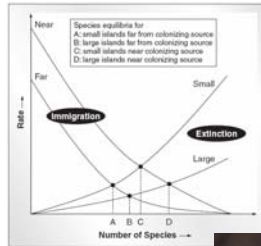
Lecture 16, 11 Oct 2007
Paradigms
Populations

Conservation Biology
ECOL 406R/506R
University of Arizona
Fall 2007

Kevin Bonine
Cathy Hulshof



Upcoming Readings
today: Text Ch. 5, Song of Dodo excerpt
Tues 16 Oct: Text 188-193
Thurs 18 Oct: Ch 7, Ch 8

Thanks to Scott Bonar, Ed Moll, Taylor Edwards
Q4 due 13 November

1

Conservation Biology Lab 406L/506L

Friday 19 Oct 1230 –> 1530
Meet 1230h S or W side BSE (4th and Highland)

Hat, water, sunscreen, close-toed shoes

Readings on Course Website re:
Sewage Treatment Plant, Sweetwater Wetland

2

Debate 23 Oct 2007:
Should the Tumacacori Highlands be Wilderness?

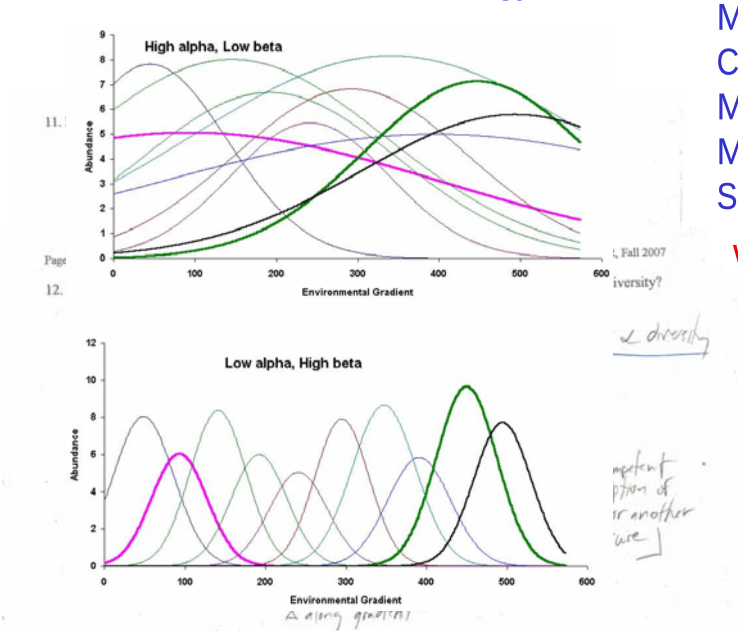
Three groups – one will debate, another will evaluate, third will observe, then we rotate.

406		506
	Debate 1 (20 Sept.)	Debate 1 (20 Sept.)
	Group A debate	506 A assist
	Group B evaluate	506 B assist
	Group C observe	506 C observe
	Debate 2 (23 Oct.)	Debate 2 (23 Oct.)
	Group A observe	506 A observe
	Group B debate	506 B assist
	Group C evaluate	506 C assist
	Debate 3 (15 Nov.)	Debate 3 (15 Nov.)
	Group A evaluate	506 A assist
	Group B observe	506 B observe
	Group C debate	506 C assist

3

Exam 1

Phenology?



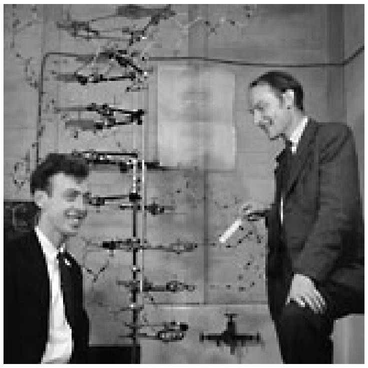
Mean	80.1
Median	83.5
Count	34
Max	95.5
Min	43
SD	11.9

w/o bonus

4

Paradigms In Conservation

(Chapter 5)



1- Genetic Diversity (MVP, PVA)

2- Island Biogeography

3- Metapopulations

4- Habitat Heterogeneity

5- Disturbance

Genetics in Detail (Chap 6)
Populations in Detail (Chap 7)

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1-Genetic Diversity

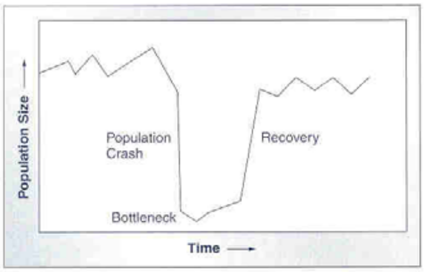


Figure 5.2
A graphical representation of population size before, during, and after a population bottleneck.

Small Populations
- -reduced gene flow
- -inbreeding depression
- -drift
- -stochasticity
- -effective population size (N_e)

Vs.
Declining Populations

6

Effective Population Size

- $N_e = 4N_mN_f / (N_m+N_f)$
- Eg: a population of seals with 6 males and 150 females? (Number or Breeders)
- $N_e = (4*6*150)/(6+150) = \sim 23$

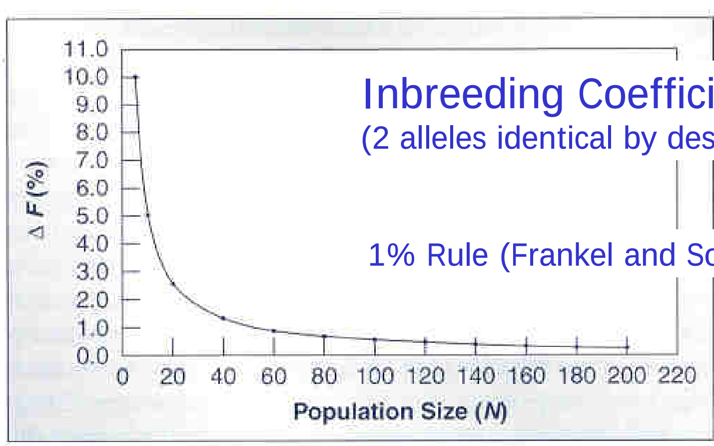


Figure 5.3
Percent change in the inbreeding coefficient (Δ*F*) at different population sizes. Note that the value of the inbreeding coefficient increases as population size declines.

After Frankel and Soulé (1981). Van Dyke 2003

Quickly lose rare alleles in bottlenecks

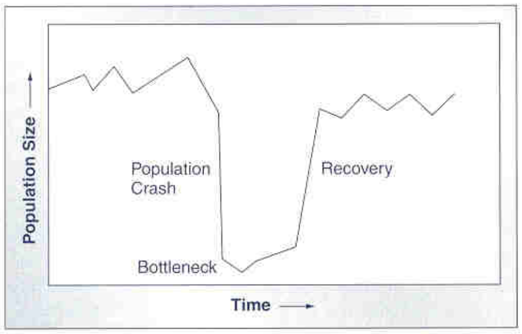
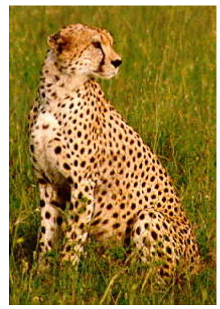


Figure 5.2
A graphical representation of population size before, during, and after a population bottleneck.



Cheetah
Major Histocompatibility Complex

9

Genetic Drift

When populations number less than a few hundred individuals random events become more important to genetic structure of population than natural selection

> 3,000-10,000 breeding adults

10

Cyprinodon macularius

Desert Pupfish

Photograph Courtesy of John Rinne

Desert pupfish declined due to the introduction and spread of exotic predatory and competitive fishes, water impoundment and diversion, water pollution, groundwater pumping, stream channelization, and habitat modification.

Healthy population of almost 10,000 fish inhabits this oasis. This last refuge of a unique fish is being actively managed.

Population Extinction Vortex

(problems with small populations)

F Vortex: inbreeding depression, lethal equivalents (homozygous recessives)

A Vortex: genetic drift and loss of variation (can't adapt)

R Vortex: r = spontaneous rate of increase (coupled with environmental stochasticity)

D Vortex: discontinuity (isolation)

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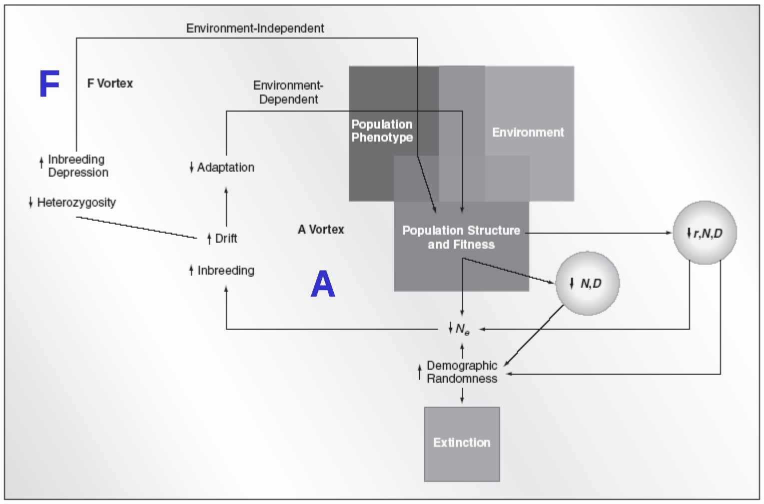

Figure 5.5
The F vortex and A vortex, two accelerating and degenerative cycles of population decline driven by an increasing level of inbreeding depression (F vortex) or a decreasing ability of the population to adapt to a changing environment (A vortex). Both are exacerbated in small populations. *N* is the population size, *D* is the population distribution, *r* is the population's instantaneous rate of increase, and N_e is the effective population size.
After Gilpin and Soulé (1986).

VanDyke 2003

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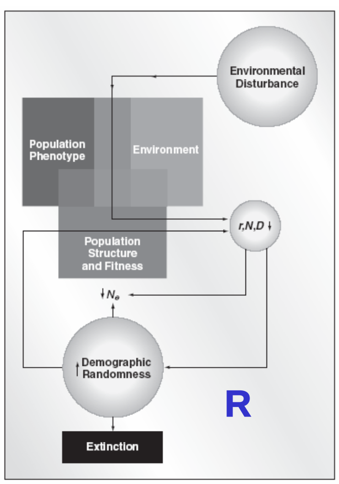

Figure 5.6
The R Vortex, an accelerating and degenerative cycle of population decline driven by increasing vulnerability to environmental disturbance at low population sizes. *N* is population size, *D* is population distribution, *r* is the population's instantaneous rate of increase, and N_e is the effective population size.
After Gilpin and Soulé (1986)

VanDyke 2003

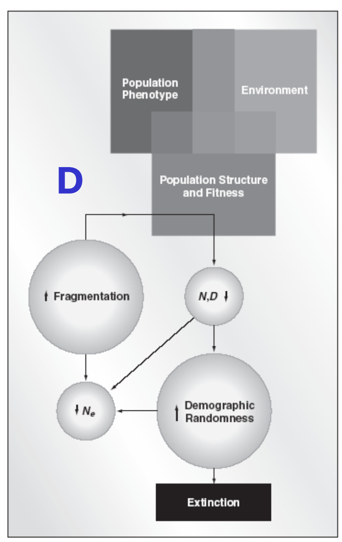

Figure 5.7
The D or discontinuity vortex, an accelerating and degenerative cycle of population decline driven by the fragmentation of the population into smaller and smaller subunits. *N* is population size, *D* is population distribution, and N_e is the effective population size. A lowering of *N* and an increase in demographic randomness can alter the spatial distribution of a population, introducing or increasing fragmentation. More fragmented distributions increase the likelihood of local extinctions.
After Gilpin and Soulé (1986).

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Hardy Weinberg and Heterozygosity

two alleles: p, q

$$(p + q)^2 = p^2 + 2pq + q^2$$

Under Hardy Weinberg Equilibrium
$H_e = 2pq$
H_o can be calculated

If p=0.6, q=0.4,
then $2pq = 0.48 = H_e$

Inbreeding, if $H_o < H_e$

Outbreeding, if $H_o > H_e$

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Wright's Fixation Index

Fst = 0, or <0.01 indicate little divergence among pops.

Fst > 0.1 indicate much divergence among pops.

Hardy Weinberg Equilibrium, two alleles: p, q
Expected heterozygosity = 2pq

Fst = (Ht-Hs)/Ht (H= heterozygosity)

Ht → Total Pool

Hs → Separate populations

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Equilibrium Heterozygosity ($\Delta H = 0$)

$$H^* = 2Nm$$

H = heterozygosity
N = population size
m = mutation rate

Therefore, smaller populations have lower equilibrium heterozygosity

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Assumption: reduced genetic variation in a population correlated with reduced ability to adapt to changing environmental conditions.

Minimum Viable Population (MVP)
(Frankel, Soule, Franklin, Shaffer)

50/500/+ Rule

Short term

Mid term

Long Term

PVA...

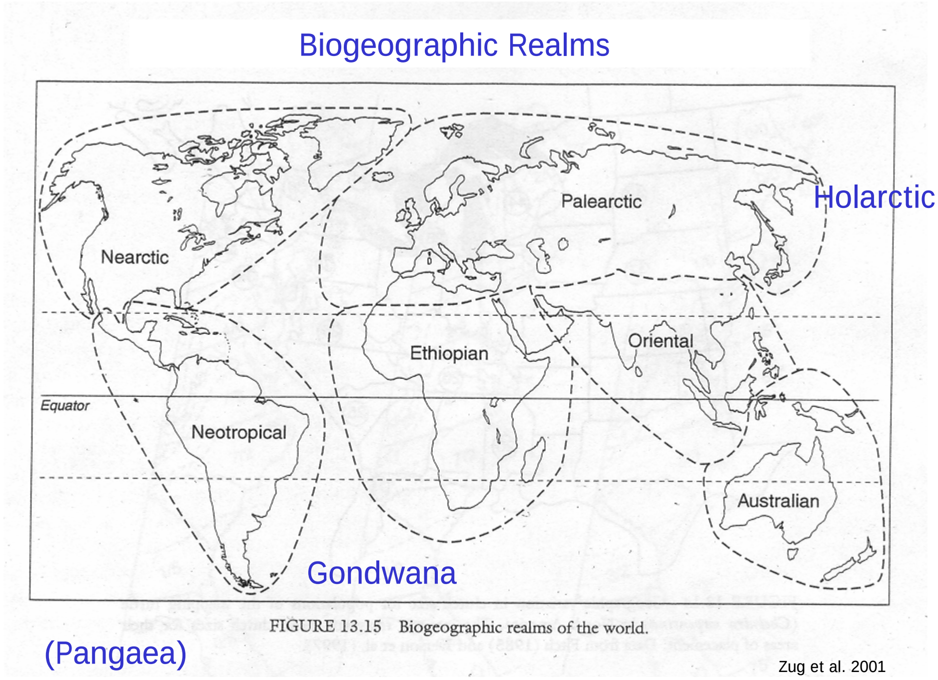

FIGURE 13.15 Biogeographic realms of the world.

2. Island Biogeography

Quammen Excerpt from *Song of the Dodo* (p.52-55)

Lyell
Wallace
Darwin

MacArthur
Wilson

Frogs vs. Birds
dispersal

Oceanic vs. Continental
succession

Size, Age, Distance
~equilibrium

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Dispersal

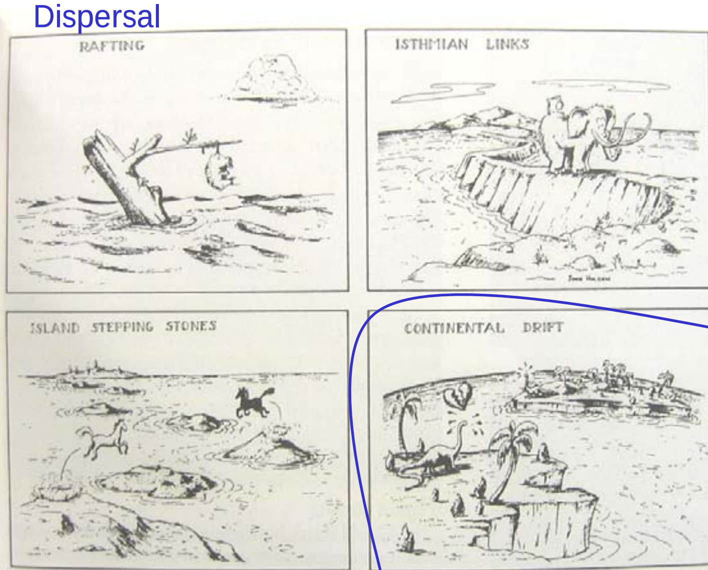

Figure 19.5 These sketches by John Holden illustrate various explanations for the occurrence of similar species on landmasses that are presently separated by vast oceans. (Reprinted with permission of John Holden)

Tarbuck and Lutgens 1999

Vicariance

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Islands, especially Continental, affected by:

- Plate tectonics
- Climate (glaciation, drought)
- Sea level

Table 5–5 **The amount of time during two Pleistocene intervals that sea levels in southeast Asia were at or below present levels (BPL; given in meters). The approximate number of years in each time period, the approximate percentage of years in each time period, and the estimated number of times within each period that sea level fell below the level shown in column 1 are given.**

Connectivity

	Past 150,000 years			Past 250,000 years		
Sea Level BPL (m)	Years	% of time	Events	Years	% of time	Events
120	3,000	2	1	15,000	6	2
100	7,000	5	1	29,000	12	2
75	14,000	9	1	42,000	17	2
50	40,000	27	5	99,000	40	5
40	65,000	43	7	136,000	54	6
30	93,000	62	5	167,000	67	6
20	107,000	71	4	201,000	80	6
10	134,000	89	3	227,000	91	3

Source: after Voris 2000, Table 1.

Pough et al. 2004

Equilibrium Theory of Island Biogeography

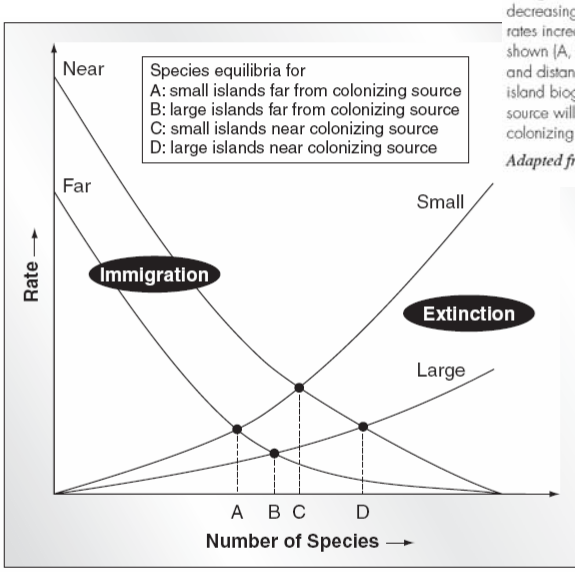

Figure 5.9
The equilibrium model of island biogeography predicts that numbers of species on an island represent an equilibrium between rates of immigration and extinction. Immigration rates increase with decreasing distance from an island's colonizing source. Extinction rates increase with decreasing area of the island. The four equilibria shown (A, B, C and D) depict different combinations of island size and distance from its colonizing source. The equilibrium theory of island biogeography predicts that large islands near a colonizing source will have more species than small islands far from a colonizing source.

Adapted from MacArthur and Wilson (1967).

VanDyke 2003

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Equilibrium Theory of Island Biogeography

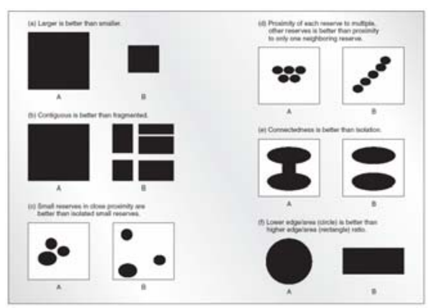

Figure 5.10
A graphical representation of the "rules" of island biogeography applied to nature reserves. In each case, design A is considered superior to design B.

- Habitat Fragmentation
- Reserve Design
- Predictions vs. Observations
- Missing Factors
  - -Rescue Effect
  - -Habitat Suitability
  - -Sink vs. Source
  - -Habitat Heterogeneity
  - -Species Interactions

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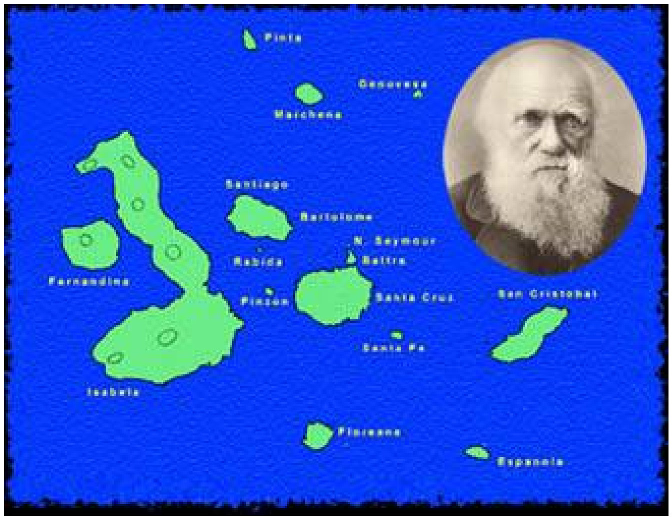

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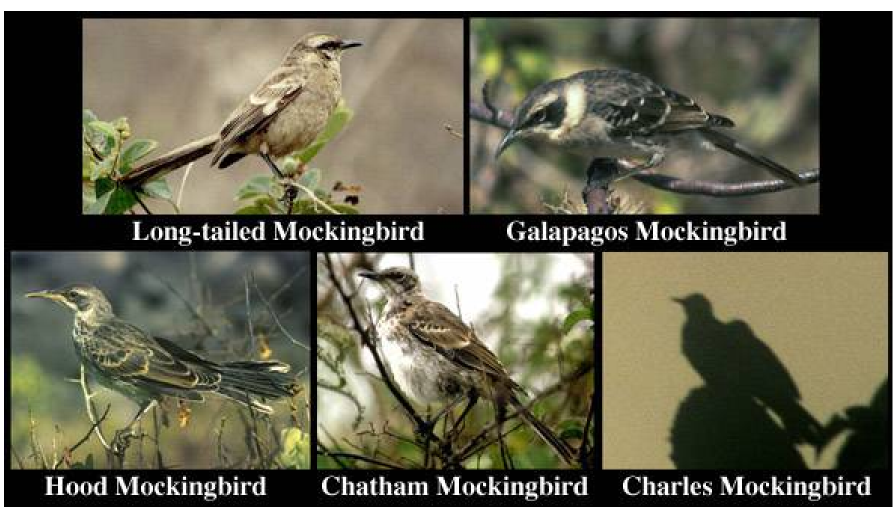
Adaptive Radiation



http://www.rit.edu/~rhrsbi/GalapagosPages/mockingbird.html

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Galapagos

Humboldt Current

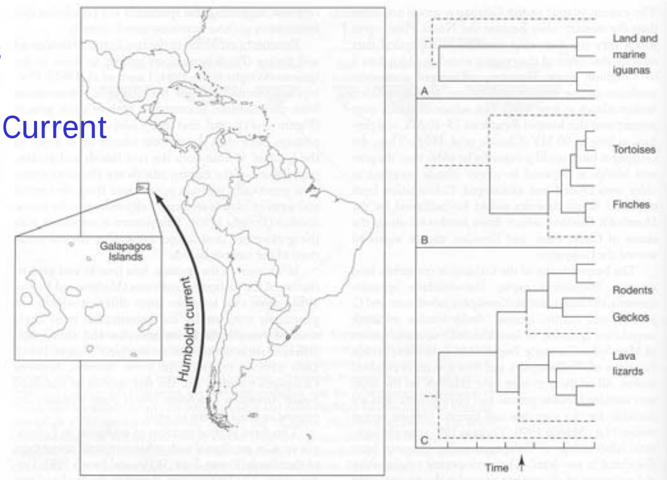

Figure 5–11 **Phylogenetic relationships and patterns of colonization of vertebrates in the Galapagos Islands.** *Left*, The location of the Galapagos Islands and the direction of the Humboldt Current, which presumably helped transport colonizers to the islands. *Right*, Three major patterns of relationships of Galapagos vertebrates. The time scale is arbitrary. The arrow on the horizontal axis indicates the time of origin of the present archipelago and/or the initial introduction of each group. Solid lines indicate the radiation of the endemic Galapagos taxa; dashed lines indicate the relationship of these taxa to their closest living mainland sister group. (A) Pattern of relationships for the land and marine iguanas (*Conolophus* and *Amblyrhynchus*), which show minimal differentiation within species, but share a remote common ancestor considerably earlier than the origin of the islands. (B) The giant tortoises (*Geochelone*) (and Darwin's finches) are endemic radiations within the archipelago stemming from a single colonization event. In the case of the tortoises, the mainland ancestral group appears to be extinct. (C) The gecko (*Phyllodactylus*), lava lizard (*Microlophus*), and rodent radiations appear to have resulted from multiple introductions from separate mainland stocks already differentiated to some degree. *(Source: Patton 1984.)*

Pough et al. 2004

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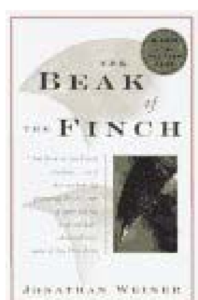
Daphne Major



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http://www.rit.edu/~rhrsbi/GalapagosPages/DarwinFinch.html

29

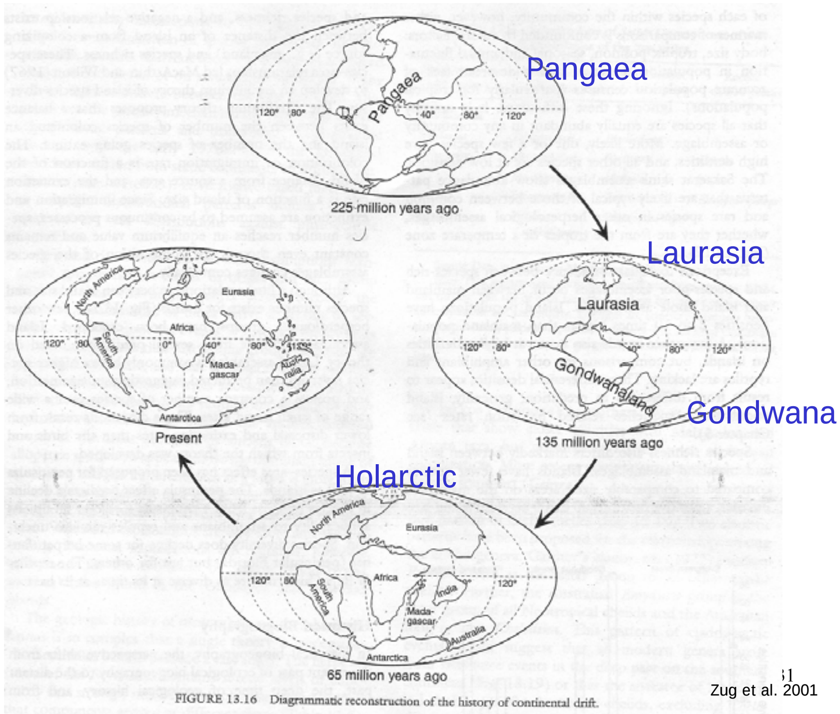

FIGURE 13.16 Diagrammatic reconstruction of the history of continental drift.


Alfred Wegener, winter 1912-1913

Crustal Plates moving 1-12 cm / year

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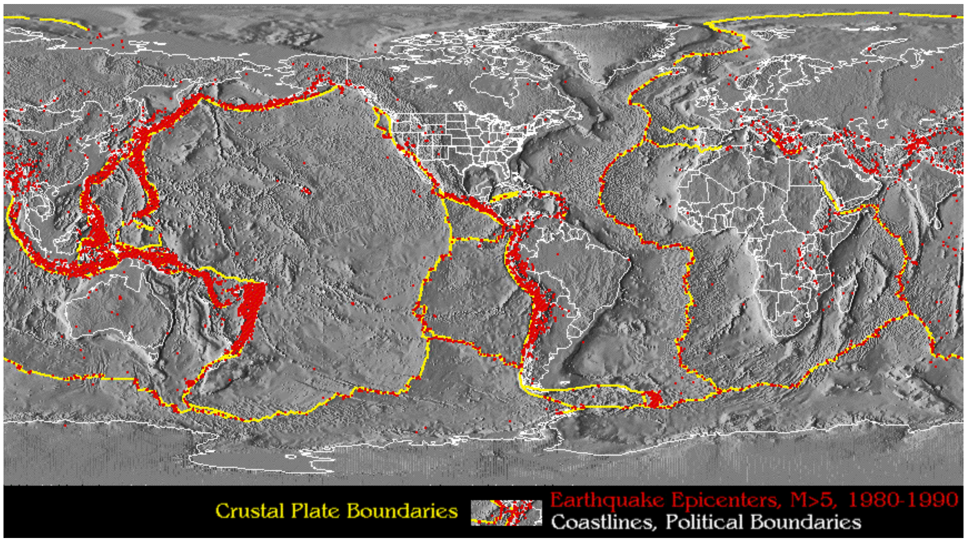
Plate Tectonics – not fully accepted until 1960s



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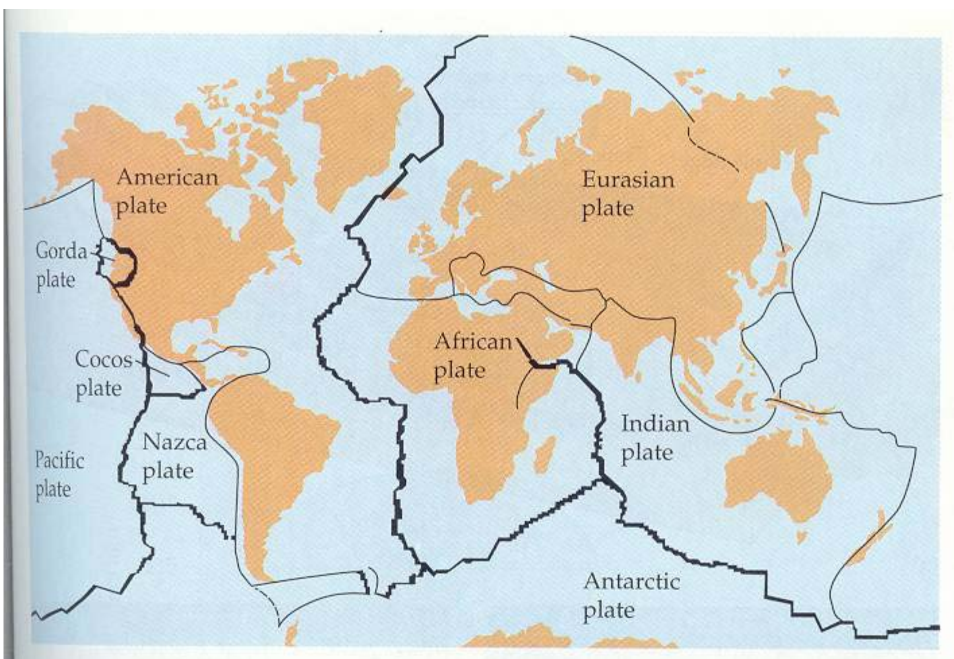
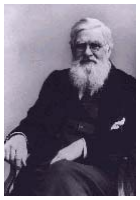
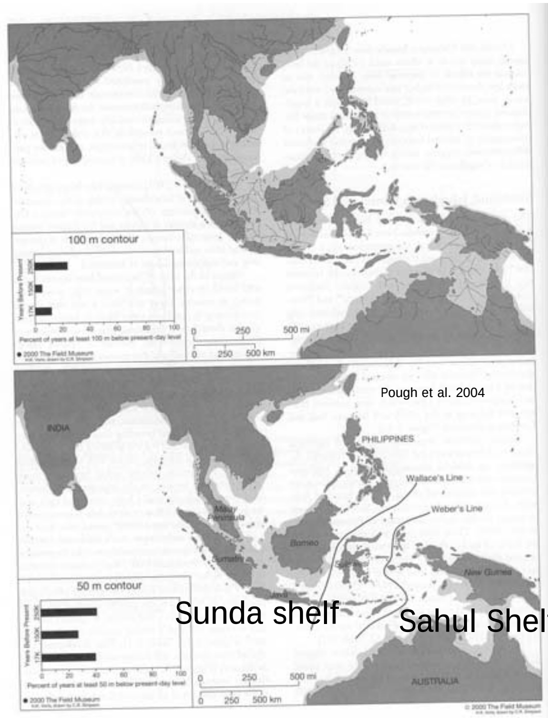


Campbell 1993



Alfred Russel Wallace
(1823 - 1913)



Wallace's Line
→
Weber's Line

Sulawesi

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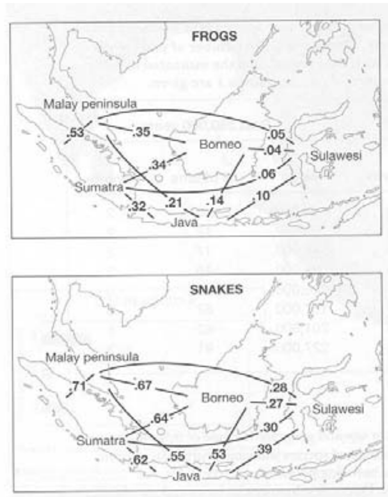
Dispersal Ability



Pough et al. 2004

Figure 5–13 **Patterns of faunal resemblance among areas of the Sunda Shelf in their frog (top) and snake faunas (bottom).** The numbers reflect the number of shared species between areas, calculated as indexes of faunal similarity, where Similarity = (2 × number of species in common)/[(number of species in area A) + (number in area B)]. Note that snakes share a much greater proportion of species among these areas than do frogs. This very likely results from differing dispersal capabilities as well as differences in the potential for population isolation and speciation. *(Source: Inger and Voris 2001.)*

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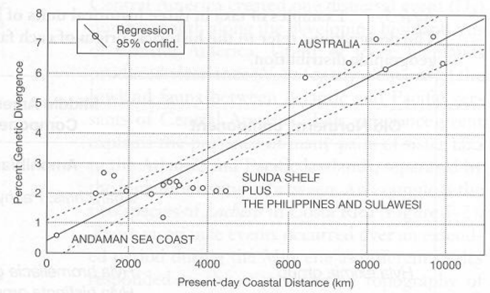
Dispersal Ability (Isolation by Distance)

Figure 5–15 **Correlation between genetic divergence and geographic coastline distance separating populations of *Cerberus rynchops* (linear regression with 95 percent confidence limits).** *(Source: Karns et al. 2000.)*



Pough et al. 2004

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3. Metapopulation:

"Spatially disjunct groups of individuals with some demographic or genetic connection"

"largely independent yet interconnected by migration"

1. All local populations must be prone to extinction
2. Persistence of entire population requires <u>recolonization</u> of individual sites.

See p.193 in VanDyke text

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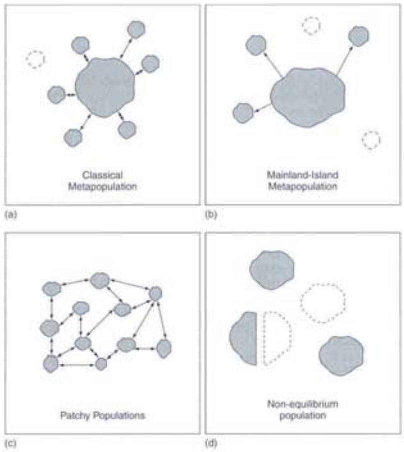

Figure 5.16
Types of metapopulation models. In a *classical metapopulation*, (a) some colonies may not exhibit high rates of movement for long periods of time. Also, colonization may unite several patches within a larger patch as a single entity that contributes to other sinks. Colonies farthest from the source are most prone to extinction. The *mainland-island metapopulation* (b) depicts local extinctions occurring mainly among a subset of populations. The mainland/source, resistant to extinction, functions as the major provider of colonists. The island and sink metapopulations have little effect upon regional persistence. In *patchy populations* (c), because of the high levels of emigration and immigration, the patches function as a single unit. It is rare that discrete local populations become extinct. The absence or insufficiency of recolonization to balance extinction distinguishes nonequilibrium populations (d). Extinction of metapopulations occurs as part of an overall regional decline (i.e., a product of the reduction, fragmentation, or deterioration of a habitat).

After Harrison (1991).

b vs. d

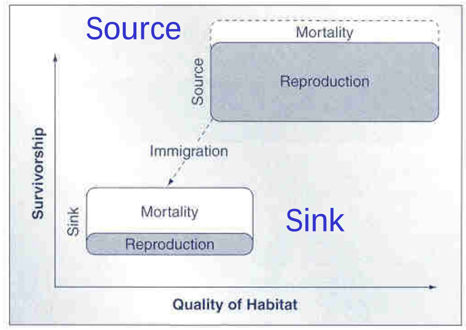

Figure 5.17
A visual representation of the source-sink model of habitat distribution. In source habitats, reproduction produces a population surplus (i.e., mortality does not decrease the number of individuals because of overcompensation through reproduction). Surplus individuals move to sink habitats where mortality exceeds survivorship. Sink habitats cannot be maintained by reproduction, but depend on immigration to maintain a population.

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Juggling Balls, Oranges, and Mites:

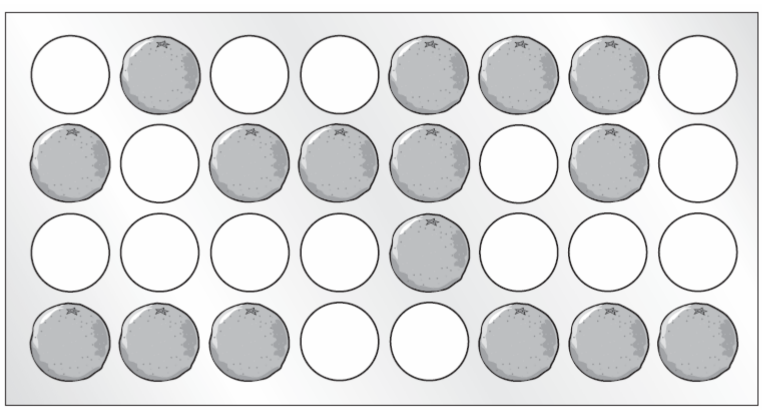

Figure 5.11
A diagrammatic representation of Huffaker's experiment on the persistence of a predator-prey system of two species of mite. Dark circles represent oranges that mites could colonize and white circles represent rubber balls of "nonhabitat" that they could not colonize.

After Huffaker (1958) and Huffaker, Shea, and Herman (1963).

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Metapopulation:

Hydrothermal Vents

Lowland Leopard Frogs
(thanks to Don Swann)

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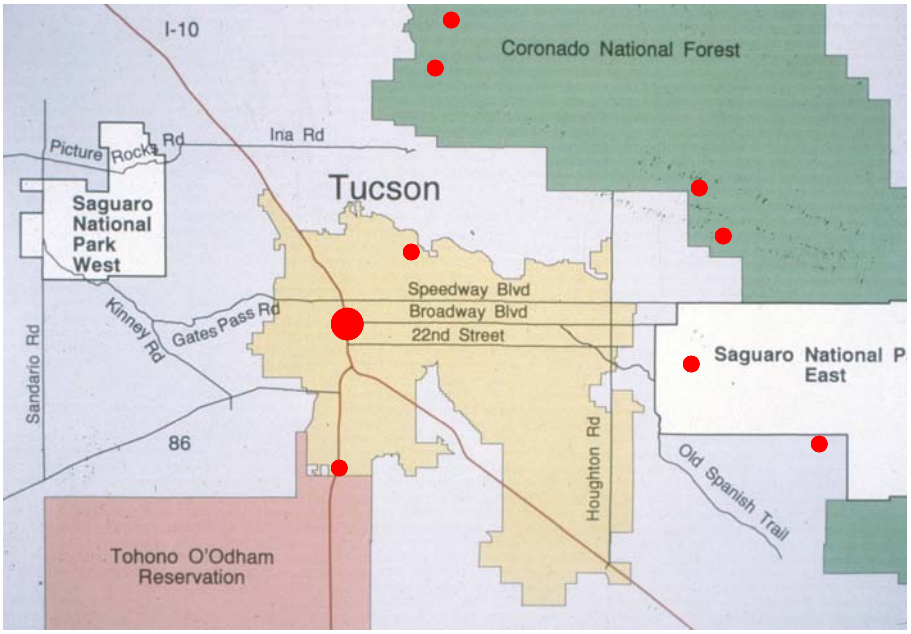
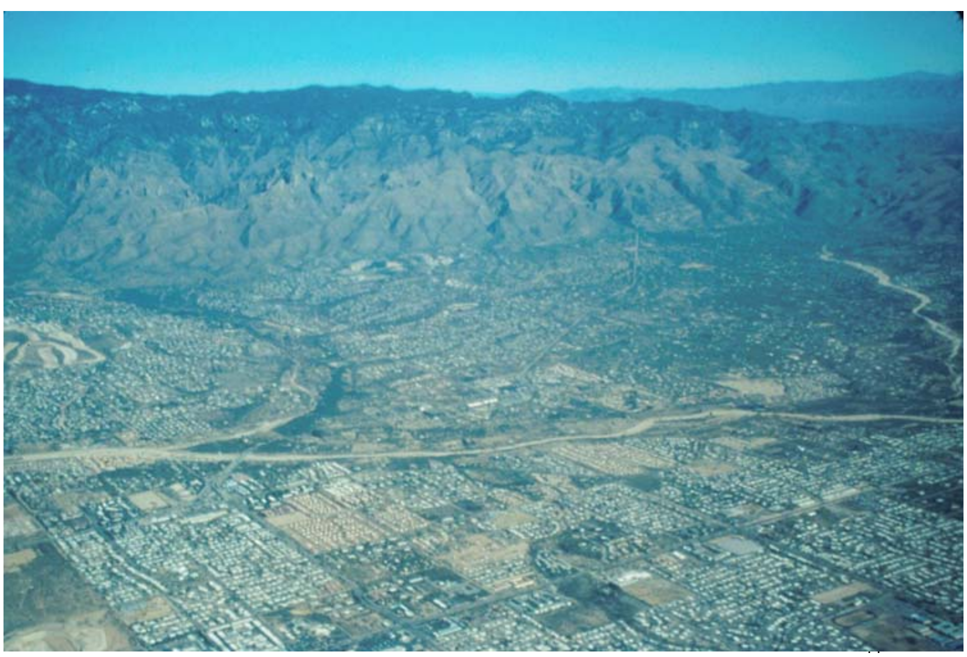
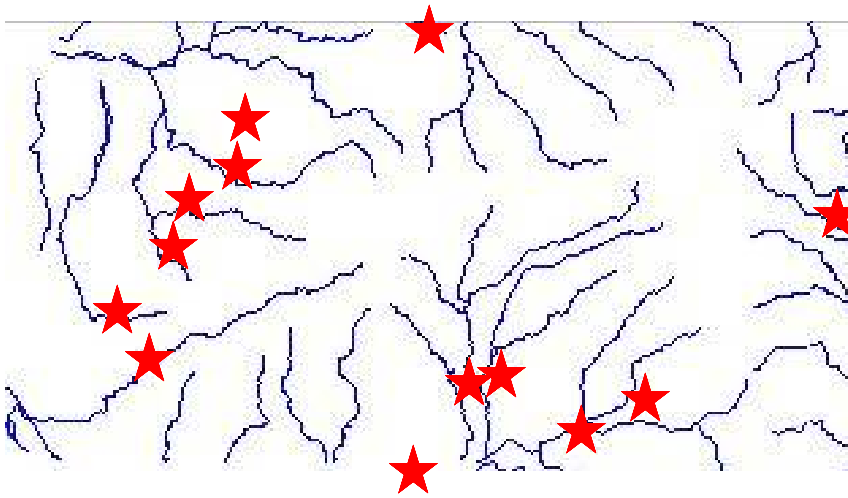

I-10
Coronado National Forest
Picture Rocks Rd
Ina Rd
Tucson
Saguaro
National
Park
West
Speedway Blvd
Broadway Blvd
22nd Street
Kinney Rd
Gates Pass Rd
Sandario Rd
86
Saguaro National P
East
Houghton Rd
Old Spanish Trail
Tohono O'Odham
Reservation

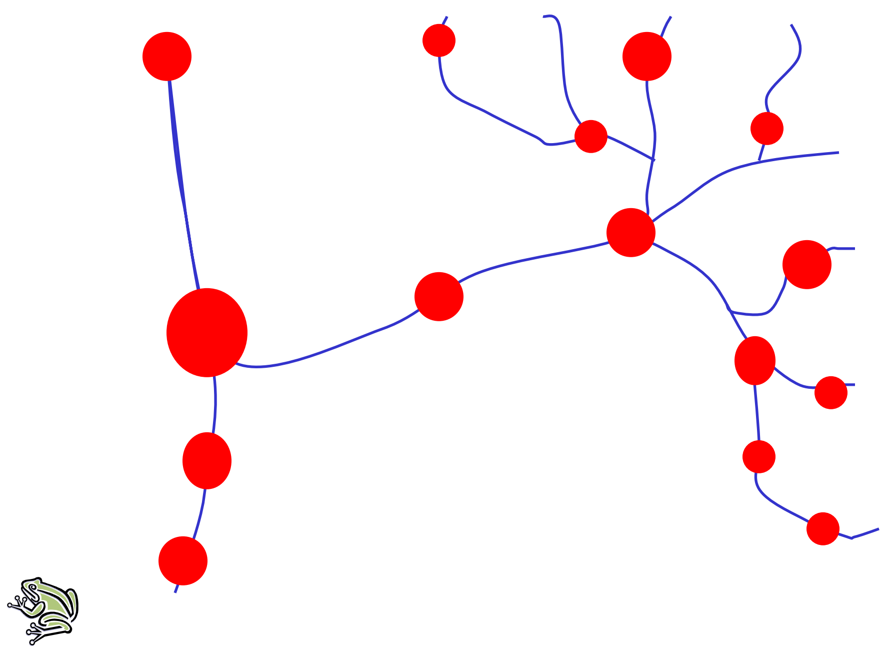




4 km

Distribution of Lowland Leopard Frogs
in Rincon Mountains, 1996-2001

45



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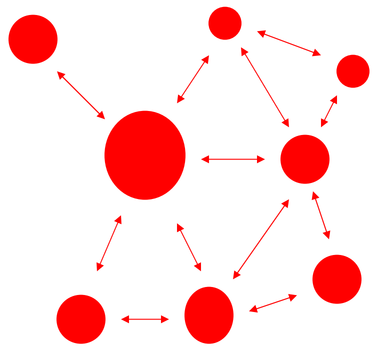

Metapopulation Dynamics

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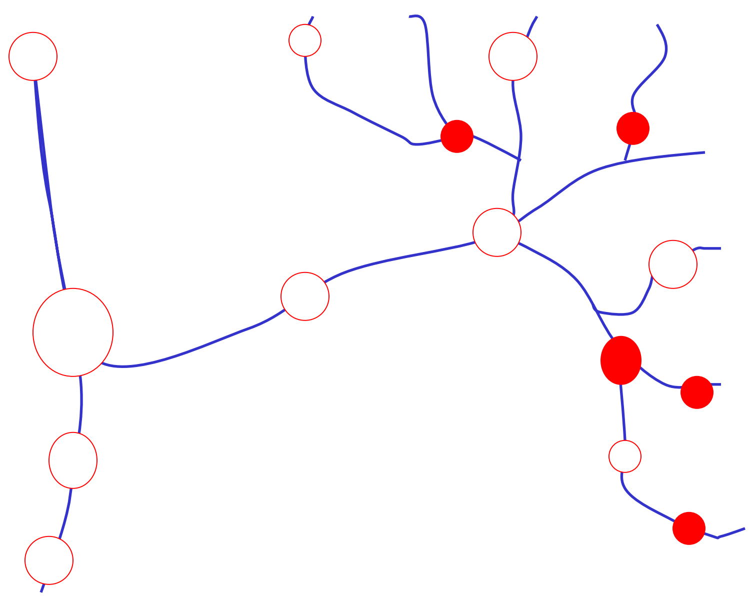

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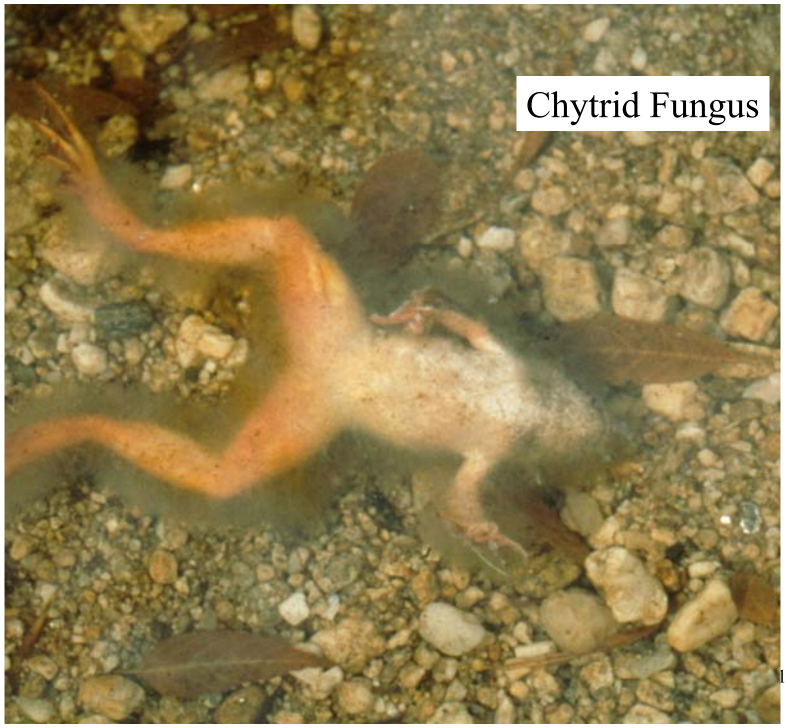

4. Habitat Heterogeneity

Conserve Bigger Area?

Conserve More Diverse Habitats?

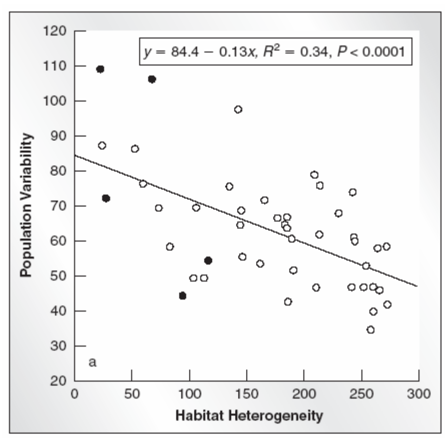

Figure 5.23
Populations of bush cricket (*Metrioptera bicolor*) subunits exemplify that population size is less variable as heterogeneity increases. Dark circles indicate patches where local extinctions occurred. White circles indicate patches with extant populations. Population variability was measured by the coefficient of variance (cv) of local population size, and habitat heterogeneity was measured using digitized infrared aerial photographs. Each patch was assigned values according to how much the patch deviated from the standard level of gray in the photographs (SD-hue).
After Kindvall (1996).

5. Disturbances

-Endogenous
-Exogenous

An SUV is seen covered by sand as residents walk to their homes to inspect the damage by hurricane Ivan Wednesday, Sept. 22, 2004 in Pensacola Beach, Fla. Beach residents were allowed to see their homes for the first time since the hurricane. (AP Photo/Alan Diaz)

Habitat Heterogeneity and Disturbance

Climax Community
vs. Shifting Mosaic

- Tree Fall in Forest
- Fire
- Beaver Dam on Stream

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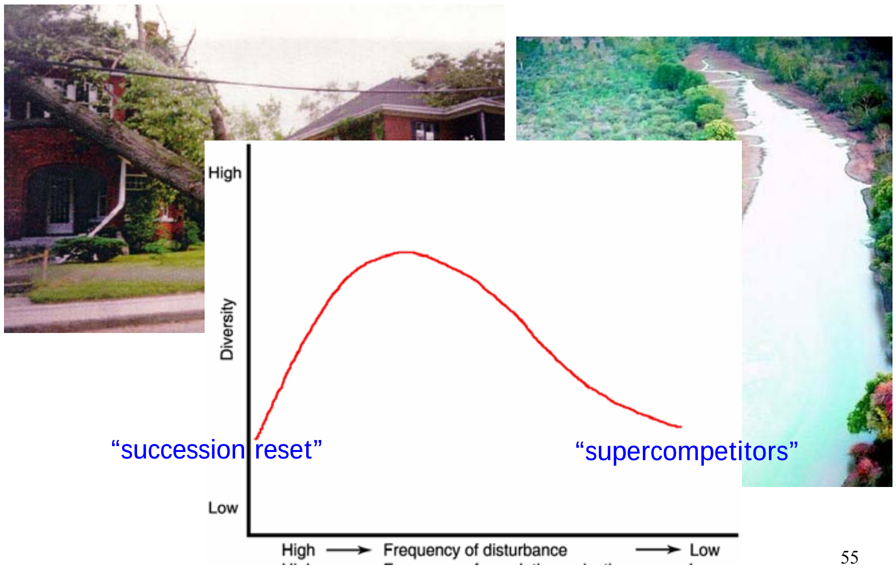
Intermediate Disturbance Hypothesis



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