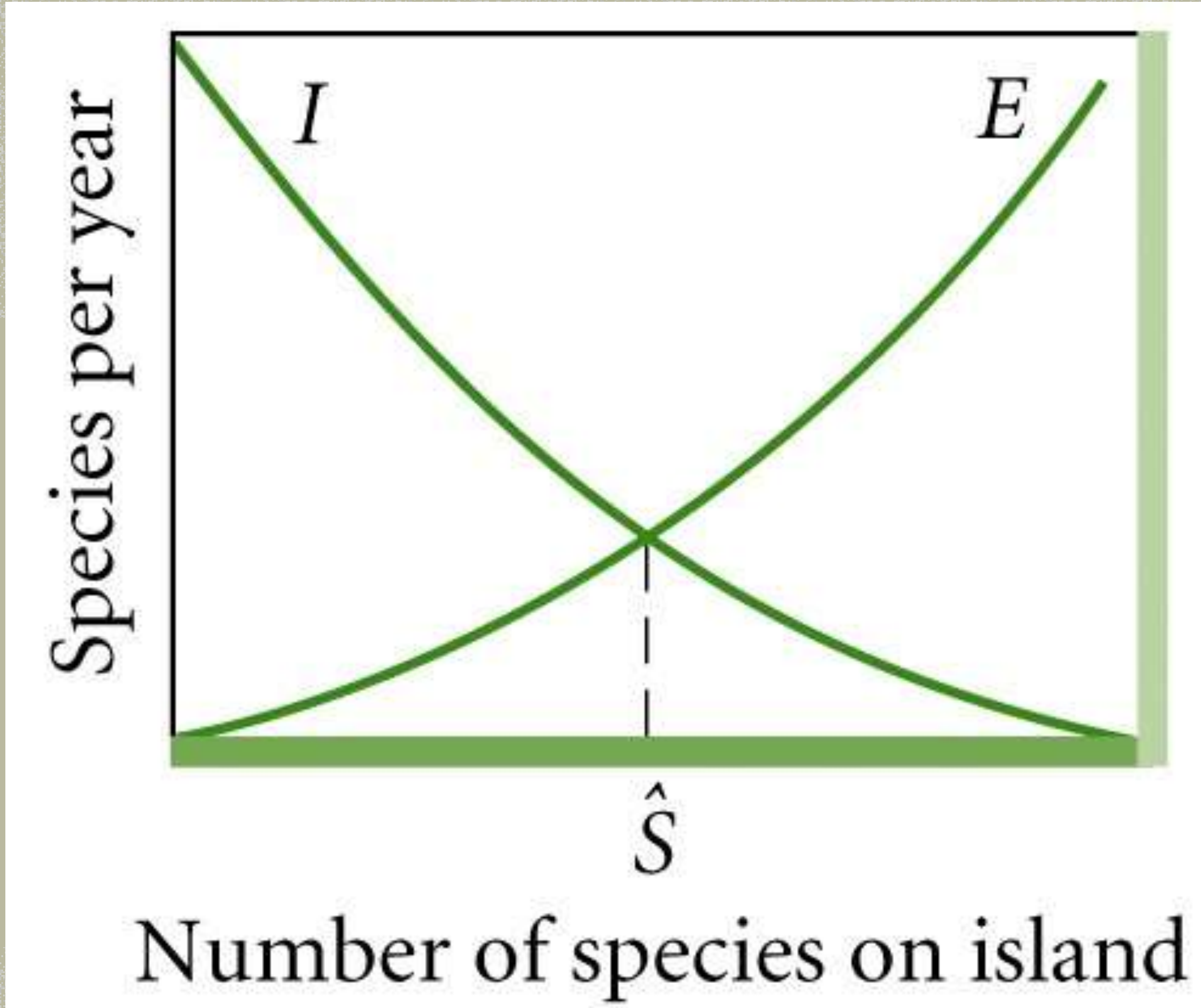
Locality	Number of species observed (regional diversity)	Average number of species per habitat (local diversity)	Habitats per species	Relative abundance per species per habitat (density)	Relative abundance per species	Relative abundance of all species
Panama	135	30.2	2.01	2.95	5.93	800
Trinidad	106	28.2	2.35	3.31	7.78	840
Jamaica	56	21.4	3.43	4.97	17.05	955
Tobago	53	21.4	3.63	4.71	17.10	906
St. Lucia	33	15.2	4.15	5.77	23.95	790
Grenada	30	15.5	4.63	5.36	24.82	745
St. Kitts	20	11.9	5.35	5.88	31.45	629

Note: *Based on ten counting periods in each of nine habitats in each locality. The relative abundance of each species in each habitat is the number of counting periods in which the species was seen (maximum 10); this times the number of habitats gives the relative abundance per species; this times the number of species gives the relative abundance of all species together.*
(From Cox and Ricklefs 1977, Wunderle 1985.)

Where fewer species occur, each is likely to be more abundant and to live in more habitats

29.3 The number of species on islands depends on immigration and extinction rates.

- The theory of island biogeography developed by MacArthur and Wilson.
- Fig. 29-8



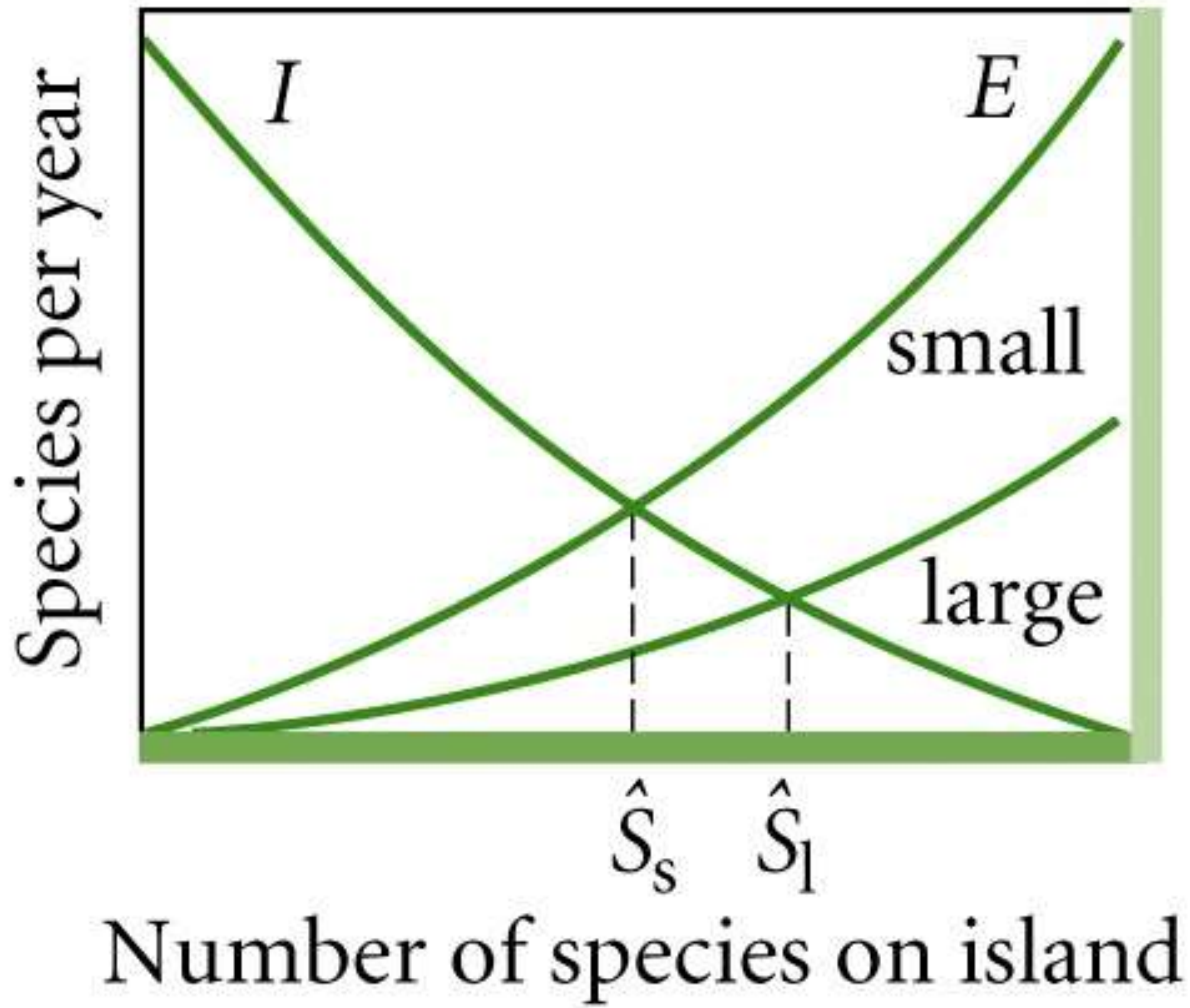


Fig. 29-9 The MacArthur-Wilson equilibrium model

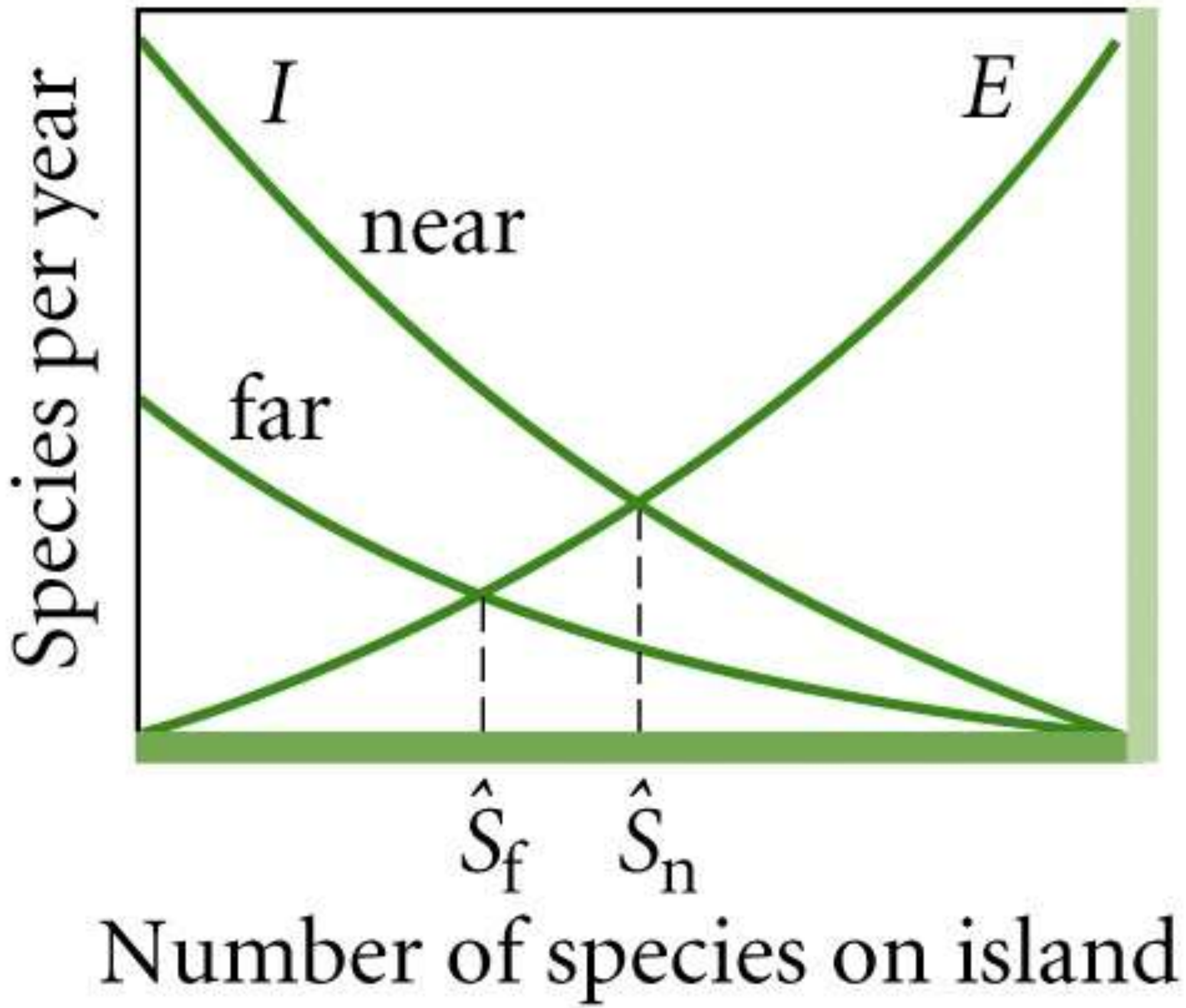


Fig. 29-10 The MacArthur-Wilson equilibrium model

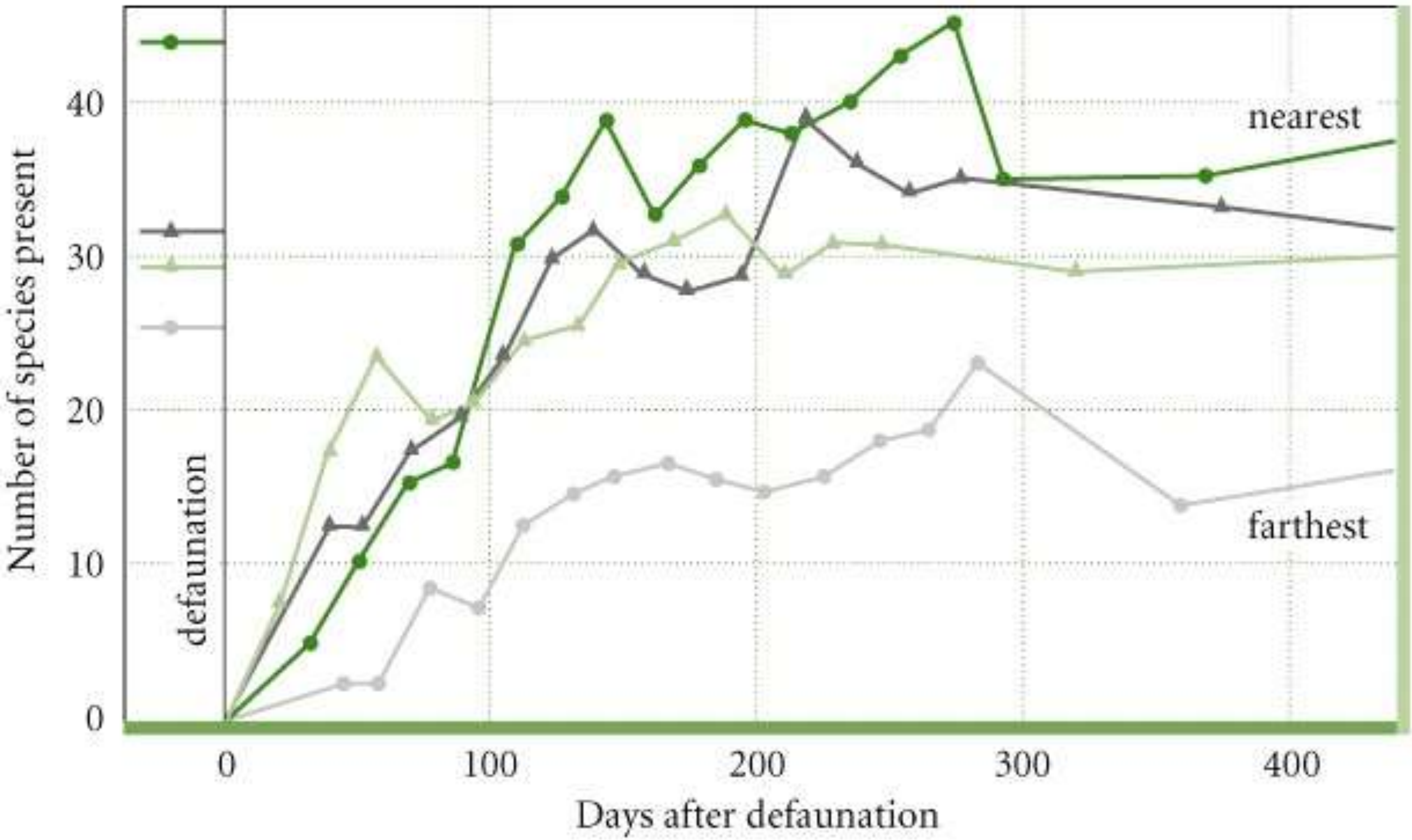


Fig. 29-11 Recolonization curves for four small mangrove islands in the lower Florida Keys whose entire faunas, consisting almost solely of arthropods, were exterminated by methyl bromide fumigation.

- New species are generated by the evolutionary process of speciation rather than immigration from elsewhere.

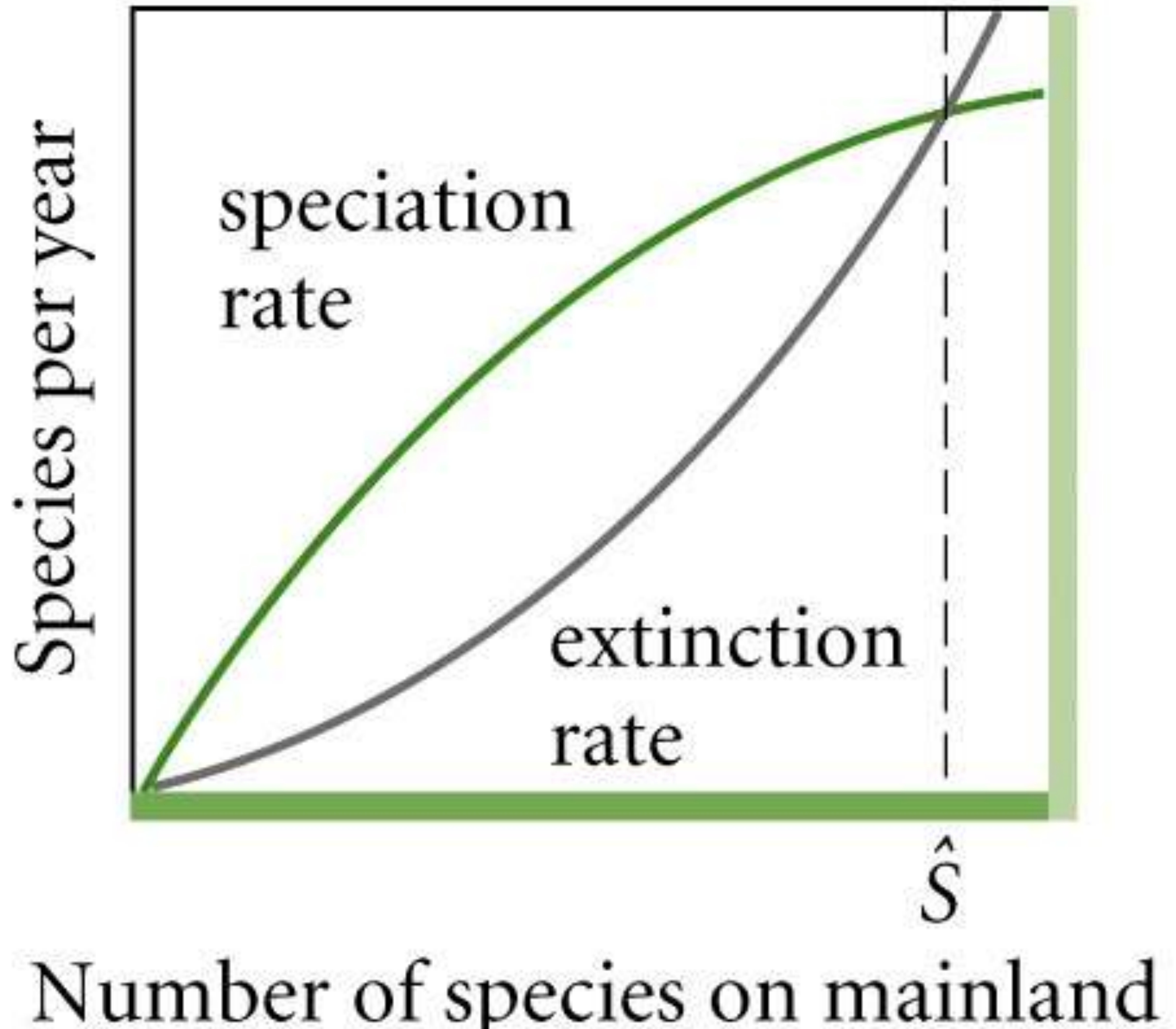


Fig. 29-12 Equilibrium model of the number of species in a mainland region with a large area.

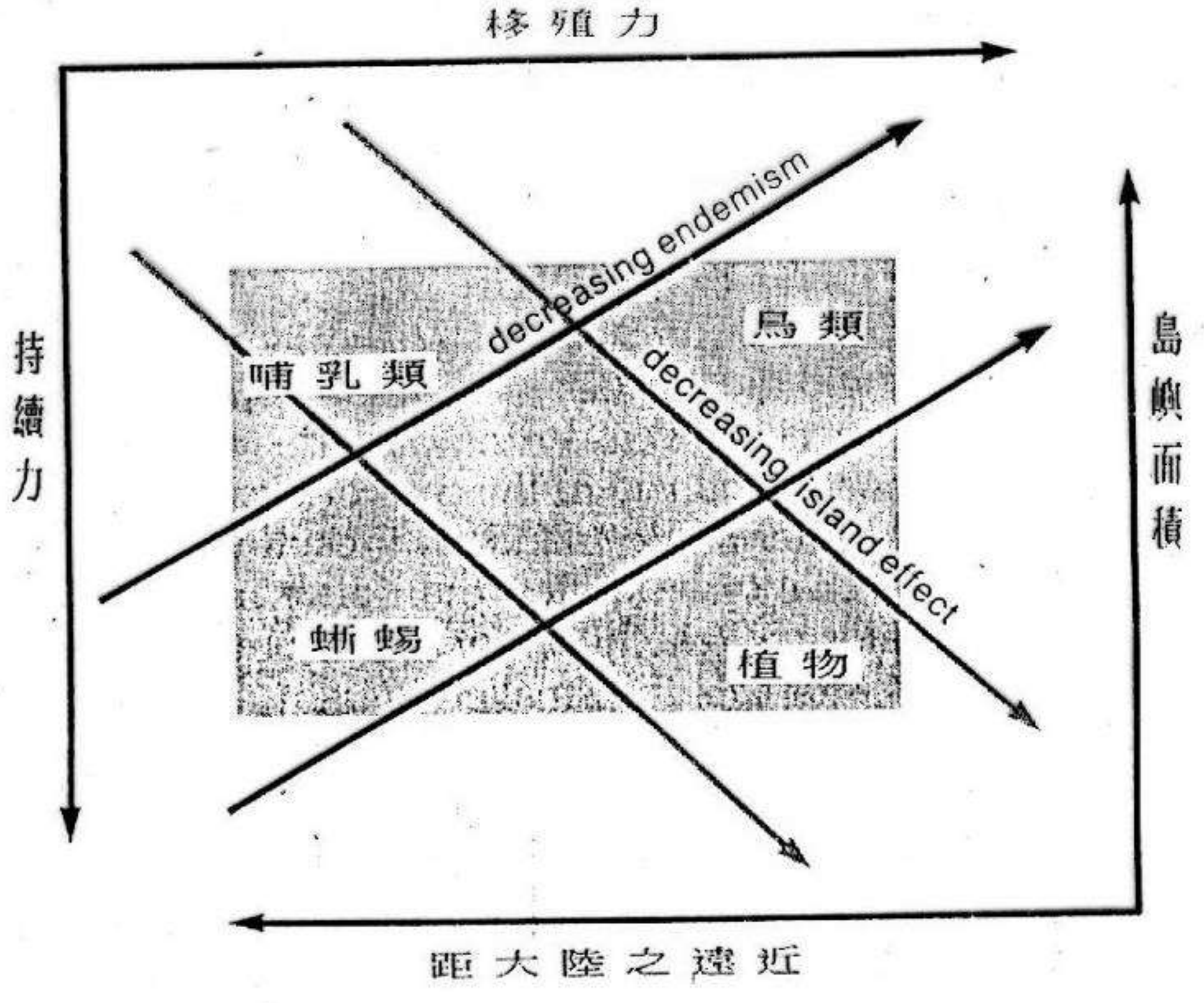
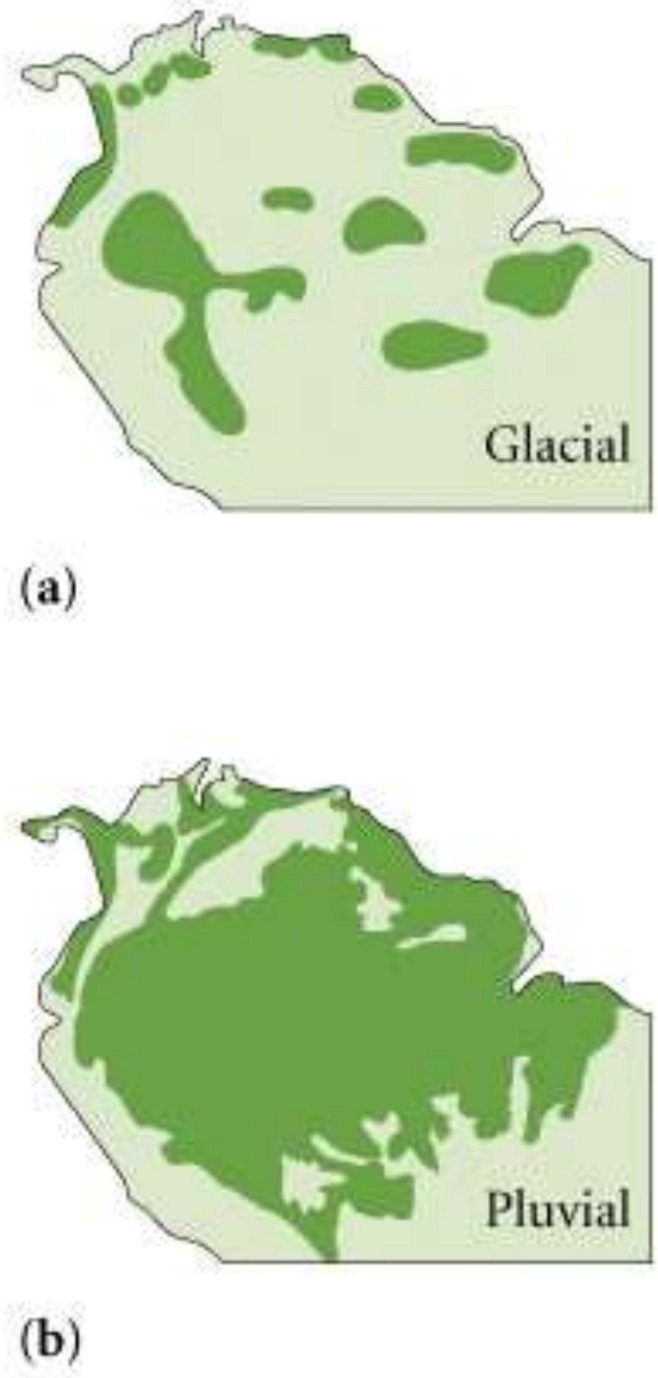


Fig. 00 島嶼生物地理學(Case & Code, 1987)

29.4 Are species produced more rapidly in the tropics than at higher latitudes?

- Haffer and Prance have suggested that fragmentation of tropical forests during the periodic dry periods of the recent Ice Age (fig.29-13) provided opportunities for allopatric speciation in the Tropics.
- If so, we would expect to find more species per genus in tropical forests than in their temperate zone counterparts.

Fig.29-13 Approximate distribution of lowland rain forest in South America
(a) during the height of glacial periods
(b) at present.



But, in fact, tropical forests present their tremendous diversity to us as much at the family and genus levels as at the species level.

為何熱帶地區有較高的diversity?

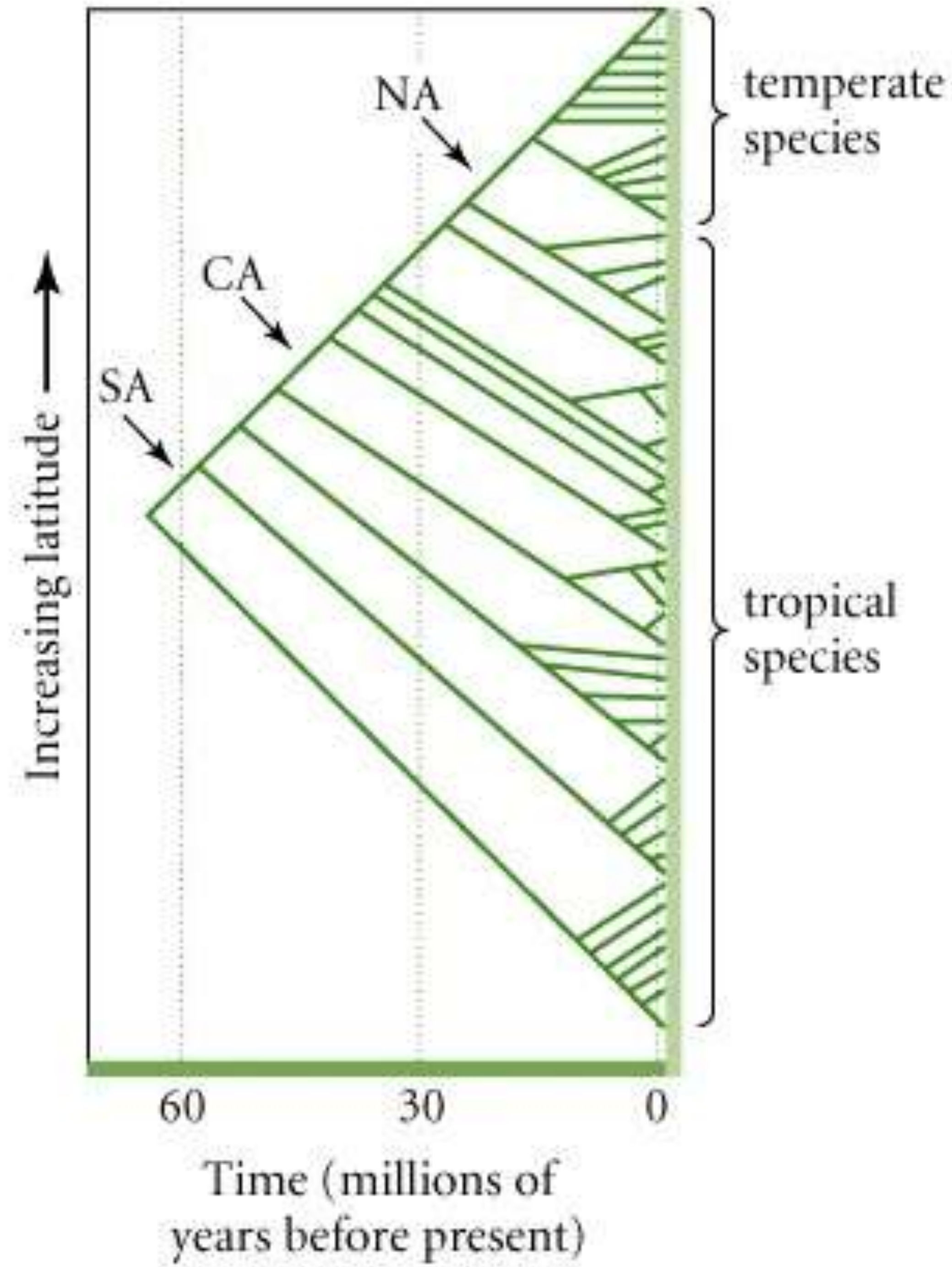
- The difference in diversity between the species rich tropical site and the temperate zone site resides primarily at the family level.
- In fact, the tropical forests are decidedly poor in closely related species.
- Their great number of higher taxa reveals the ancient roots of diversity there.

TABLE 29-2 Taxonomic levels of diversity among forest trees in several regions

Taxa	Number of taxa: Europe	Number of taxa: Eastern North America	Number of taxa: Eastern Asia
Orders	16	26	37
Families	21	46	67
Genera	43	90	177
Species	124	253	729
Percentage of genera predominantly tropical	5	14	32
Number of genera in fossil record	130	60	122

(From Latham and Ricklefs 1993.)

Fig. 29-14 Hypothetical primitively tropical clade having both temperate and tropical species.



29.5 The time hypothesis suggests that older habitats are more diverse.

- Tropical regions have enjoyed longer periods of stability and, thus, have had more time for species differentiation.
- This idea is now referred to as the time hypothesis of species diversity.
- The fossil record is so fragmentary that this test can be applied to only a few taxa and is restricted to certain types of habitats

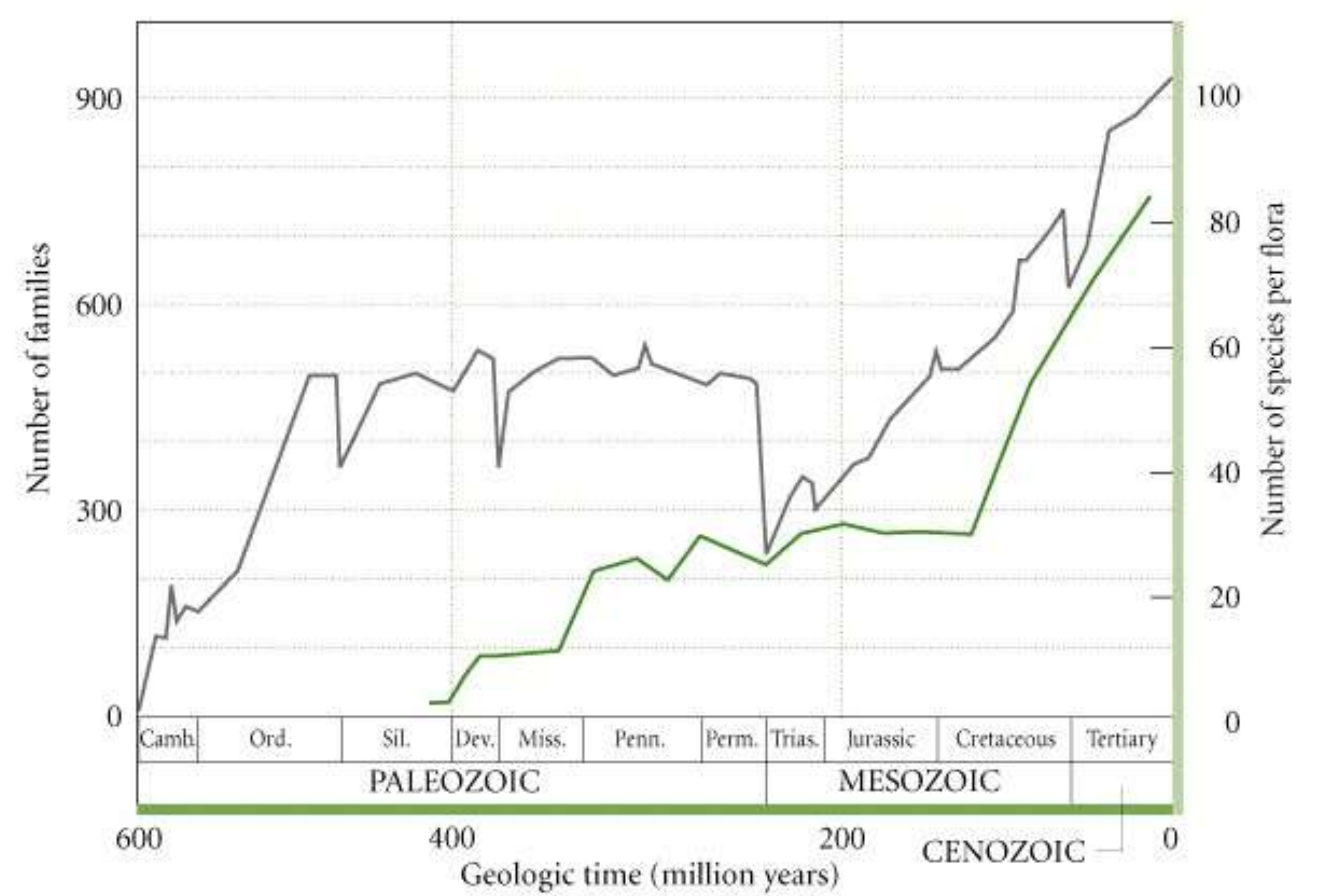


Fig. 29-15 Changes in the global total number of families of marine animals (gray line) and changes in the average number of species represented in local fossil floras of terrestrial plants (green line).

- The idea that time alone accounts for latitudinal differences in species diversity is too simplistic to provide a full explanation of tropical diversity.
- Local/ deterministic factors include primary production, the structural features of the habitat, the action of predators and herbivores, disturbance, and competition.

29.6 Niche theory(職位理論) provides the framework for the theory of regulation of species diversity.

- Ecologists use the term niche to express the relationship of individuals or populations to all aspects of their environments -- and hence their ecological roles within communities.
- Hutchinson(1957) first defined the niche concept formally.

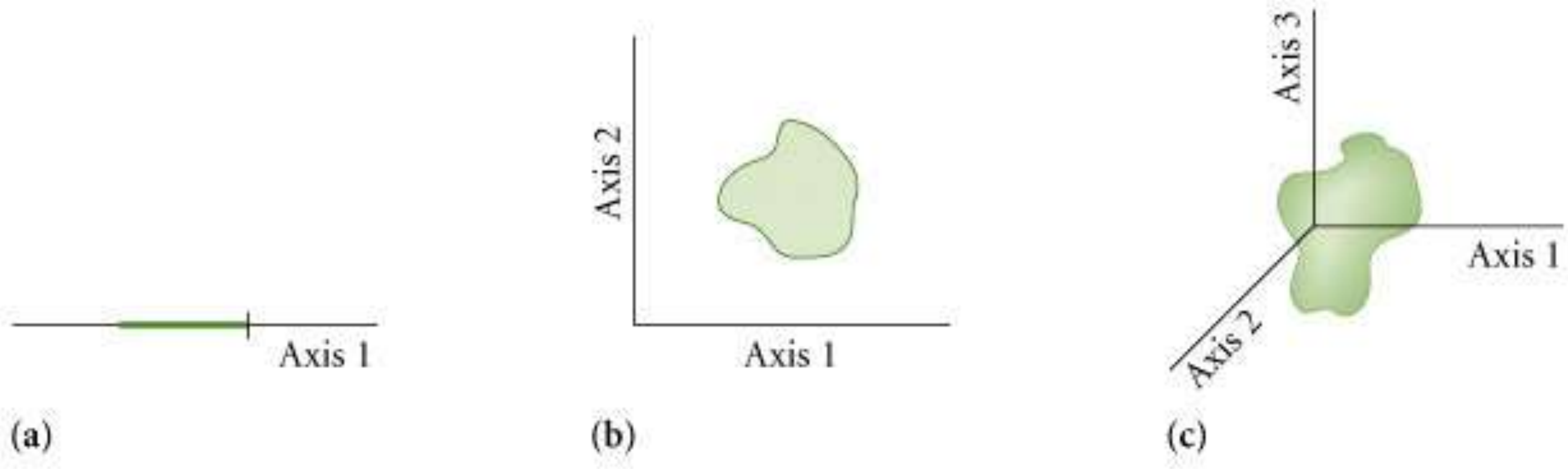


Fig. 29-16 Portrayal of an ecological niche with a single axis (a),
two axes (b)
and three axes (c).

Niche breadth

niche width

niche size

niche overlap

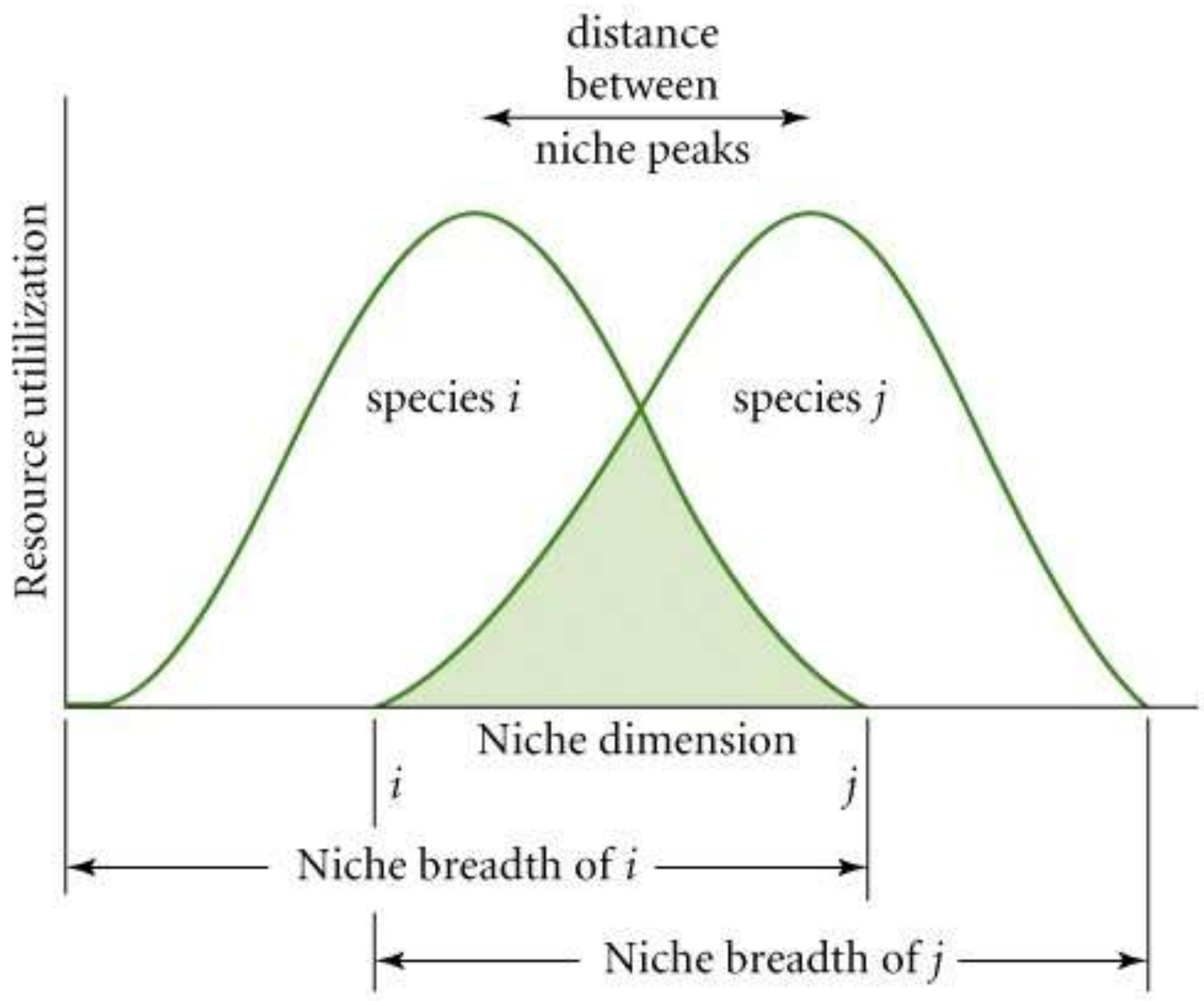


Fig. 29-17 Positions of two species i and j along a single resource dimension.

Fig. 29-19 how resource utilization along a single niche axis can be altered to accommodate more species.

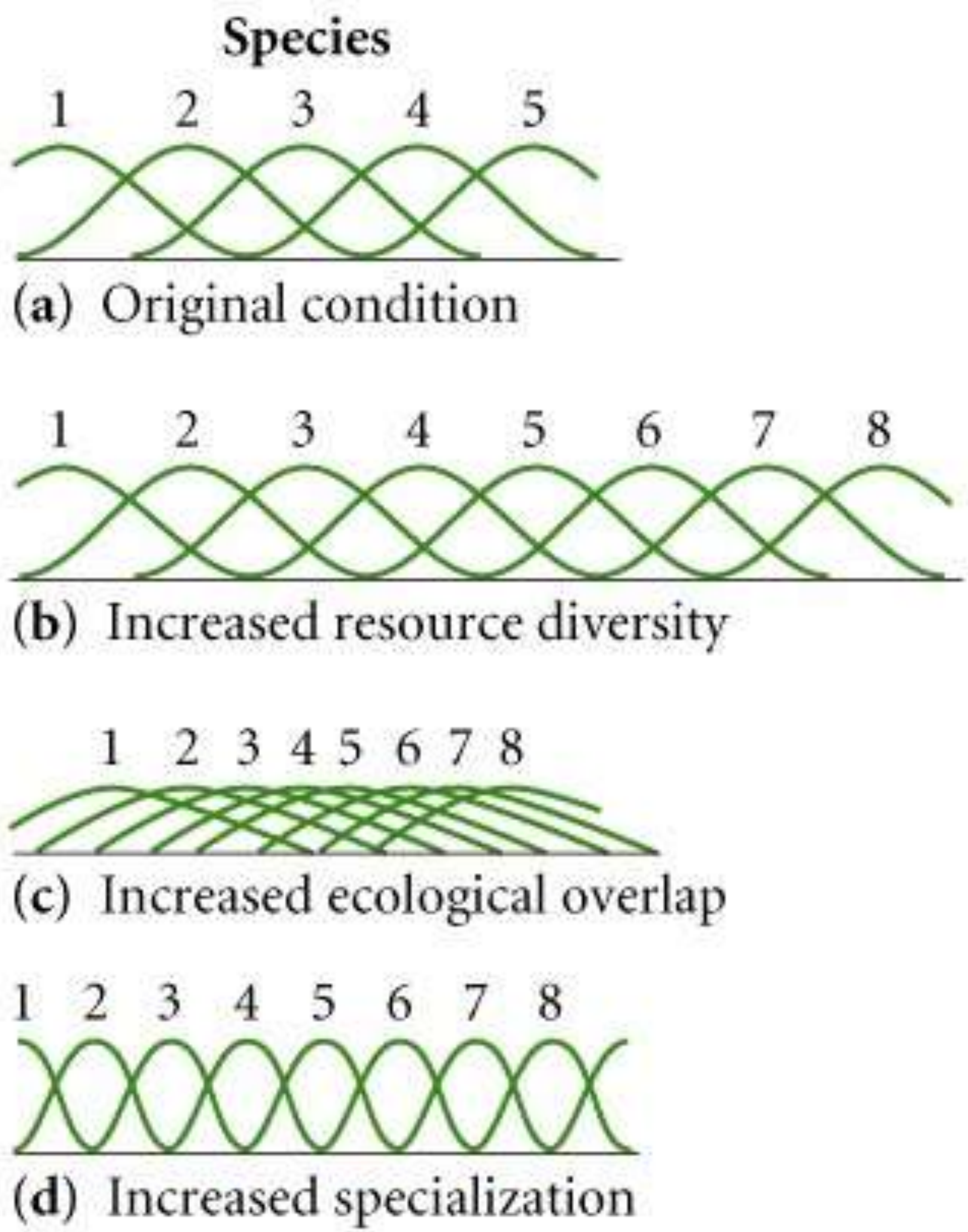
(a) original condition

(b) increased resource diversity

(c) increased ecological overlap

(d) increased specialization

(c + d) is sometimes called **species packing**.



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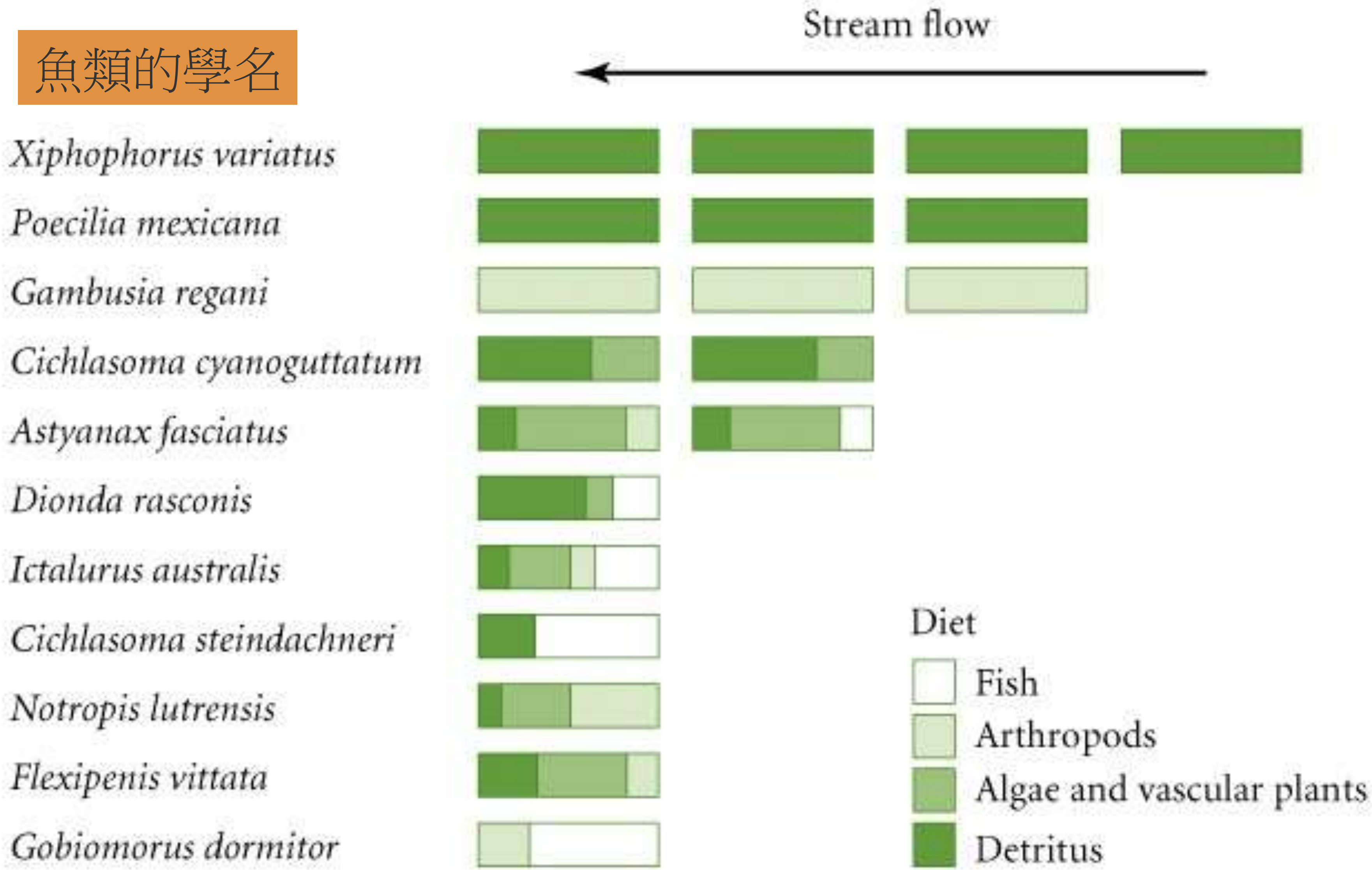
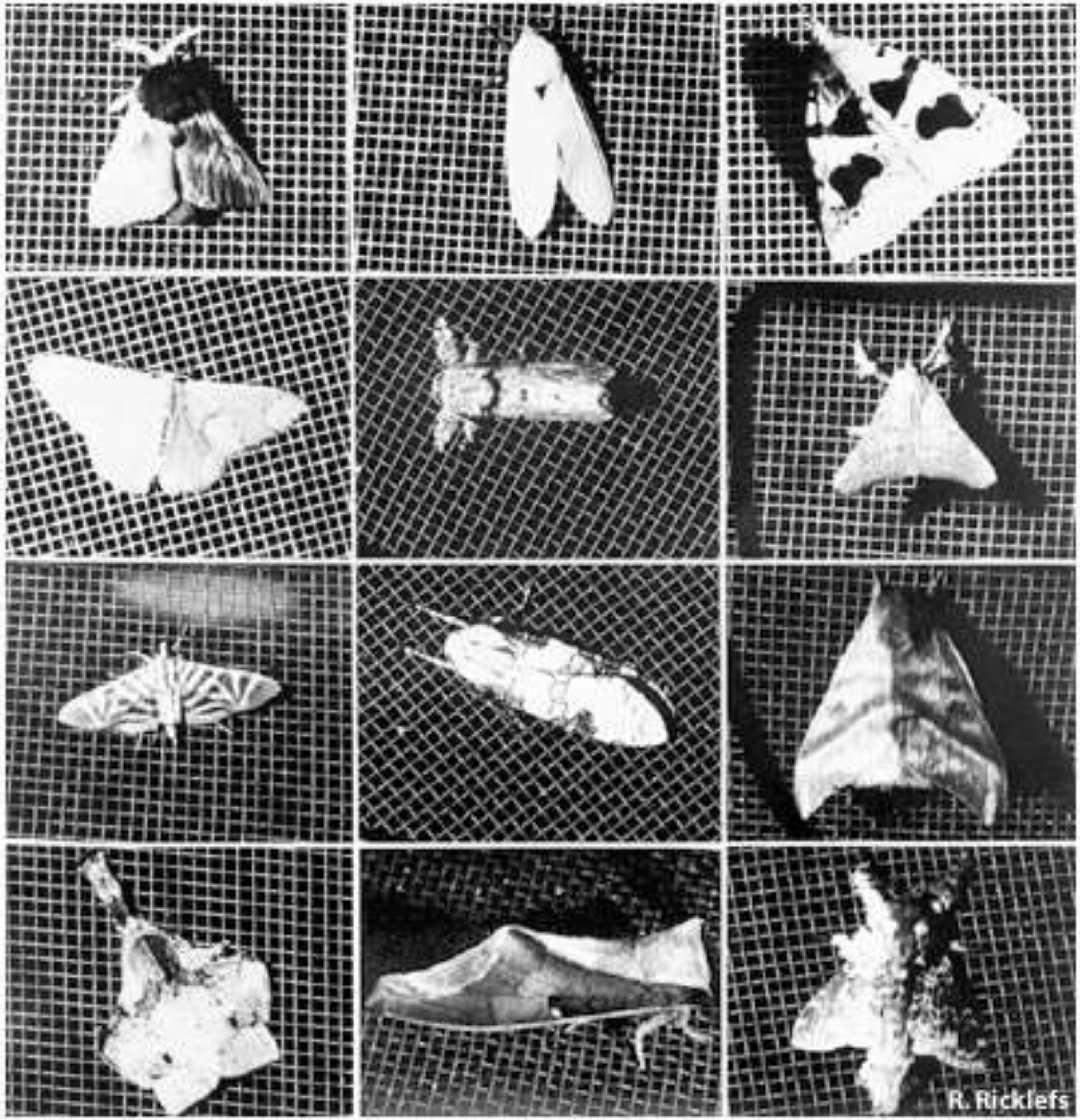


Fig. 29-20 Food habits of fish species in four communities from a spring with one species(right) to downstream communities with up to eleven species.

Escape space and aspect diversity

- The part of the niche space that is defined by adaptations of prey organisms that help them avoid predation is referred to as escape space.
- The morphological appearance, or aspect, reflects characteristics of the resting place and the searching techniques of the predators to be avoided. (aspect diversity)

Fig. 29-21 Representative species of moths from Panama. These moths show the variety of appearances in the community, which reflect the characteristics of their resting places and searching techniques of their predators. (aspect diversity)



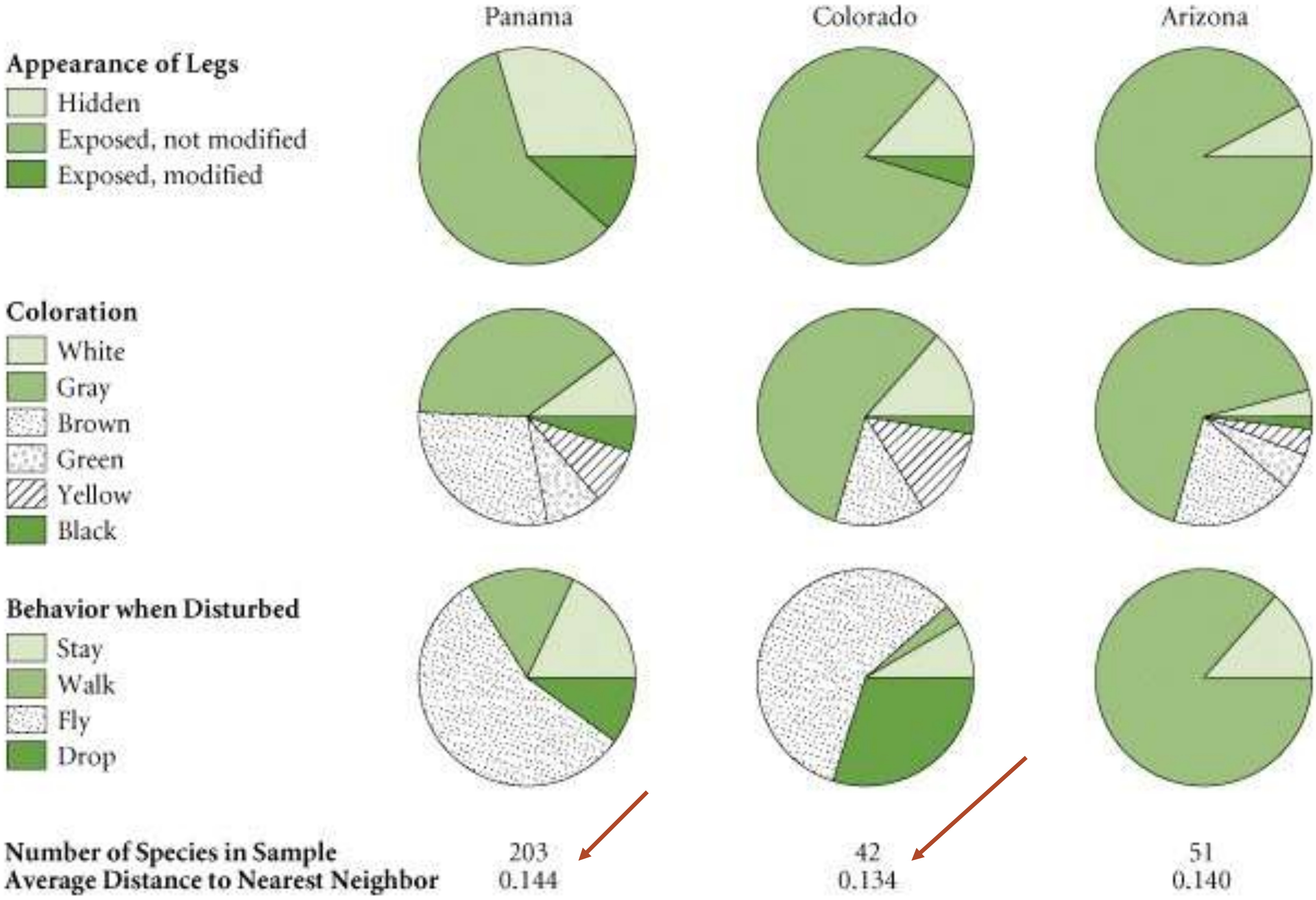


Fig. 29-22 Moths Diversity from three localities.

Aspect diversity

- Species were added to the communities by expansion of the niche space utilized rather than by denser packing of species in the same space.
- Variation in the amount of escape space used could arise from a number of factors.

29.7 Species diversity increases with primary production in some cases.

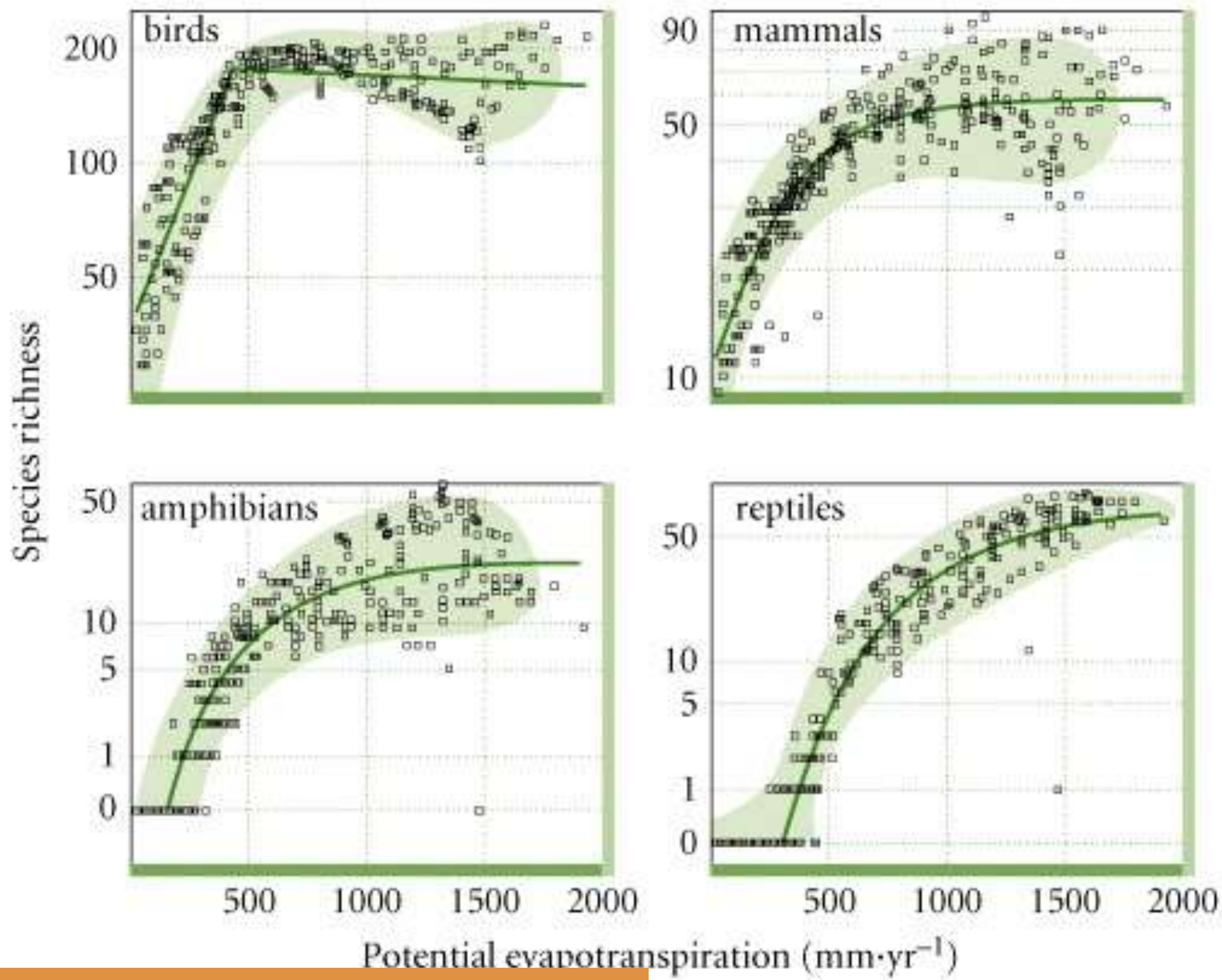


Fig. 29-13 Relationship of potential evapo-transpiration to species richness.

Productivity-stability hypothesis

TABLE 29-3 Plant productivity and the number of bird species in representative temperate zone habitats

Habitat	Approximate productivity ($g\ m^{-2}\ yr^{-1}$)	Average number of bird species
Marsh	2,000	6
Grassland	500	6
Shrubland	600	14
Desert	70	14
Coniferous forest	800	17
Upland deciduous forest	1,000	21
Floodplain deciduous forest	2,000	24

(From Tramer 1969; productivity data from Whittaker 1975.)

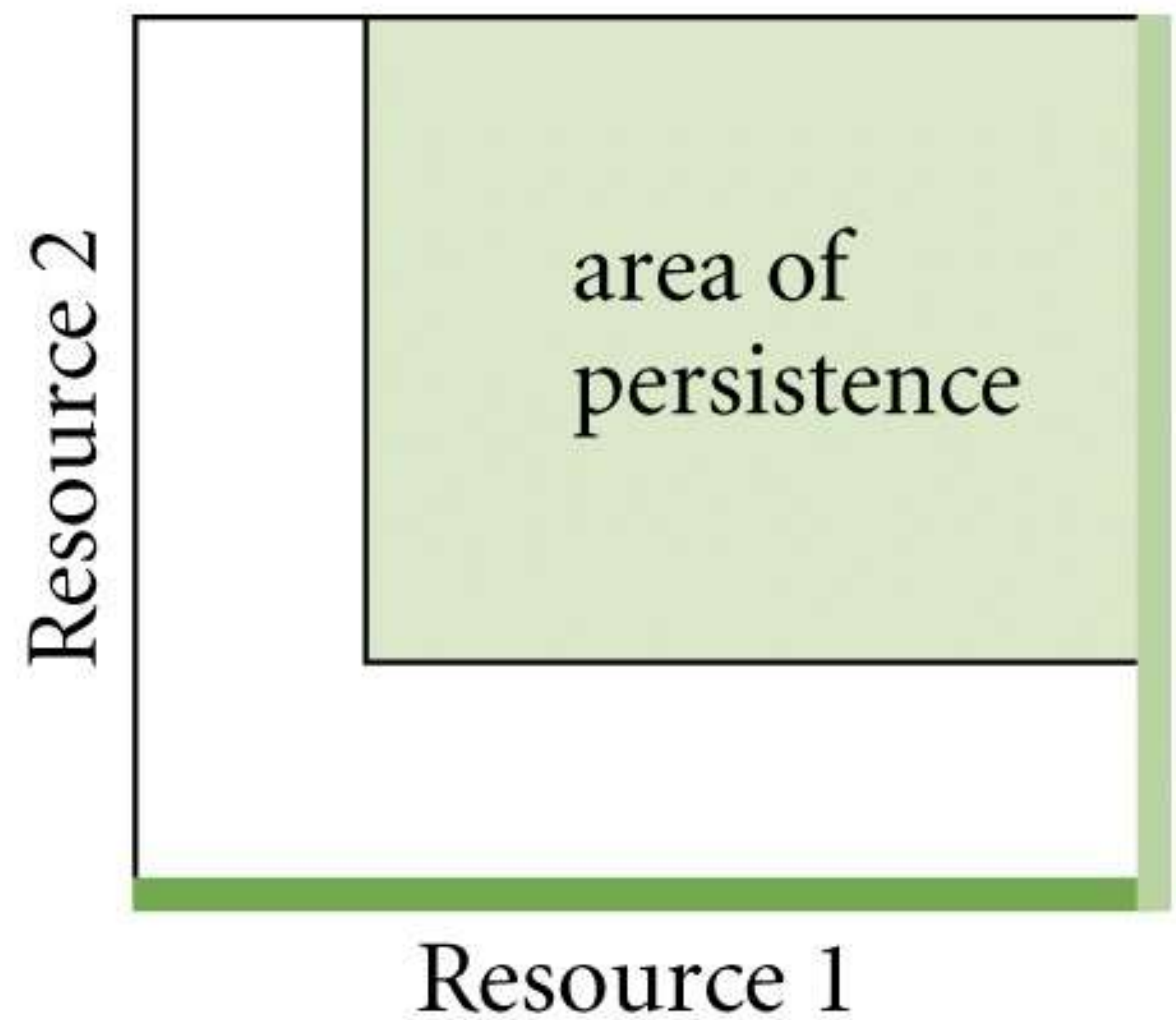
Fig. 29-24 The paradox of enrichment
(a) Sonoran desert of Baja California

Deserts are less productive than marshes, but they are more diverse. In general, habitat structure overrides productivity in determining species diversity.

Fig. 29-24 (b) marsh at Malheur Refuge.

29.8 Environmental and life history variation may affect species diversity.

- Fig. 29-25 The persistence of a species requires minimum critical levels of two resources (shaded area)



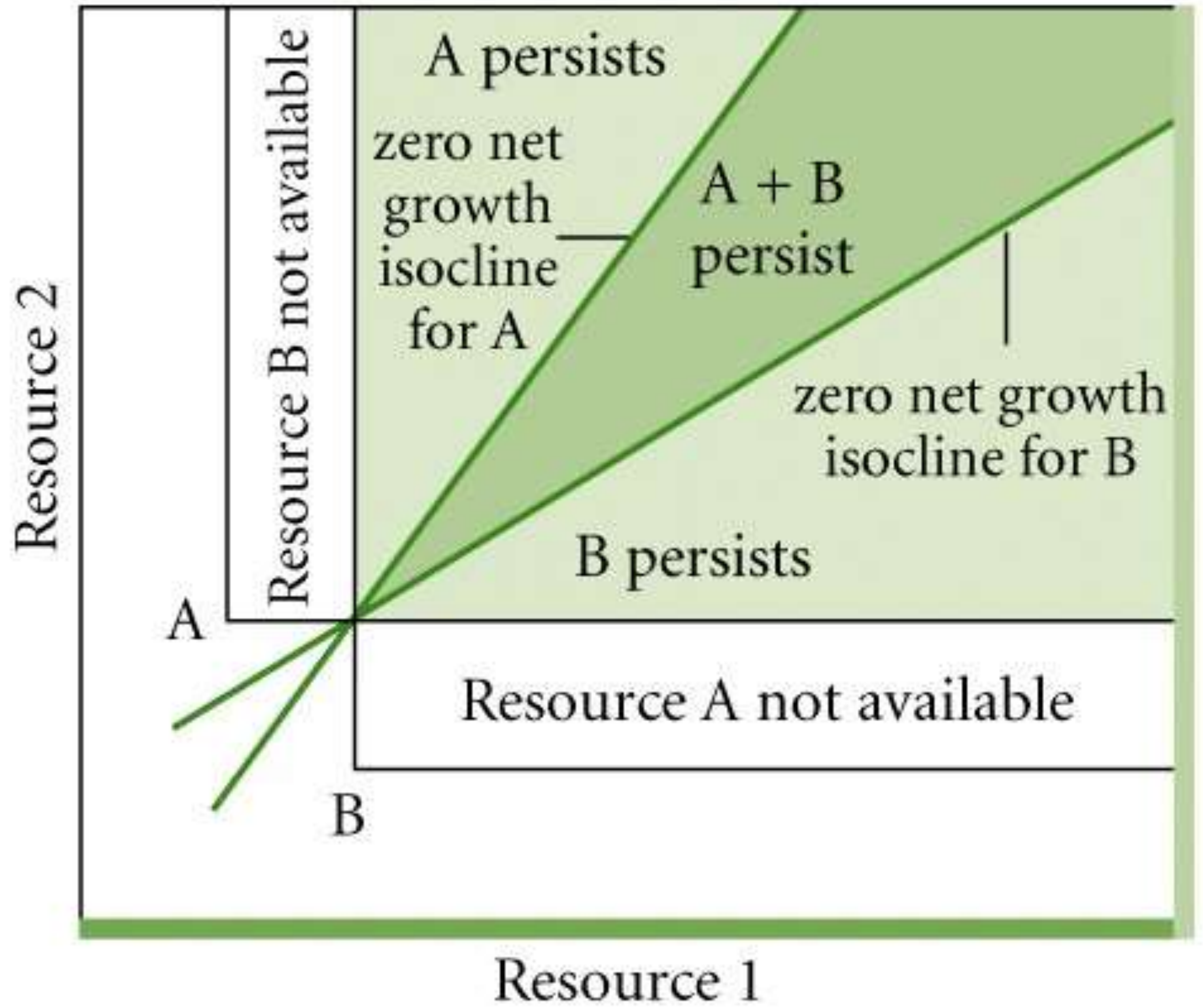


Fig. 29-26 Conditions for the coexistence of two species according to Tilman's resource model.

The shaded areas represent the ranges of resource conditions available in different habitats.

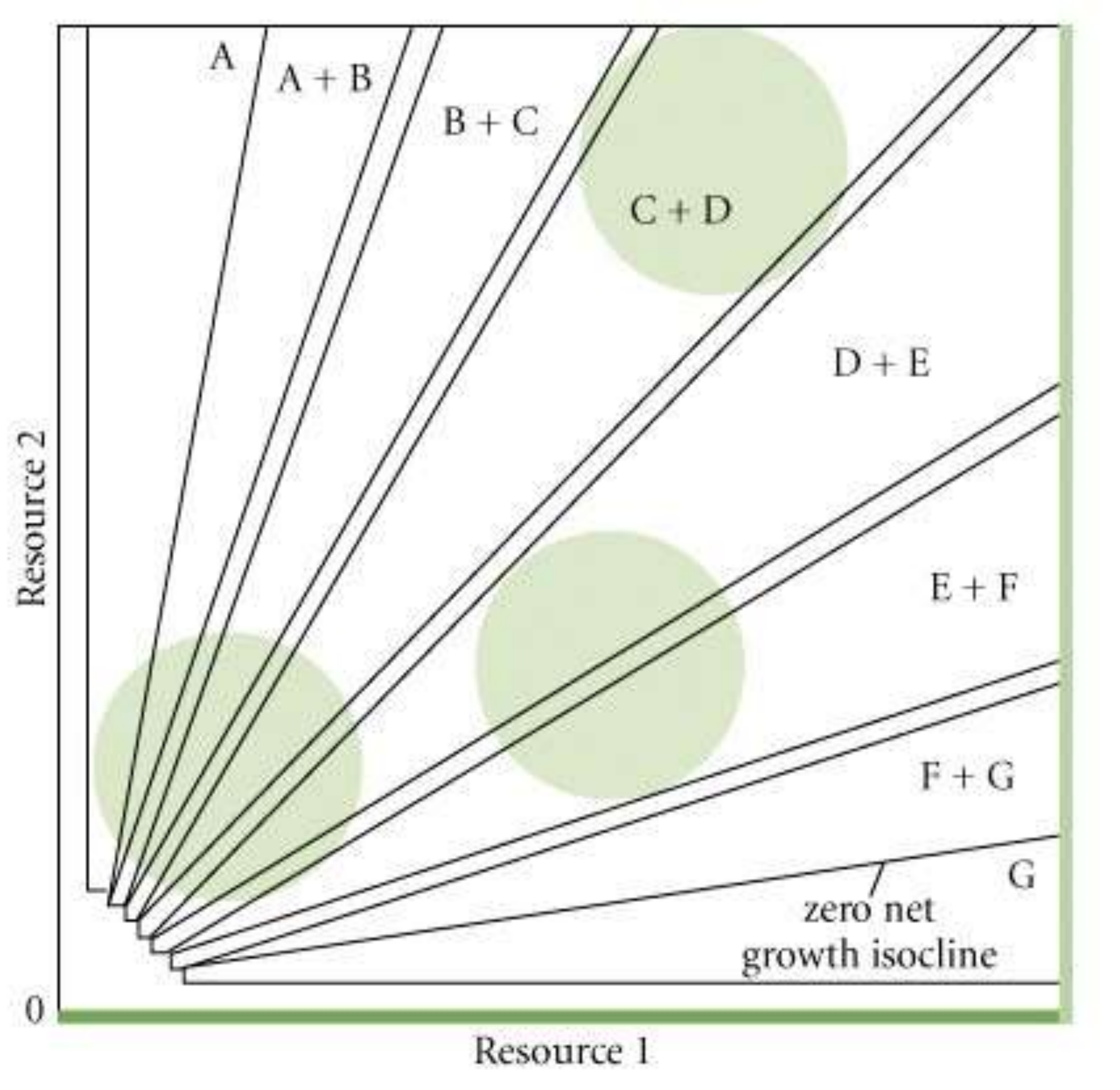


Fig. 29-27 seven-species competition for two essential resources, showing the regions of coexistence.

- Chesson and Warner (1981) have suggested that year-to-year variation in reproductive rates, such that each species is favored in some years, may lead to coexistence.
- Juvenile fish colonize coral heads at random. Individuals of all species have equal opportunity to take the place of adults that die or otherwise leave their territories in the reef.
- This idea is known as the lottery hypothesis.

29.9 The activities of predators and herbivores may affect species diversity.

- When predators reduce populations of prey species below the carrying capacity of their resources, they may reduce competition and promote coexistence.
- Selective predation or herbivory on superior competitors may allow competitively inferior species to persist in a system.

The effects of predation on diversity

- The effects of predation on diversity have been well documented in aquatic systems, in which the introduction of a predatory starfish, salamander, or fish can greatly change the community of primary consumers and producers.

Pest pressure hypothesis

- Herbivores could promote the high diversity of tropical forests.
- Consumers locate abundant species easily, and their own populations grow to high levels.
- This idea became known as the pest pressure hypothesis.

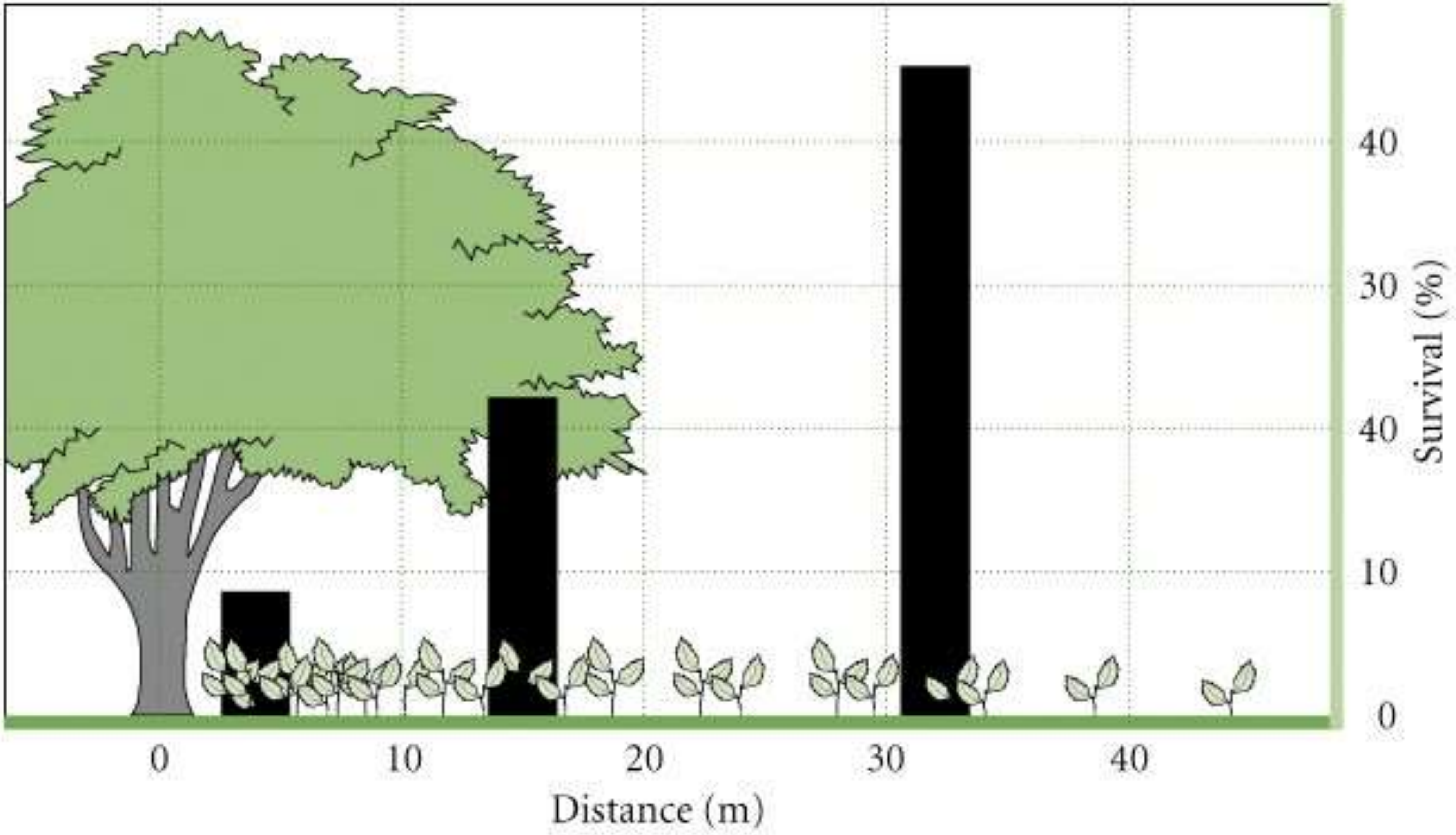
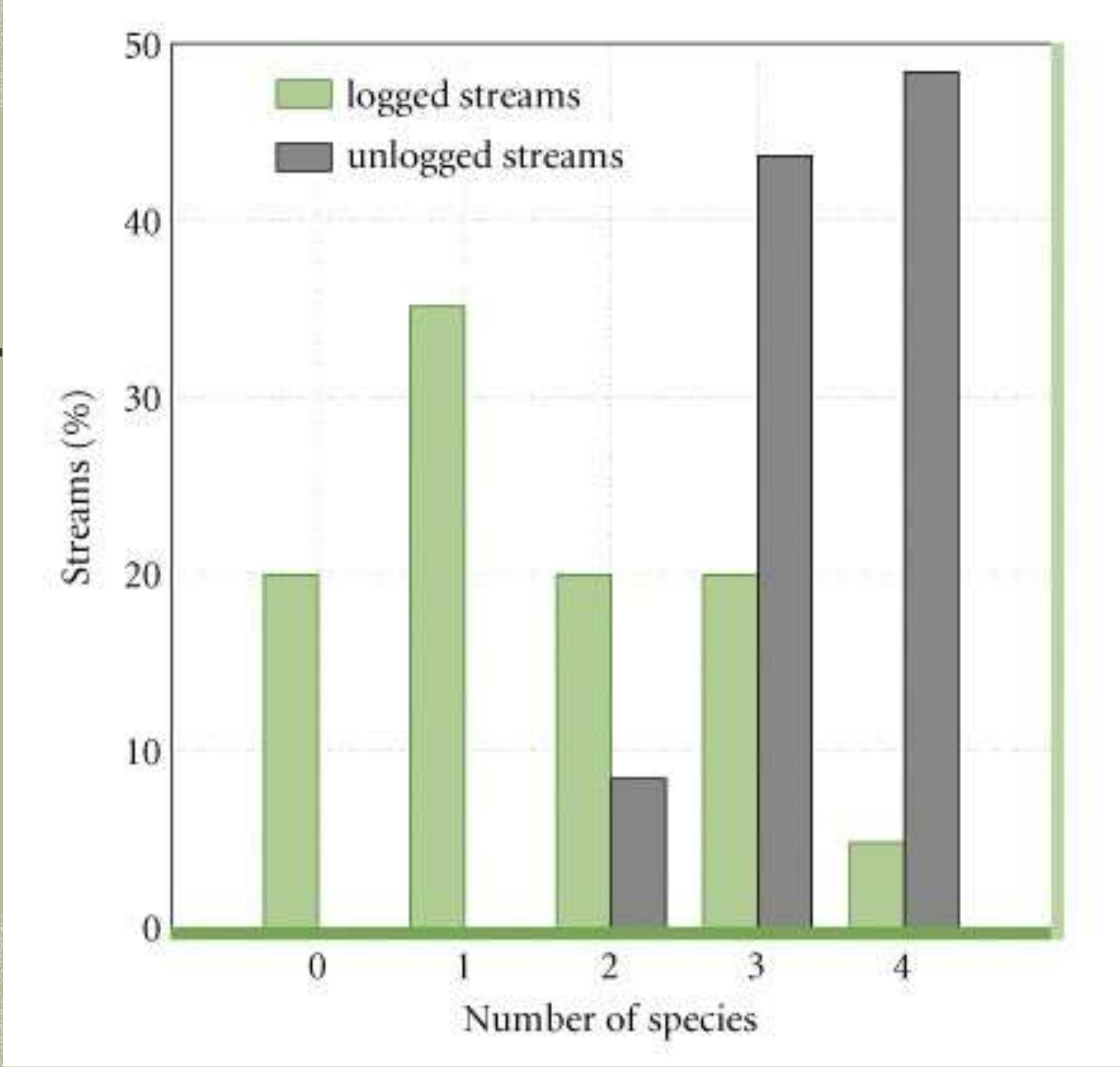


Fig. 29-29 The pest pressure hypothesis. Herbivores will be more common among the dense seedlings near the parent tree.

29.10 Can reduced competition explain high diversity?

- Fig. 29-30 Amphibian species diversity in streams.
- Logging reduces the availability of habitats, leading to a reduction in the number of species.



Intermediate disturbance hypothesis

- Disturbances caused by physical conditions, predators, or other factors open space for colonization and initiate a cycle of succession by species adapted to colonize disturbed sites.
- With a moderate level of disturbance, the community becomes a mosaic of patches of habitat at different stages of regeneration.

Rates of turnover of individual forest trees do not differ systematically between temperate and tropical areas.

TABLE 29-4 Turnover of canopy trees in primary forests in tropical and temperate localities

Locality	Turnover time (years)*	Turnover rate (% per year)
Tropical		
Panama	62–114	0.9–1.6
Costa Rica	80–135	0.7–1.3
Venezuela	104	1.0
Gabon	60	1.7
Malaysia	32–101	1.0–3.1
Temperate		
Great Smoky Mountains	49–211	0.5–2.0
Tionesta, Pennsylvania	107	0.9
Hueston Woods, Ohio	78	1.3

**Turnover time does not include the time required to grow into the canopy, which is estimated to be 54–185 years for various temperate zone species.*
(Data from Runkle 1985, Putz and Milton 1982, Brokaw 1985.)

Disturbance effects

- Ricklefs (1977) proposed a different mechanism by which forest gap formation might generate diversity, based upon the idea that disturbances create a range of conditions for seed germination and seedling establishment within which different species of trees may specialize.

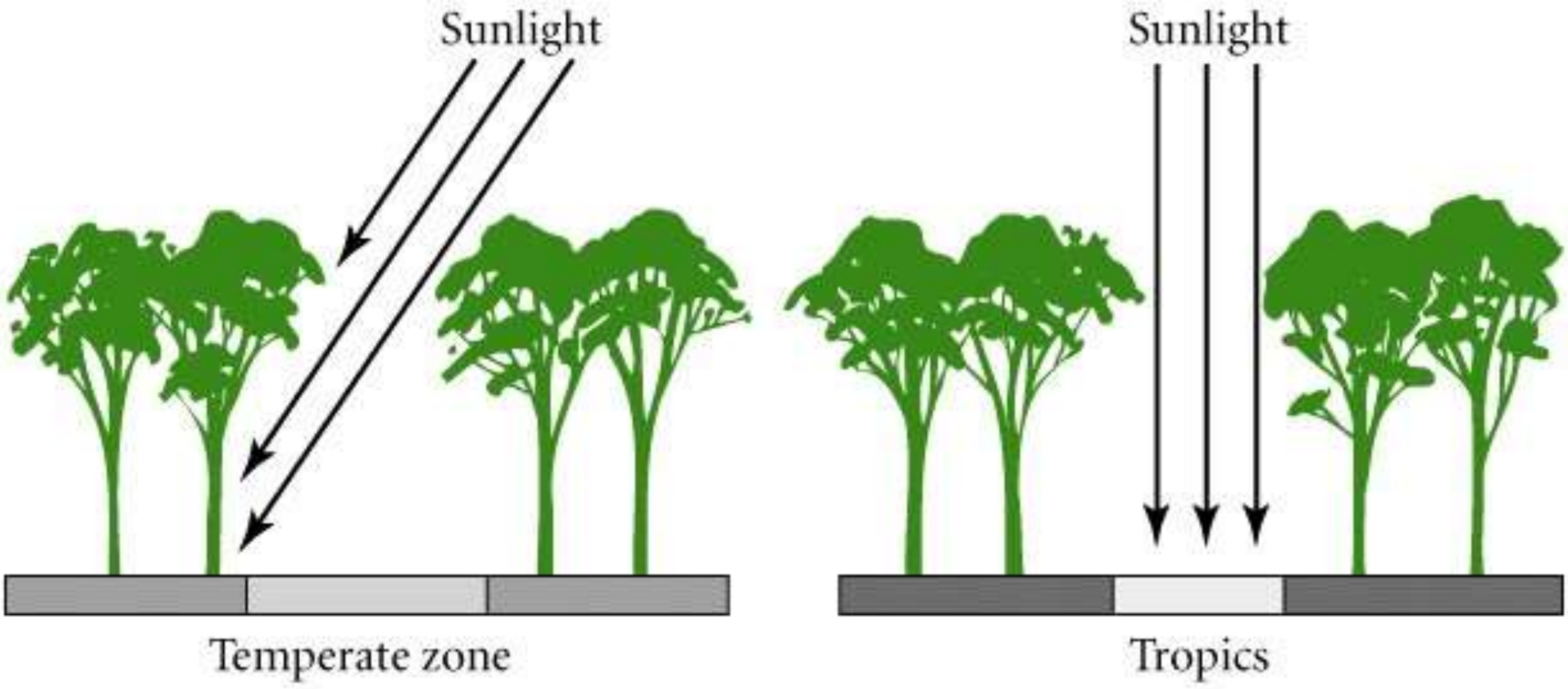
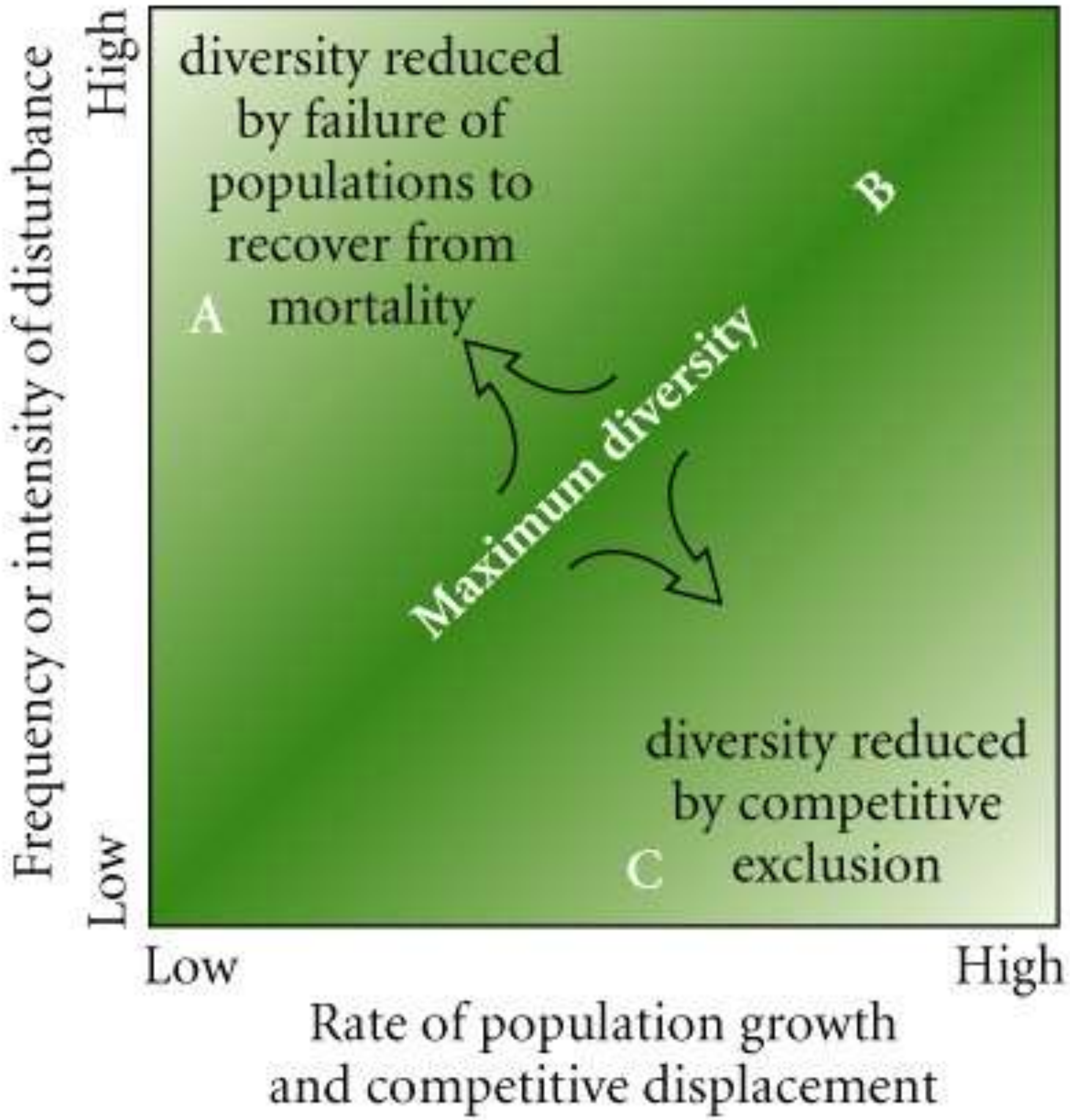


Fig. 29-31 Light admitted to the forest floor through treefall gaps changes the physical conditions for seedling establishment and decomposition on the forest floor. These changes are more intense in the Tropics.



干擾高或低，
都有可能會有
低diversity

Fig. 29-32 Relationship between the effects of disturbance and population growth on local diversity.

29.12 Do communities reveal evidence of competition between species?

- The role of species interactions, particularly competition, in modeling the structure of communities has received considerable attention.
- Randomness of distribution can be tested statistically through the use of null models, which ecologists began to apply in the late 1970s.

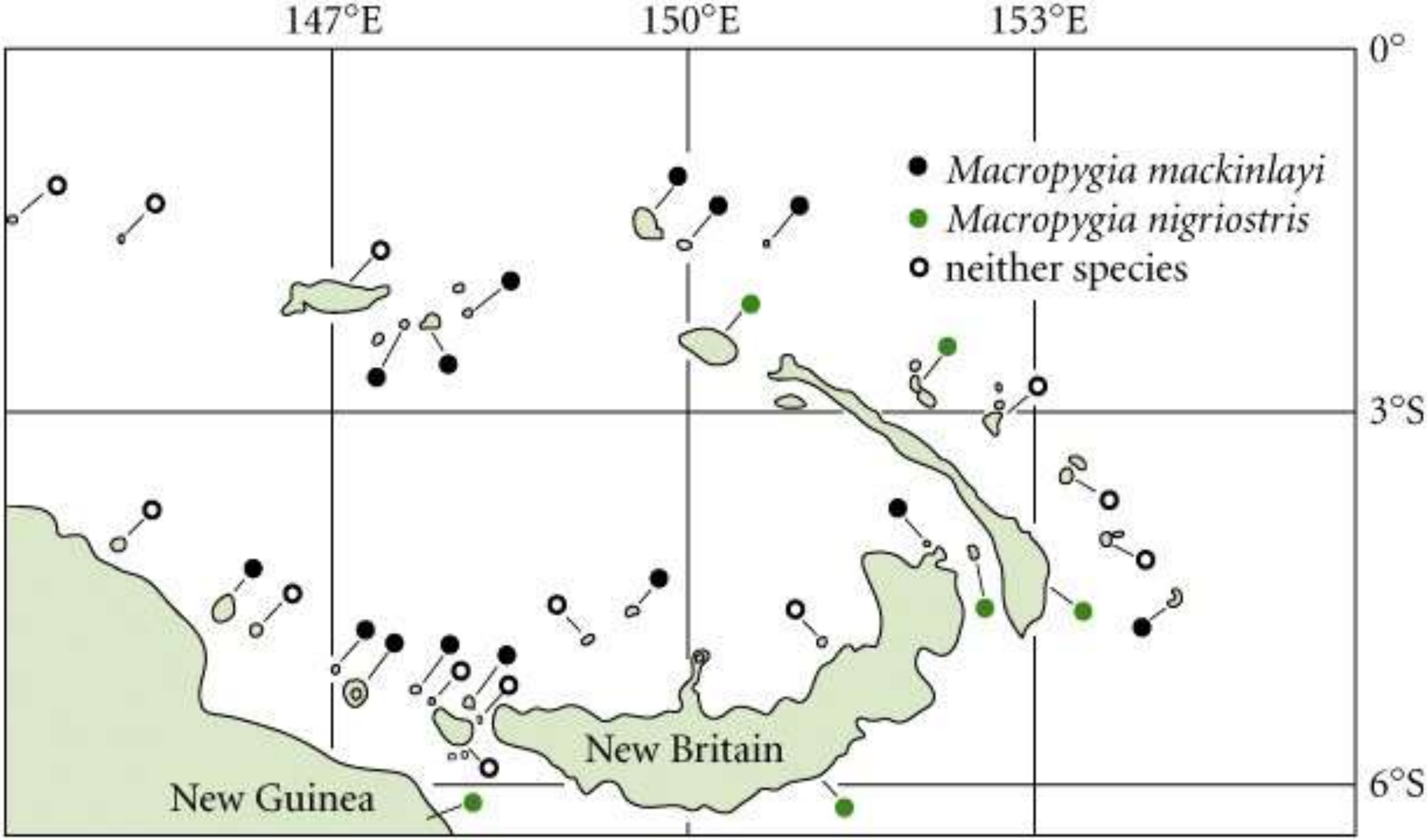


Fig. 29.33 Distribution of cuckoodoves(*Macropygia*) in the Bismarck Archipelago. Most islands have one of the two species, no island has both, and some have neither.

- 統計上，發生如此的機率是1:40(p<0.05)。
- 這會不會是真的是by chance 恰巧發生的？
- To test, they did this for birds in the West Indies.
- They then randomized the distributions of the 211 species in the sample several times and examined the results.
- Of the 22,155 possible pairs of species, an average of 12,448 had exclusive distribution in the randomized set of species.(no co-occurrence on any island)

12,448 vs. 12,757

- The exclusive distributions among pairs of species in the actual avi-fauna of the West Indies number 12,757, so close that one must accept general agreement with the randomly generated pattern.
- Connor and Simberloff concluded that interaction between species was not an important determinant of their geographic distributions.

THANK YOU