The Biogeographic Significance of a Large, Deep Canyon: Grand Canyon, Southwestern USA

Lawrence E. Stevens
Grand Canyon Wildlands Council, Inc.
And Museum of Northern Arizona

Ascalapha odorata

"Mariposa de la muerte"

"Duppy Bat"

Biogeo…What?

The Spatial Distribution of Life, Its Evolutionary History and Contemporary Ecology

- General large deep canyon (LDC) concepts
- Four ways LDCs affect species ranges and gene flow
- Examples
- Test LDC biogeography hypotheses
- Implications for management and research

Stevens, L.E. 2012. The biogeographic significance of a large, deep canyon: Grand Canyon of the Colorado River, Southwestern USA. Pp. 169-208 *in* Stevens, L.E., editor. *Global Advances in Biogeography*. InTech Publications, Rijeka. ISBN: 978-953-51-0454-4.

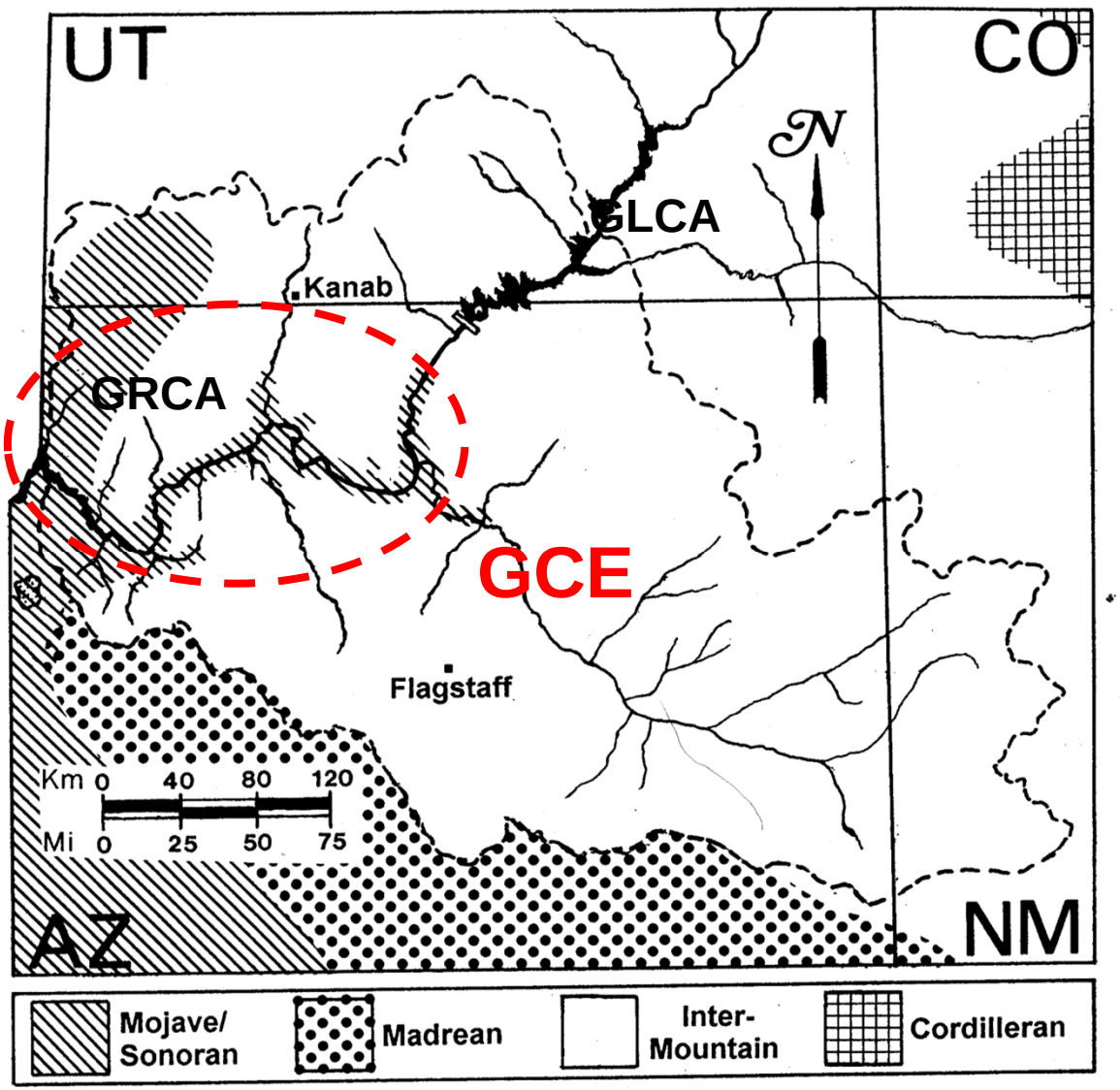
GCE:

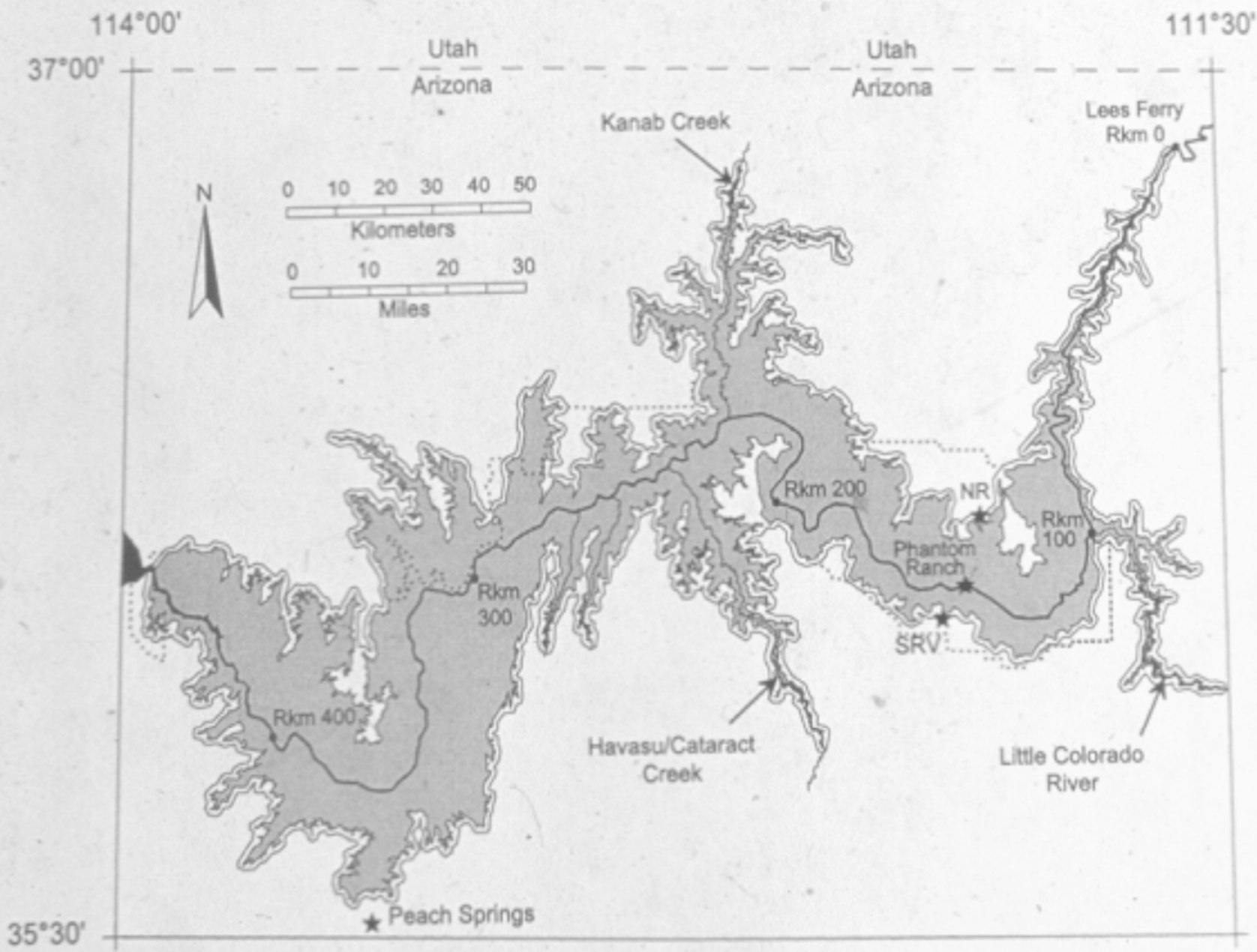
A crossroads of ecosystems through evolutionary space and time.

2 geologic provinces, 4 biomes

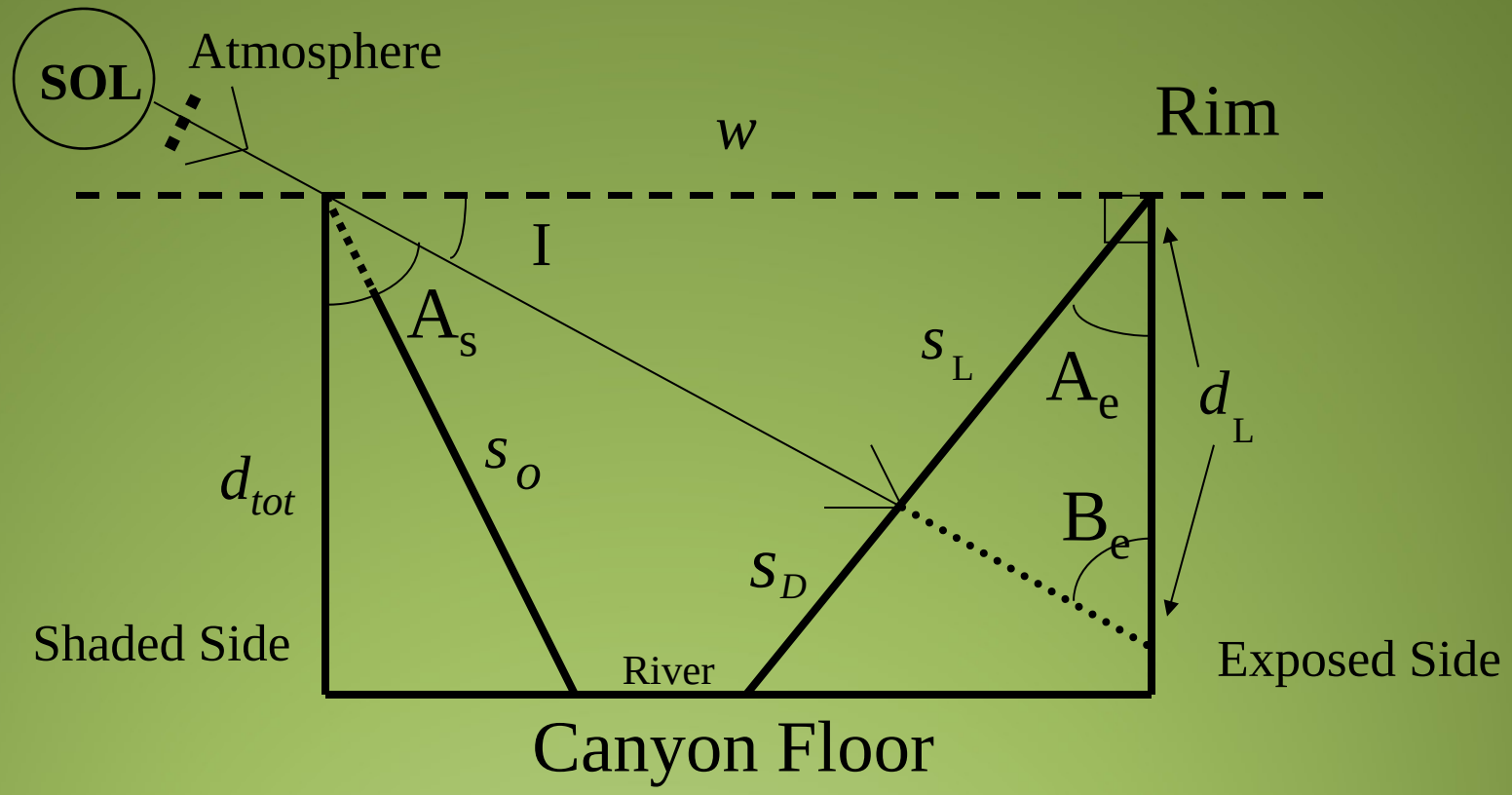
Contemporary Diversity:
~2200 plant spp.
~530 vertebrate spp.
>20K macroinvert spp?

But how and why are they distributed in relation to GC as a landform?




114°00'
111°30'
37°00'
35°30'
Utah
Arizona
Utah
Arizona
Kanab Creek
Lees Ferry
Rkm 0
N
0 10 20 30 40 50
Kilometers
0 10 20 30
Miles
Rkm 200
NR
Rkm
100
Phantom
Ranch
SRV
Rkm
300
Rkm 400
Havasu/Cataract
Creek
Little Colorado
River
Peach Springs

Large, Deep Canyons are Light-limited Ecosystems

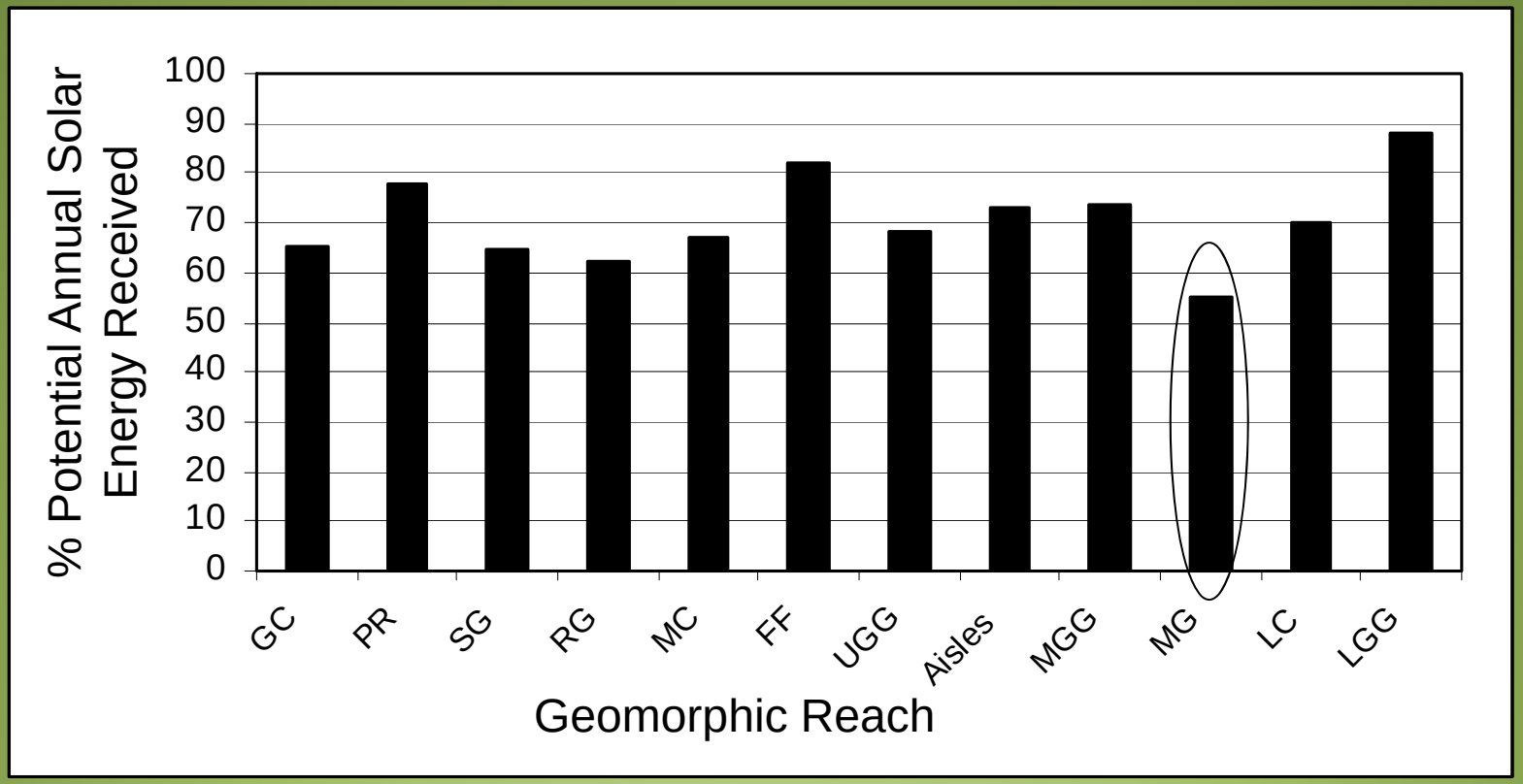


Exposed Side: $s_L = [(w \sin I)/\sin(180^o-(B_e+A_e))]\sin B_e)$

$s_D = (d_{tot}/\cos A_e)-s_L$

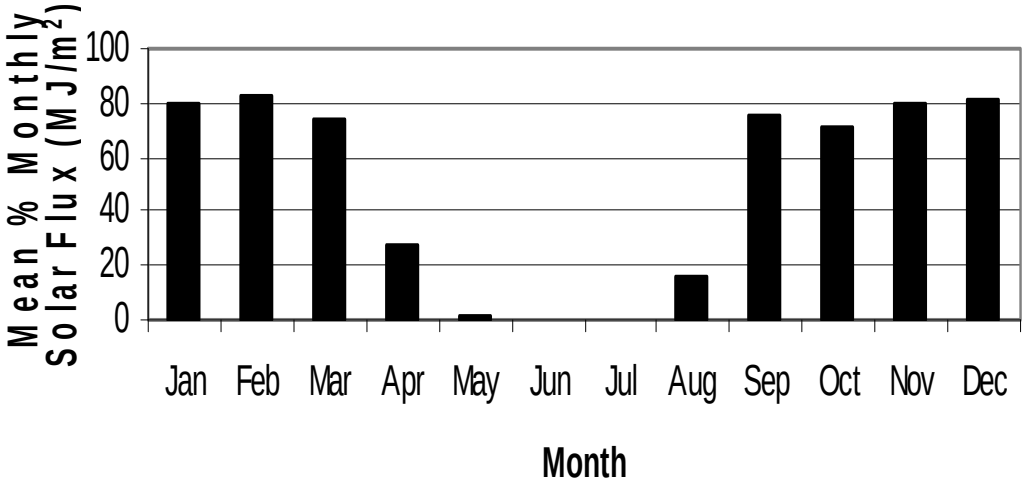
Shaded Side: If $I > A_s$ then $s_o = d_{tot}/\cos A_s$, else $s_o = 0$

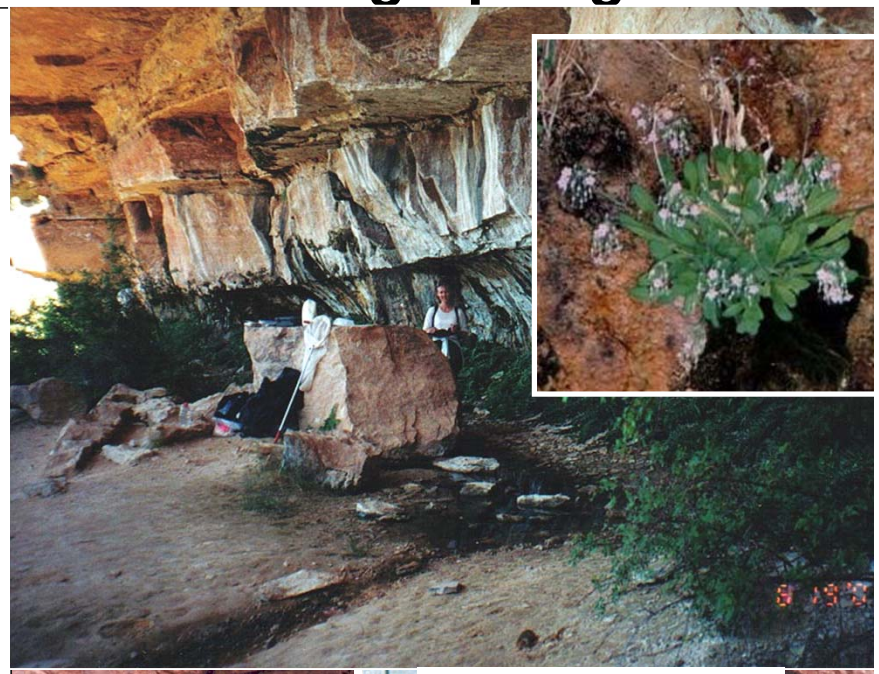
Solar Energy Limitation Varies by Geomorphic Reach



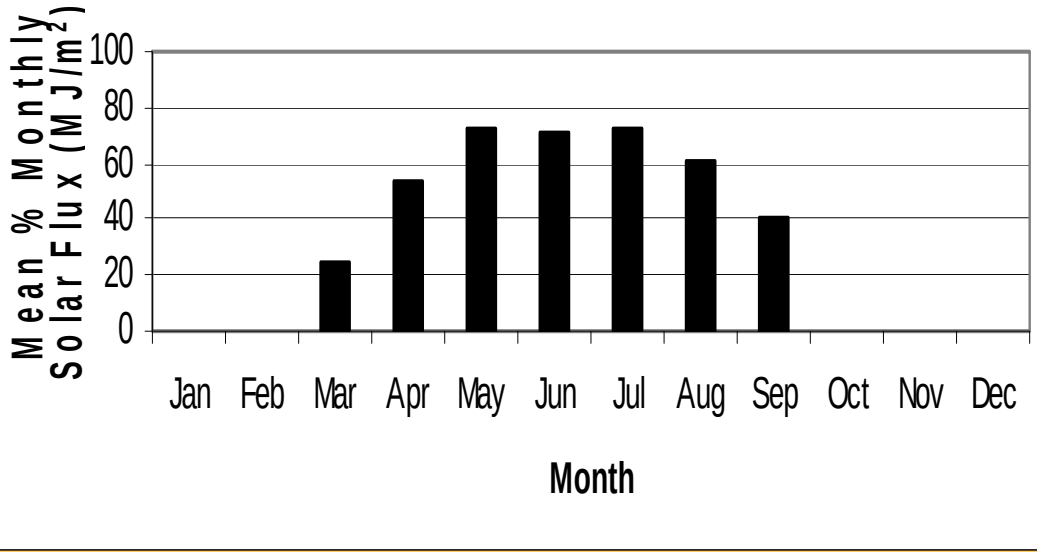
Solar Energy Received at Two East-facing Springs

A

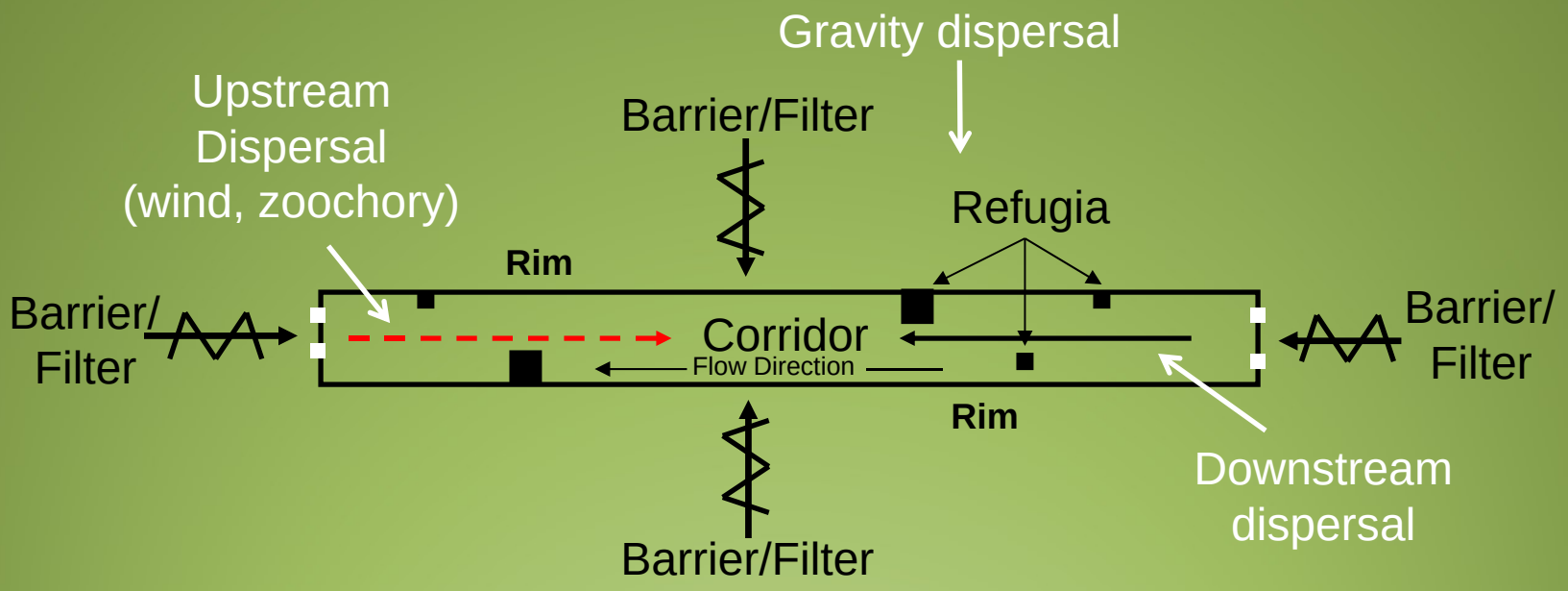




B



Gene flow and movement in large, deep canyons: Barrier, corridor, refugial, and null effects



Corridor Effects: Range extension of desert species through low elevation Colorado River corridor

Claret-cup

Desert trumpet

Banded gecko

Chuckwalla

Corridor Effects: Range and Movement

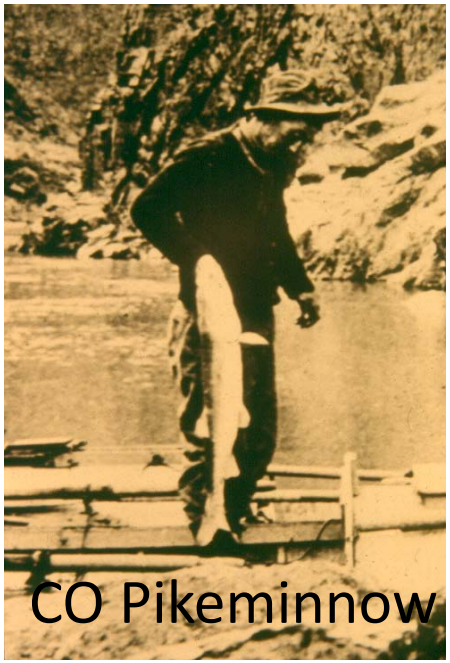
Humpback Chub

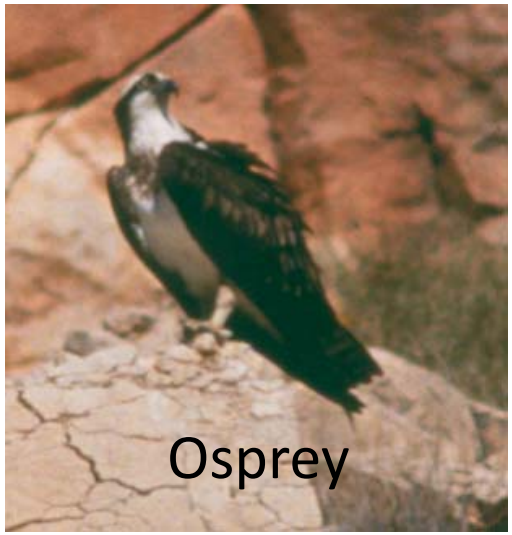
Nathanial Galloway with 2 Colorado River otters in Utah, ca 1900.

Corridor Effects: Migration


Monarch Butterfly

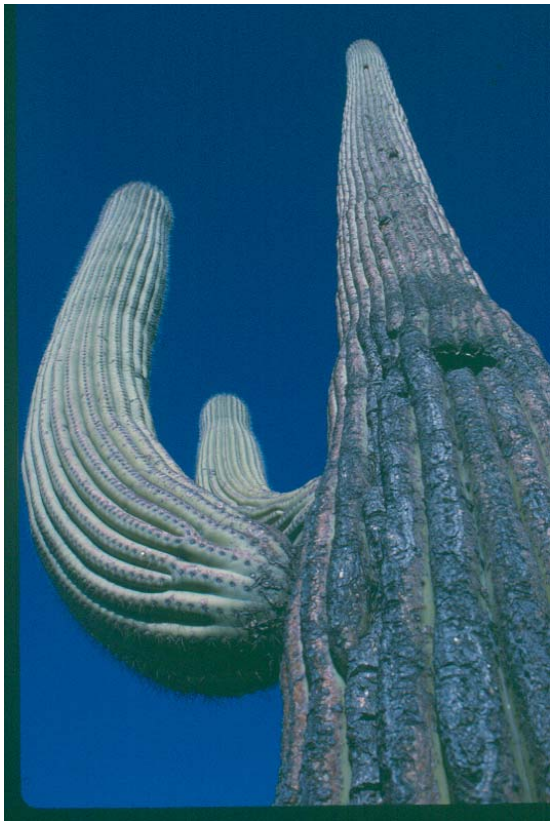

American Avocet


CO Pikeminnow


Osprey


Yuma Myotis

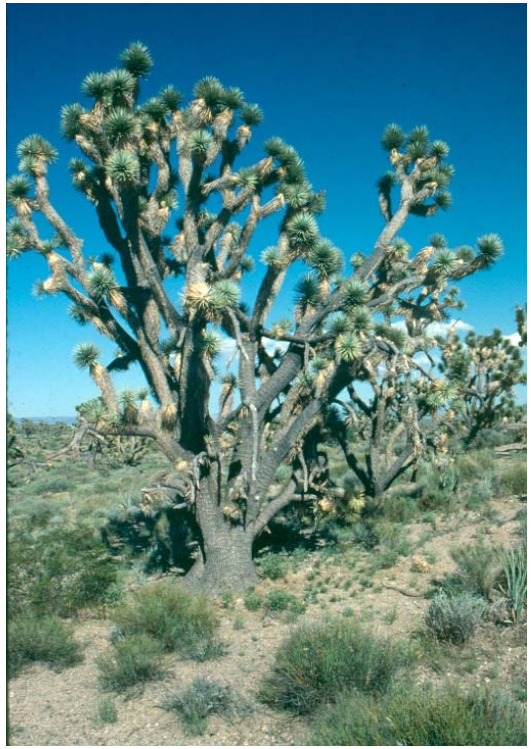
Barrier/Filter Effects:
Across-Canyon and Upstream-Downstream



Saguaro cactus

Grand Canyon Ringlet

Tassel-eared & Kaibab Squirrels



Joshua tree

Barrier/Filter Effects:
River Corridor Lockouts and Gilligans

Horned lizard – down to Lees Ferry but not further downstream in GC

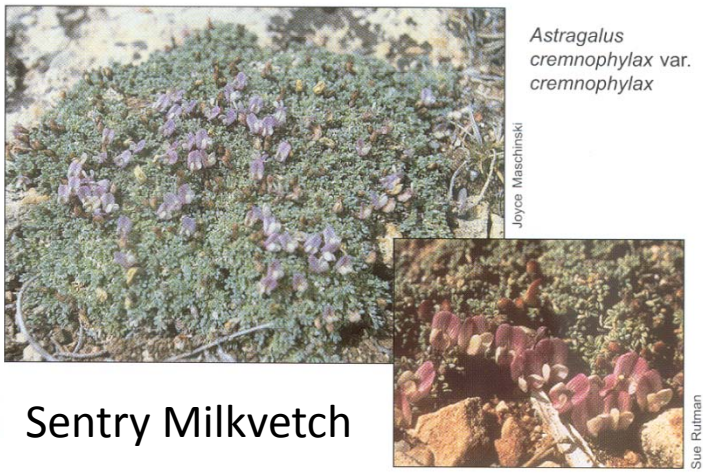
Creosotebush up to Mile 169, not upstream

Parryella filifolia – waifed from UT, non-reproductive, 3 plants

Refuge Effects and Endemism

Grand Canyon Rattlesnake

Kaibab Indra Swallowtail



Sentry Milkvetch

McDougall's Flaveria

Masked Clubskimmer

Grand Canyon Ringlet

Rare Habitats with Endemic Species

Old growth Ponderosa Pine Forest
Caves
Canyon rim edges
Desert and Plateau springs and streams, especially wet meadows

Null Biogeographic Effects


Lined Sphinx


Litaneutria minor


Raven


Desert Bighorn

Biogeographic Anomalies: Expected Taxa That Are Rare or Missing From The Inner Canyon

- Termites (rare) – insufficient retention of woody material on steep canyon slopes
- Horned toads – insufficient low gradient terraces
- Rabbits – hawk migration route, predation; rabbits fall poorly (colonization by gravity)
- Kangaroo Rats – insufficient low gradient habitat, variability in seed availability

LDC Landscape Effects

		Percent of Species Affected			
Taxon	**No. Species**	**Corridor**	**Barrier**	**Refuge**	**No Effect**
Plants	1700	49	trace	10	40
Landsnails	59	2	96	2	0
Tiger beetles	42	21	60	19	0
Butterflies	140	6	0	4	90
Mosquitoes	18	22	0	22	56
Fish*	24	96	17	13	0
Herps	58	62	38	0	0
Birds	330	27	trace	*	50
Mammals	61	20	8	2	70
Approx., Mean	2400 species	34	25	8	34
*strong flow regulation impacts					

Corridor FX = Null FX > Barrier FX > Refuge FX

67% of species affected by Grand Canyon as a landscape feature

Biogeography Insights

Continental and Regional Biogeography

1. Biogeographic affinity affects assemblage composition: Neotropical taxa at lower elevations, Nearctic taxa at higher elevations.

2. Elevation effects analogous to latitudinal effects: Not for S_R, but yes for species density (S_{DEN}), with a strong decrease in S_{DEN} across elevation.

3. Landform configuration affects species richness (S_R): >50% of plant and >75% of animal populations affected (esp. barrier, corridor effects).

Colonization History of CRE

4. Taxon mobility affects species richness: Higher S_R of volant species (GC recently changed by climate, under-colonized landscape.

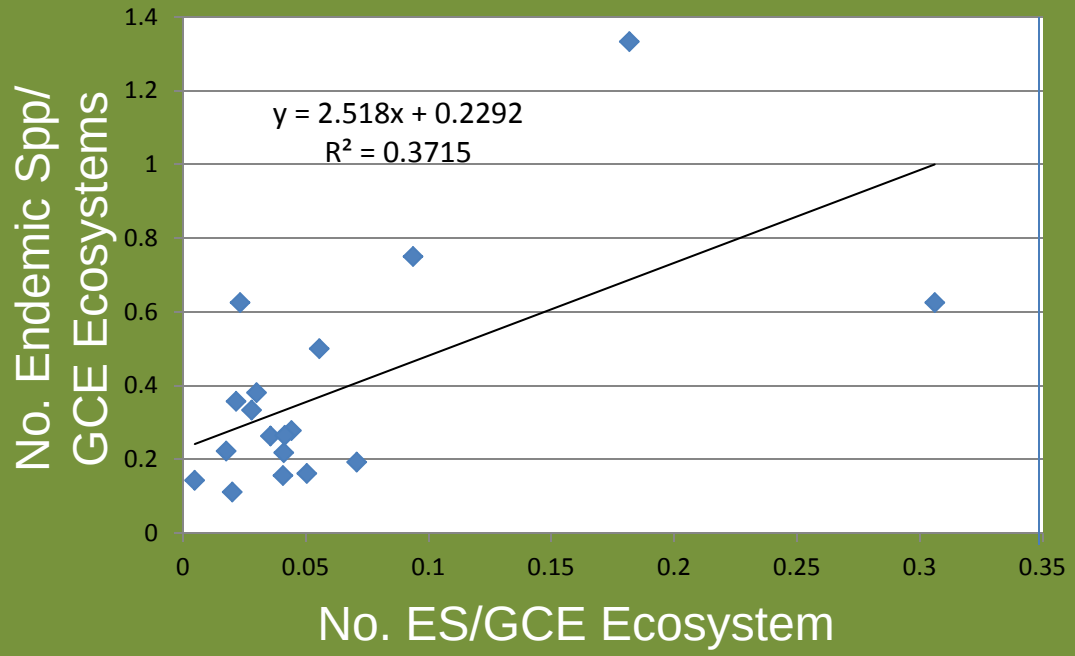
5. S_R attenuates upriver: Especially aquatic invertebrates and herpetofaunae.

6. Levels of endemism are distinctive, with >30 endemic taxa, GCE as a Pleistocene and Holocene refugium.

Management Considerations

- GCE is a mixing zone and refuge over geologic time
- Corridor FX = Null FX > Barrier FX > Refuge FX,
  >67% of species ranges , and likely gene flow affected by LCD
- <10% of animal taxa sufficiently well known to assess rarity, risks

- Endangered species are poor “umbrellas” for rare, endemic taxa



Common Butterflies of the Grand Canyon Ecoregion

Sleepy Dogface

Black Swallowtail

Many-tailed Swallowtail

Western Swallowtail

Orange Sulfur

Mourning Cloak

Dainty Sulfur

Buckeye

Acastus Patch

Red-spotted Purple

Queen

Painted Lady

Sister

Grand Canyon Brow..

Monarch

Great Purple Hairstreak

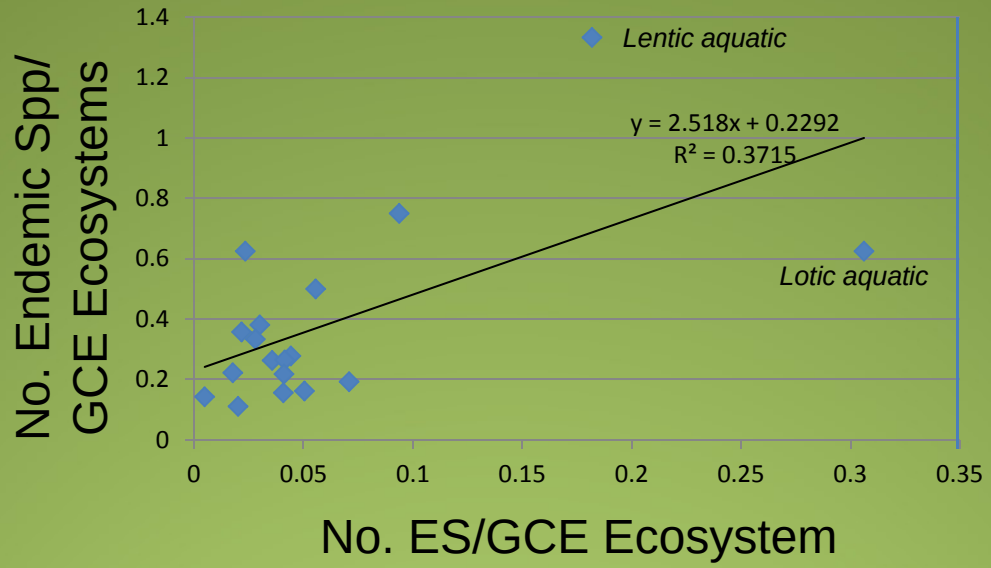
American Snout

Common White

Pygmy Blue

Common Hairstreak

Rarity Management



* Understanding invertebrate rarity requires inventory, assessment at land unit, biome, state, regional, national, and international spatial scales
- Endemism varies spatially (and temporally?), narrowly endemic to regional
- Rare GCE invertebrates may not be rare elsewhere in AZ, the Southwest, or North America

* Are all endemic taxa worthy of conservation consideration?
* Should we care about isolated populations (e.g., only population in Arizona) if a taxon is otherwise widely distributed?

Conclusions

- Many species new to science, much apparent rarity and some endemism (esp. invertebrates)
- Fewer than 10% of macroinvertebrate taxa and many vertebrates insufficiently well known to assess rarity or conservation challenges
- Occurrence in little-recognized, poorly studied habitats, such as springs and caves
- Endangered species are poor “umbrellas” for rare, endemic taxa

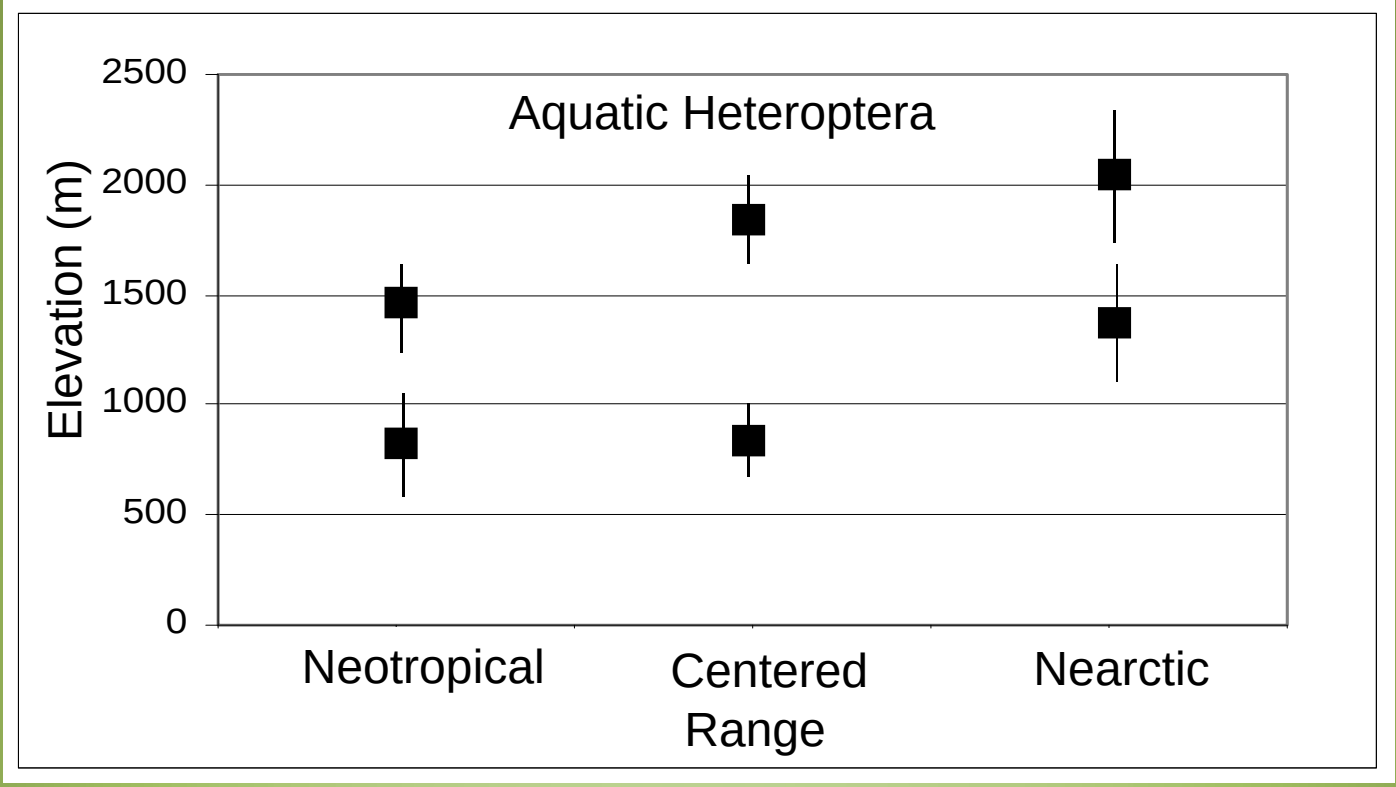
GROW THE KNOWLEDGE !

Inventory, curate, database

Biogeographic Hypothesis Tests

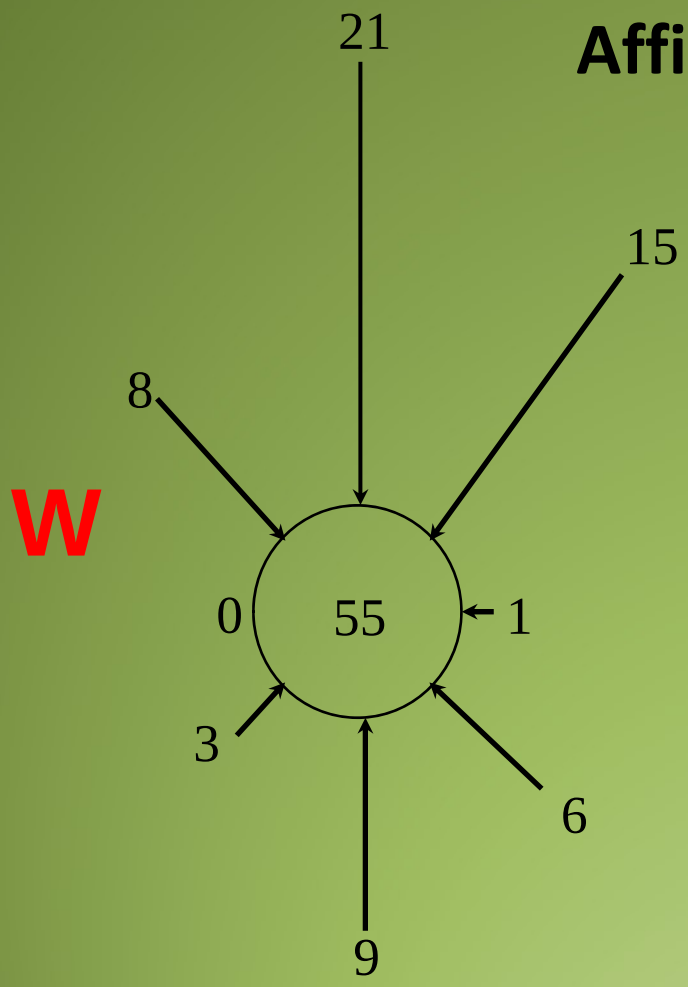
Continental and Regional Biogeography

1. Does biogeographic affinity affect assemblage composition:
   Yes, Neotropical taxa at lower elevations, Nearctic taxa at higher elevations.

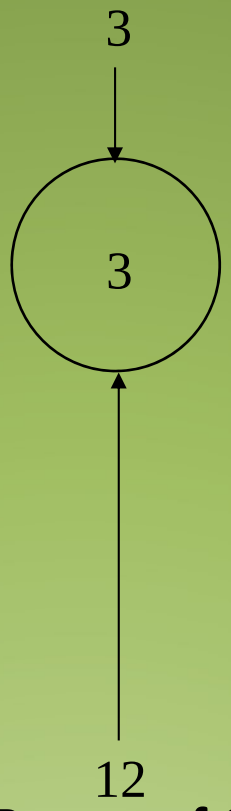


Affinity Varies by Taxon

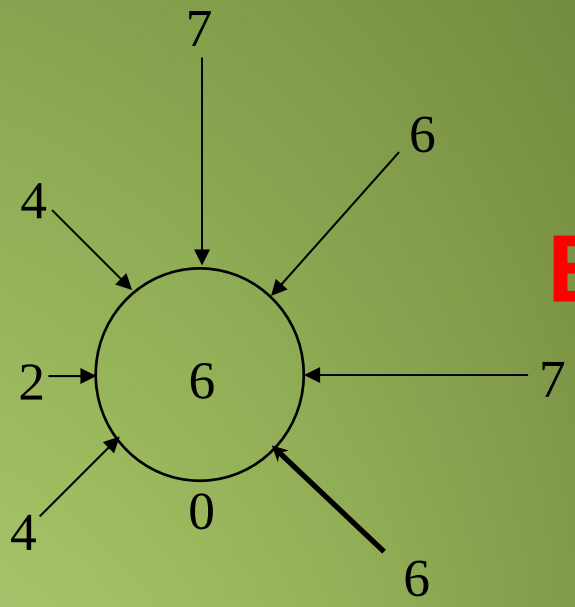
N



Ranges of 121 butterfly and skipper species



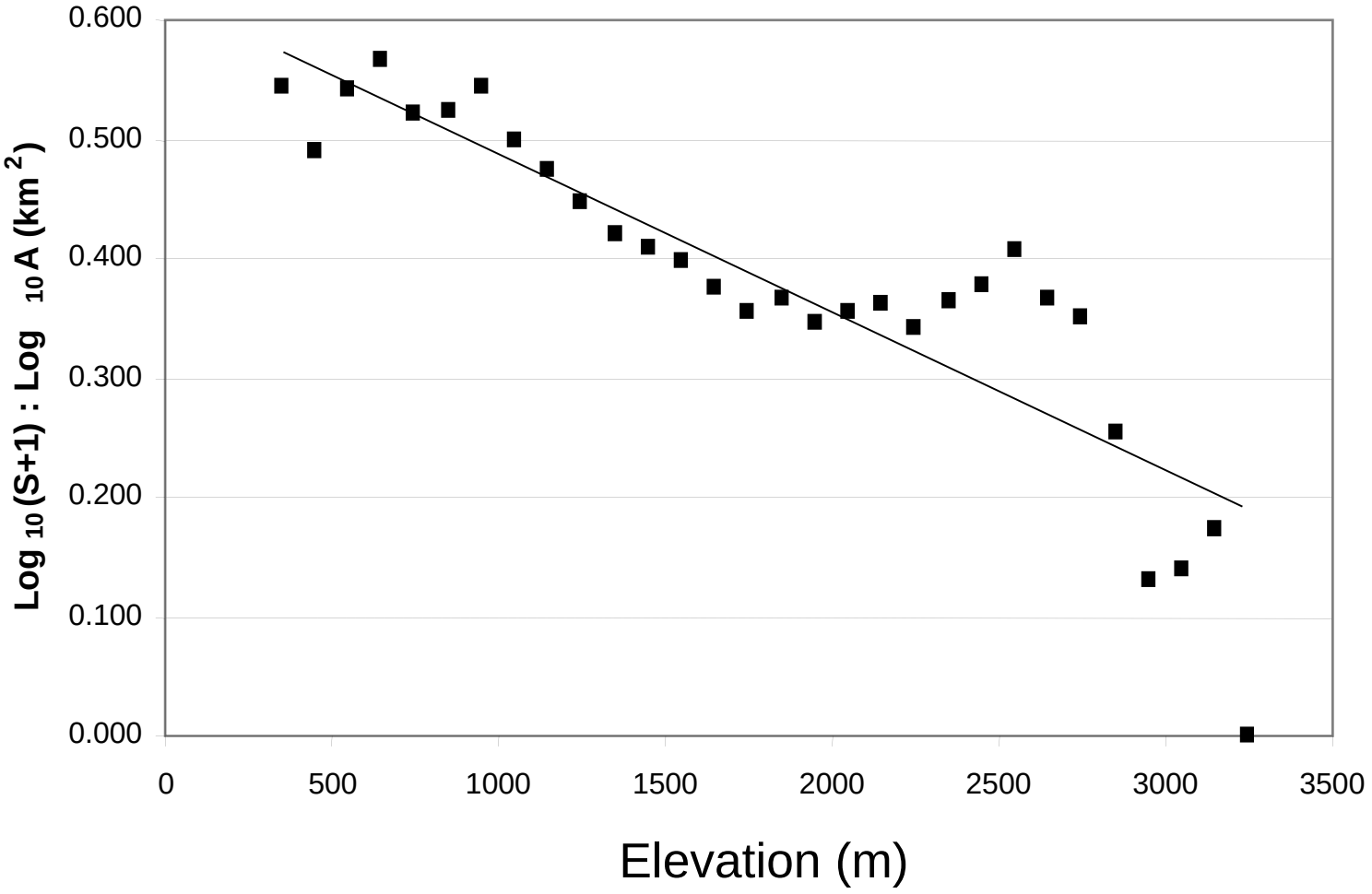
Ranges of 18 mosquito species



Ranges of 42 tiger beetle species

S

Species-area analysis of aquatic Hemiptera as a function of land area across elevation



GCE Herpetofaunal Species Richness in the GCE