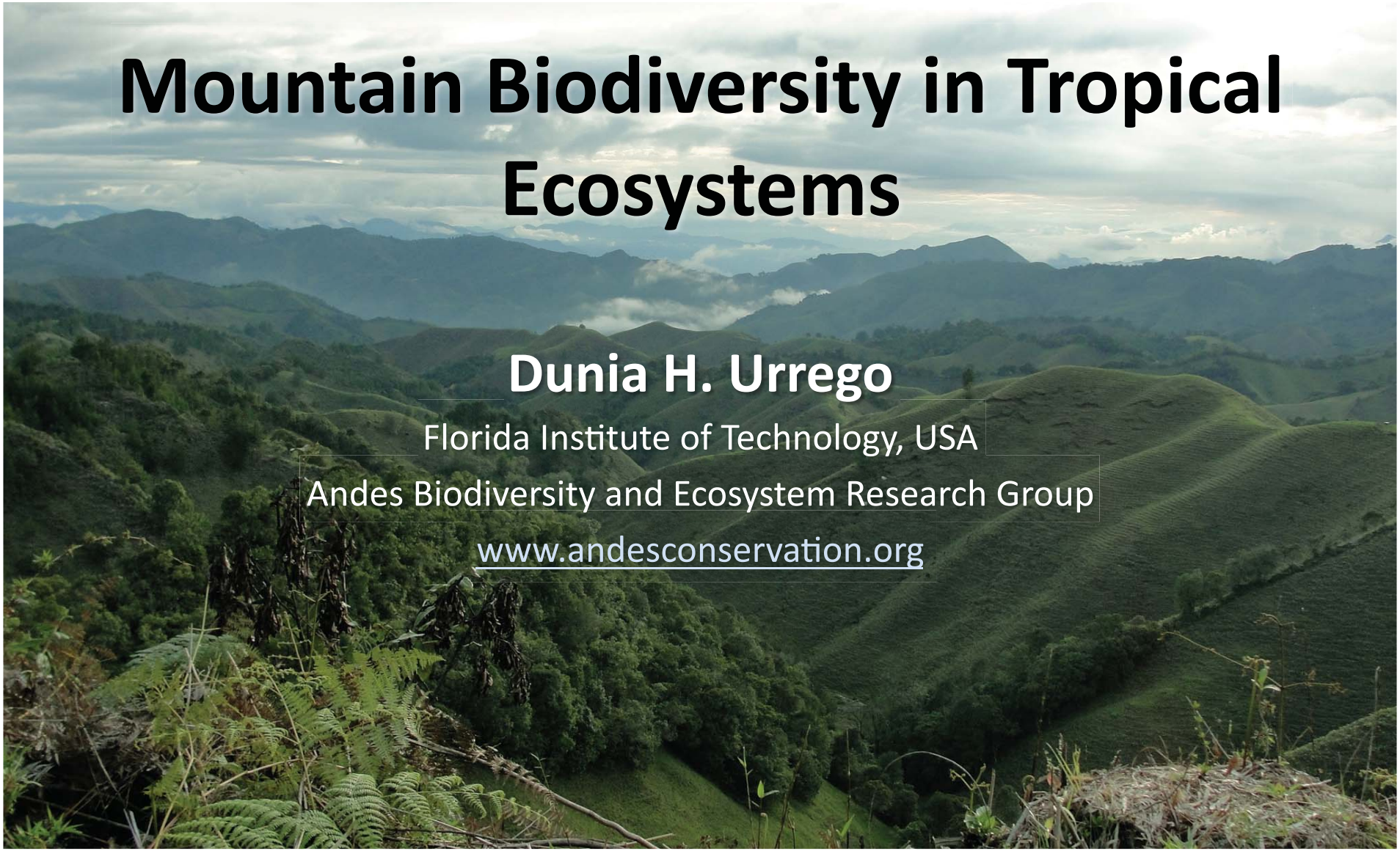
IPROMO

Mountain Partnership

Protecting Mountain Biodiversity



Mountain Biodiversity in Tropical Ecosystems

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www.andesconservation.org

Mountain biodiversity in Neotropical Ecosystems

Outline

- **PRESENT**: Biodiversity of tropical montane ecosystems

BREAK – quick introductions

- **PAST**: History tropical montane ecosystems: Species migrations in the central Andes, an example

10-min BREAK

- **FUTURE**: Striving for conservation of tropical montane ecosystems, a practical exercise

- **Overall conclusions…**

PRESENT: Biodiversity of tropical montane ecosystems

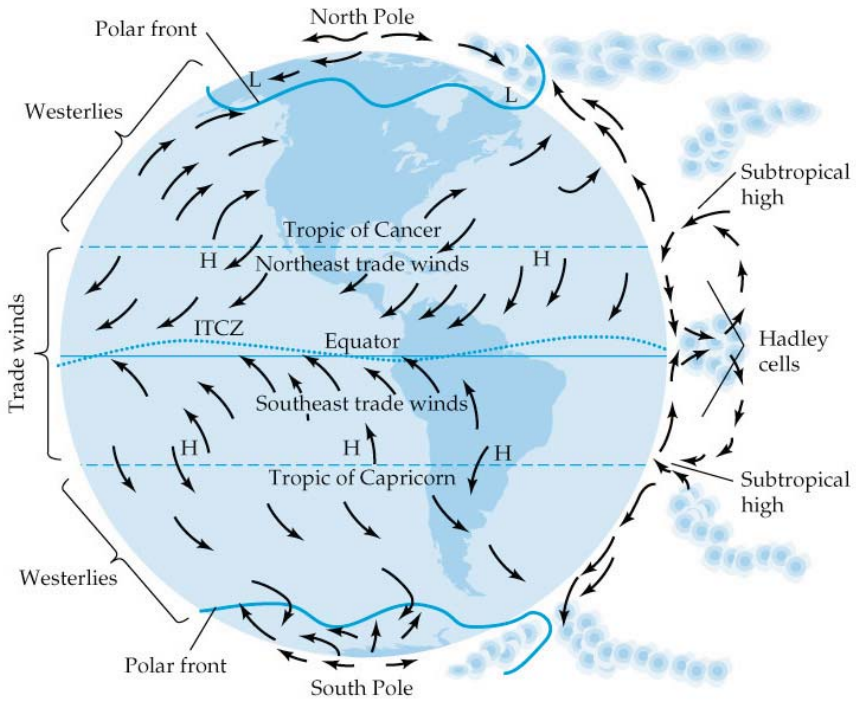
1. Physical environment and habitat heterogeneity
2. Biodiversity distribution and endemism
3. Current and near-future threats
4. Biodiversity response to current threats

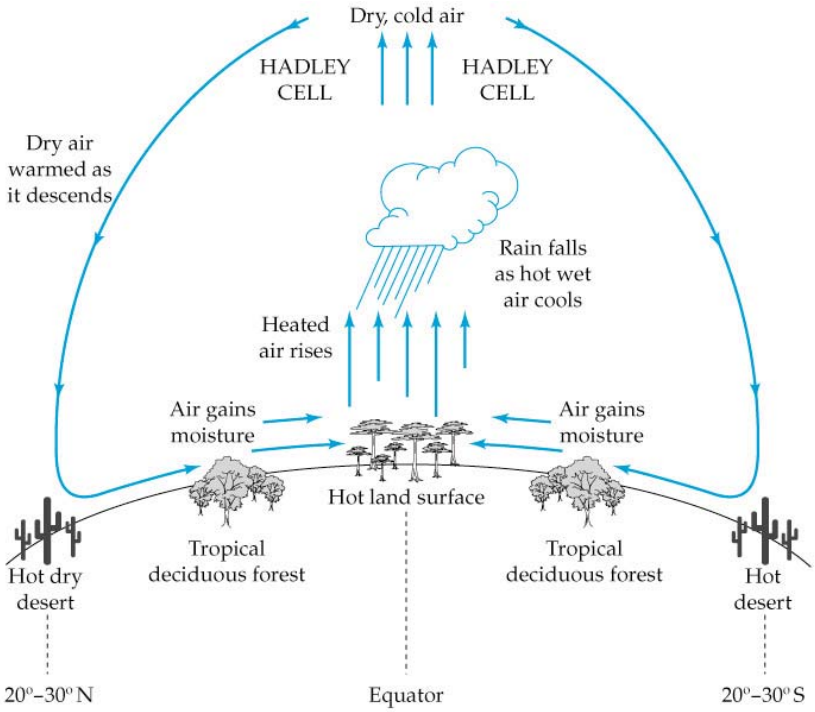
Factors that differentiate biomes

- **Climate:** maximum and minimum temperatures, growing season, precipitation, drought stress, seasonality.
- **Soil:** rate of nutrient cycling.
- **Vegetation adaptations:** size, structure, complexity, evergreen/deciduous, photosynthetic pathway.
- **Animal adaptations:** migration, hibernation, thick fur-bearing, water conservation.

Tropical biomes

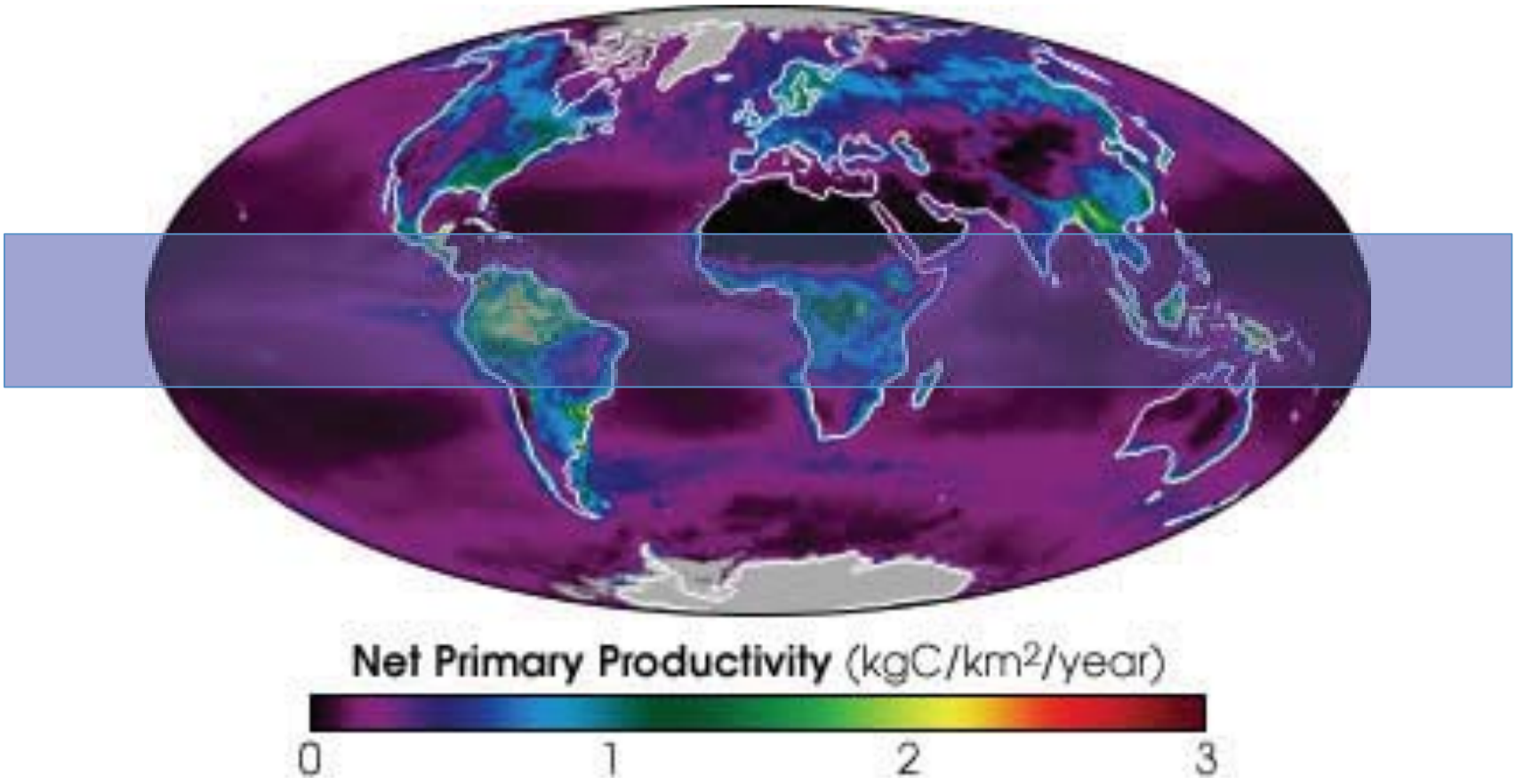
Hadley cells





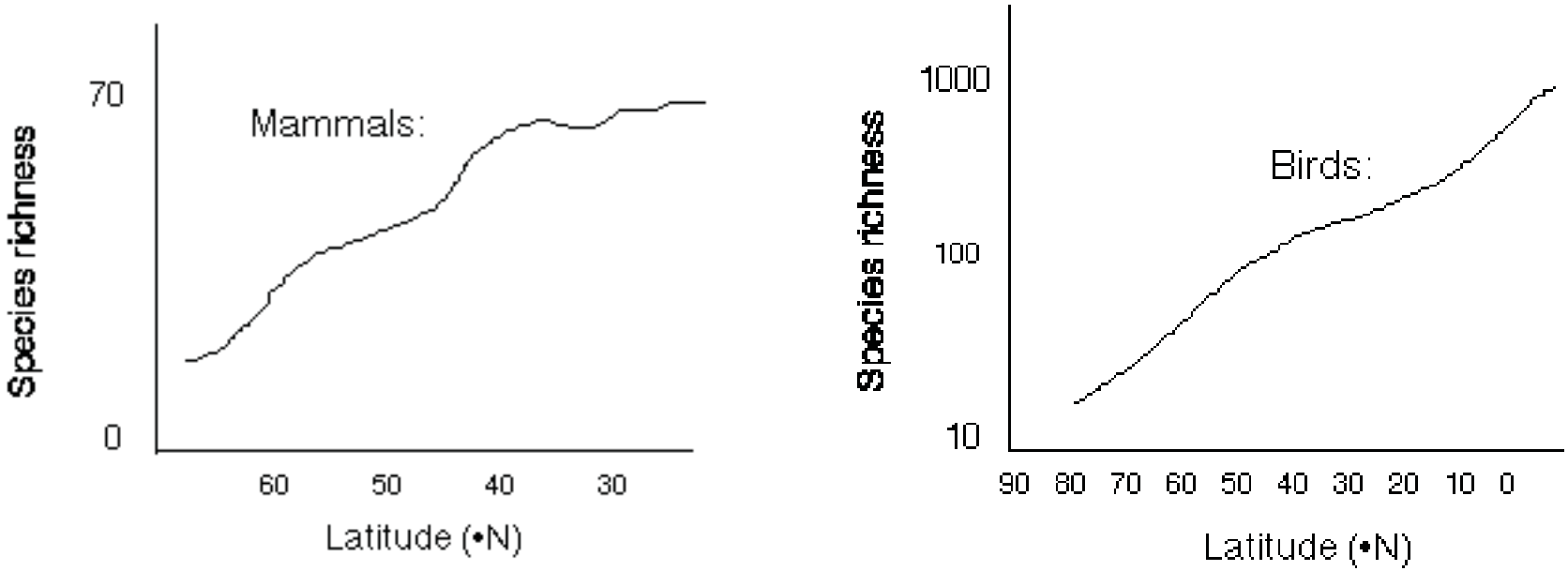
Explain occurrence of tropical rain forest and play a major role in seasonality of precipitation

Net primary productivity



Data from NASA Earth Observatory Satellite

Latitude and diversity



Highest concentrations of biodiversity in tropical regions

High diversity in tropical ecosystems

Also ecologically determined

Spatial and temporal avoidance

- Year-round growing season results in year-round insects and herbivores.
- Many tree species have < 1 individual per hectare: spatial avoidance. Benefits of being rare?
- Masting: Within a species it is common for individuals to flower and fruit synchronously.
- Seeds cannot all be consumed by predators.

Tropical montane ecosystems

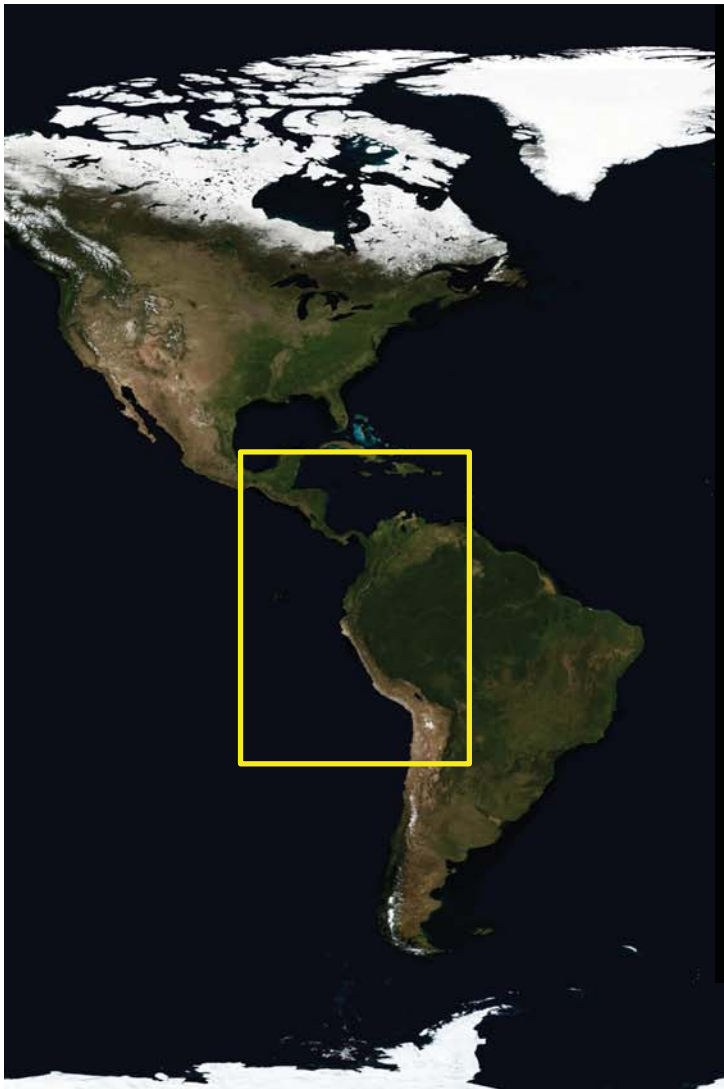
A broad definition

Between 20°LN and 20°LS

Above 500-m elevation up to snowline

Important facts

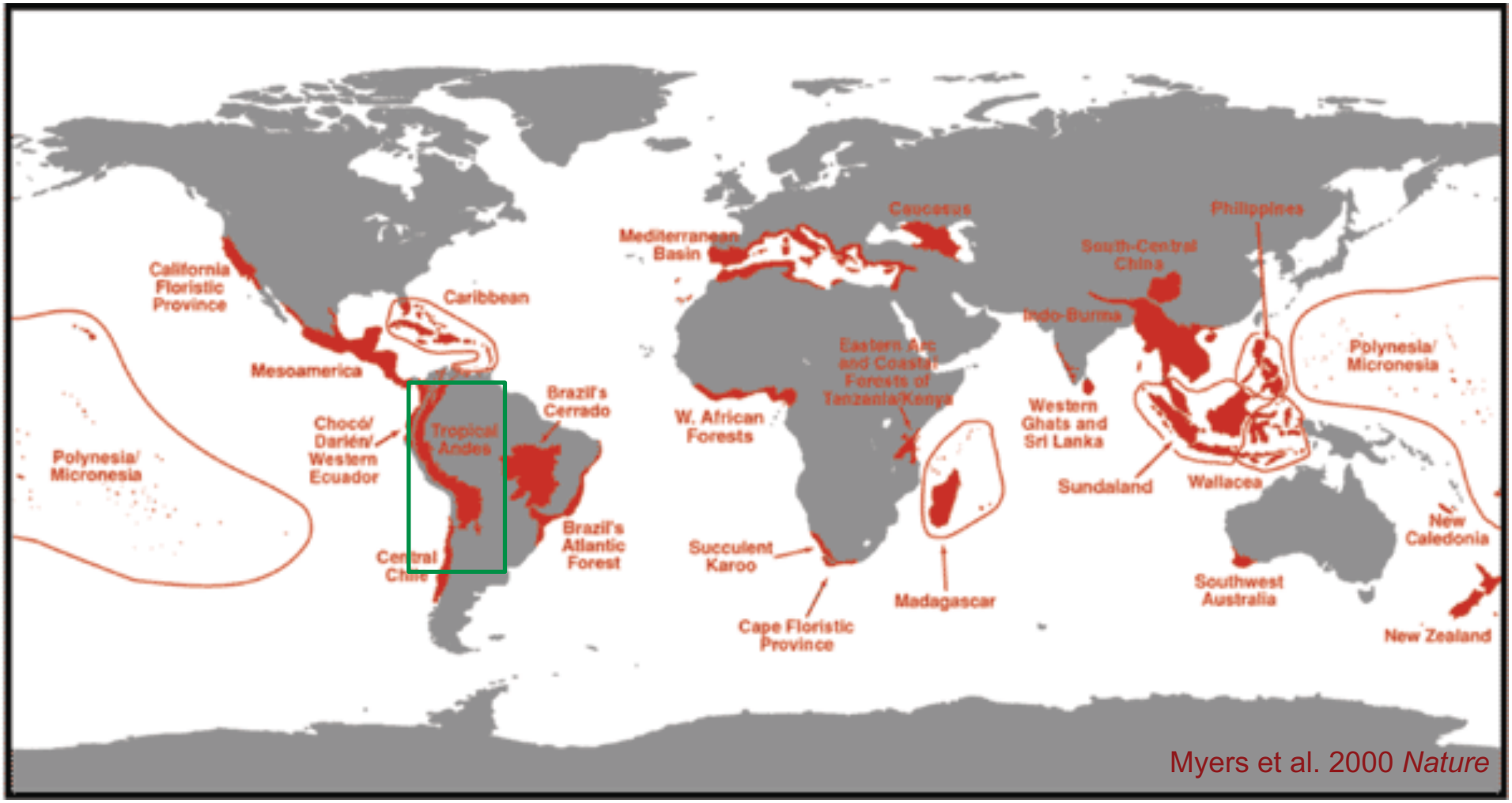
- 25% of earth's surface are mountains.
- About 8.5 million Km^2 are tropical montane areas.
- In South America: Andes one of the largest mountain chains.
- In Africa: Ethiopian Highlands, Mount Kenya, Mount Kilimanjaro, among others.
- 40% of human population live in mountain regions worldwide: highly threatened ecosystems.
- Most important biodiversity hotspots.



- Sixth of all plant life found in less than 1% of the world's land area.
- A quarter of its habitats still remain.

Neotropical montane ecosystems

Biodiversity hotspots for conservation

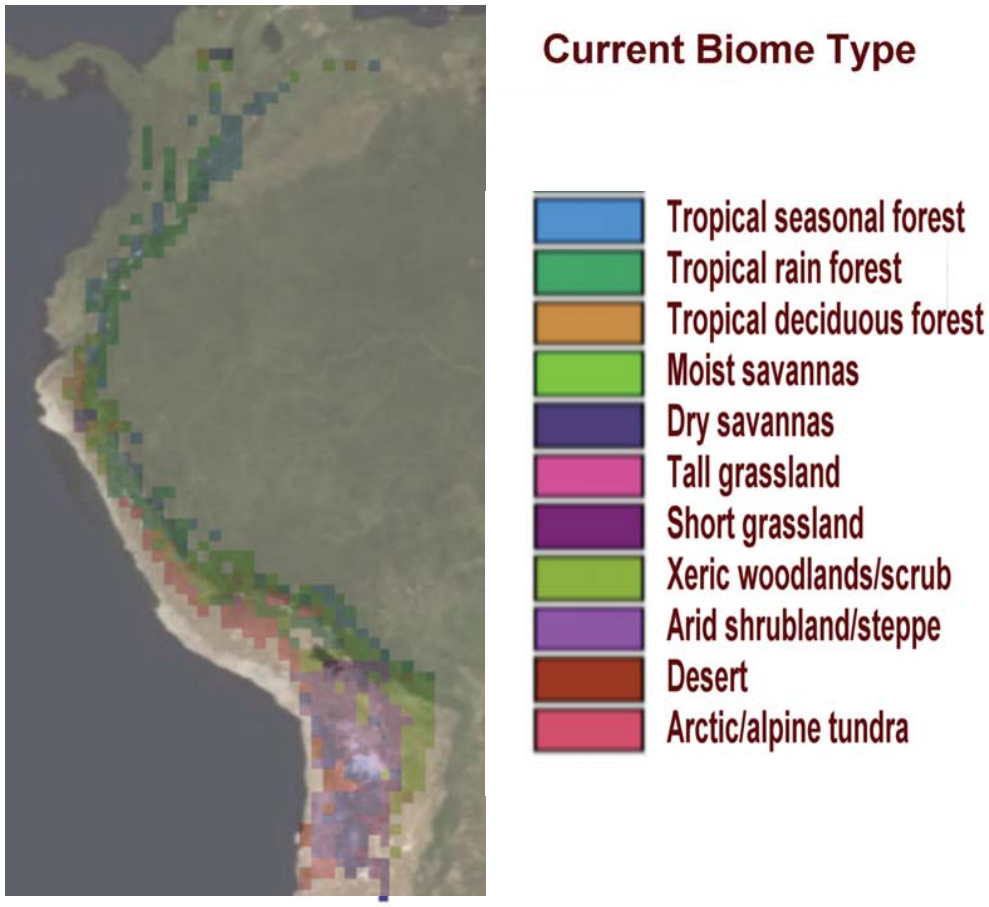


How can we support the most species at the least cost?

Places with high levels of endemism undergoing exceptional loss of habitat.

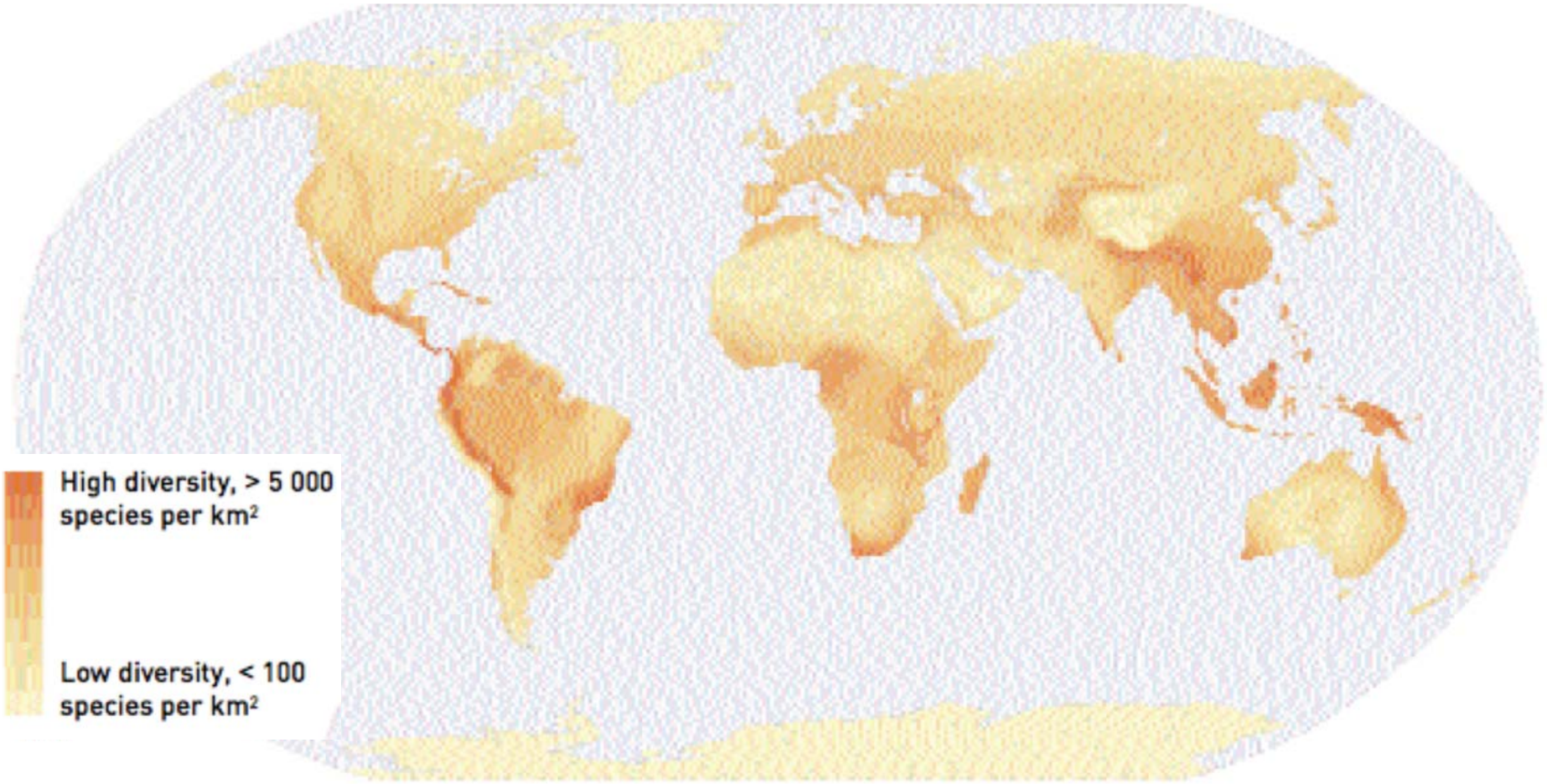
Sensitivity of montane hotspots

Andes Hotspot maps from BIOME for original class biome types



Malcolm et al. 2006 *Conserv. Bio.*

Diversity of vascular plants

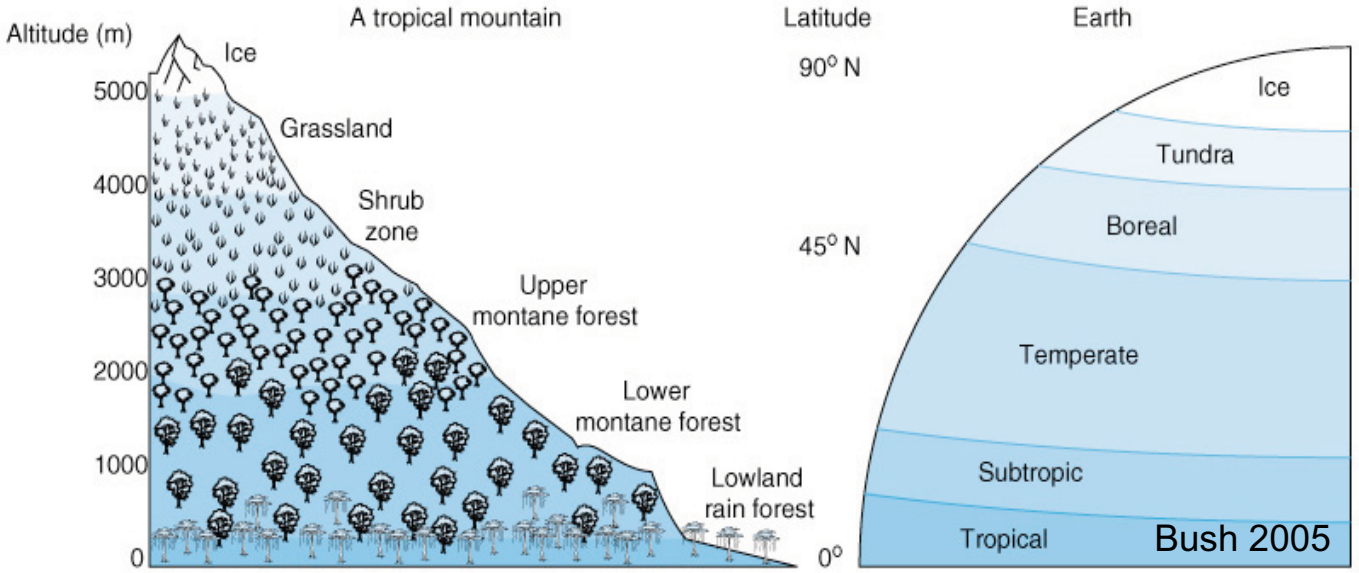


Note the close correspondence between plant-rich areas and mountain regions.

Source: Mountain Watch, W. Barthlott, University of Bonn

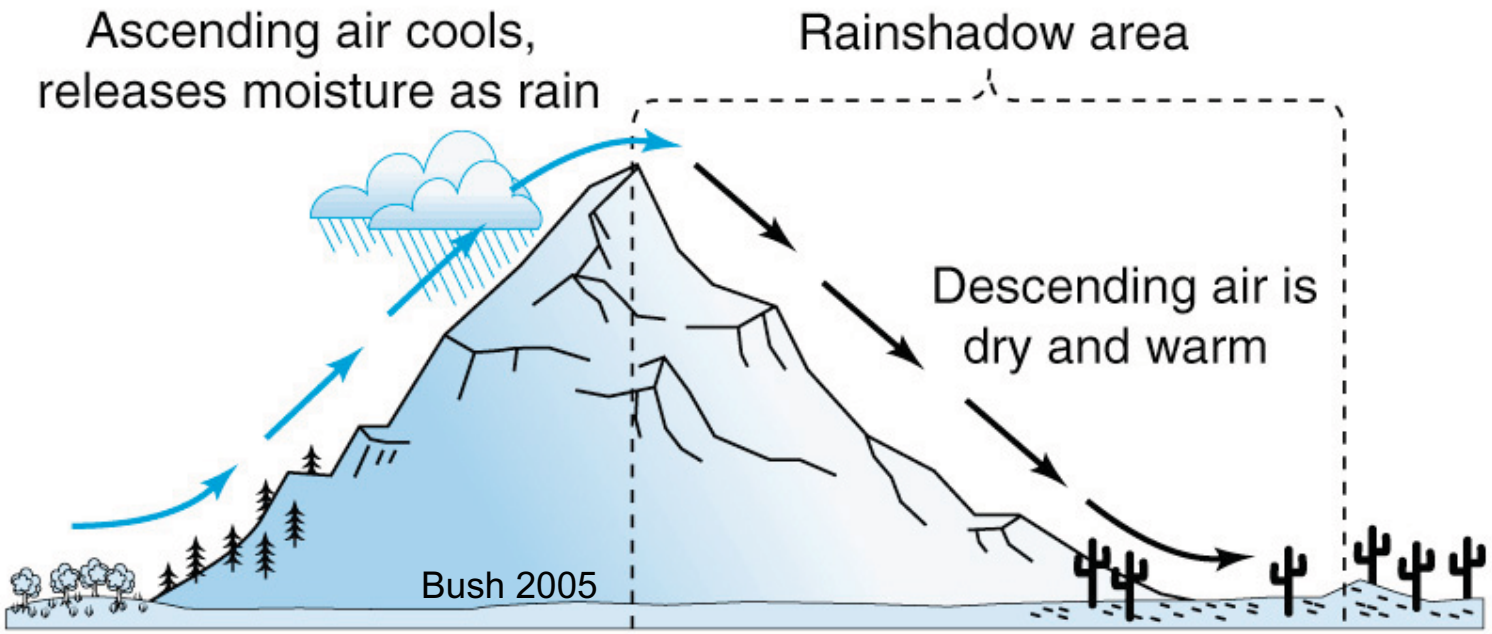
Tropical montane ecosystems

Environmental gradients

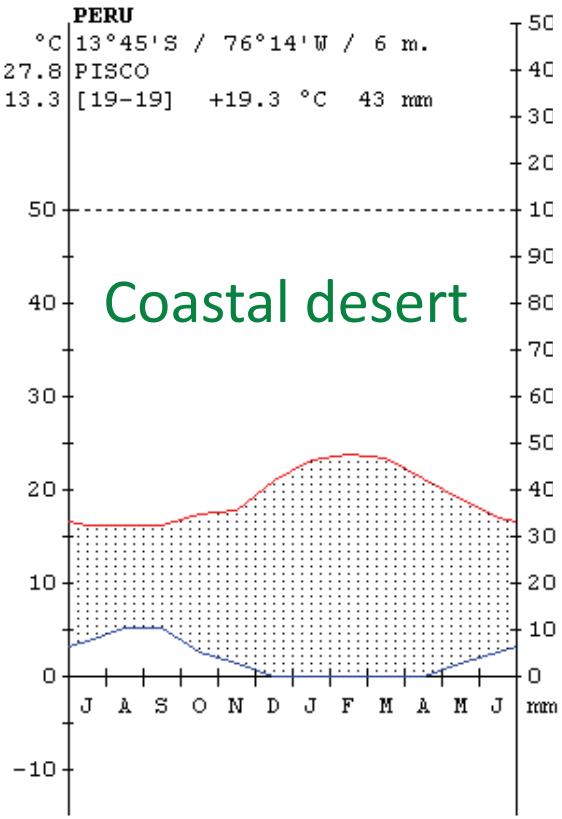


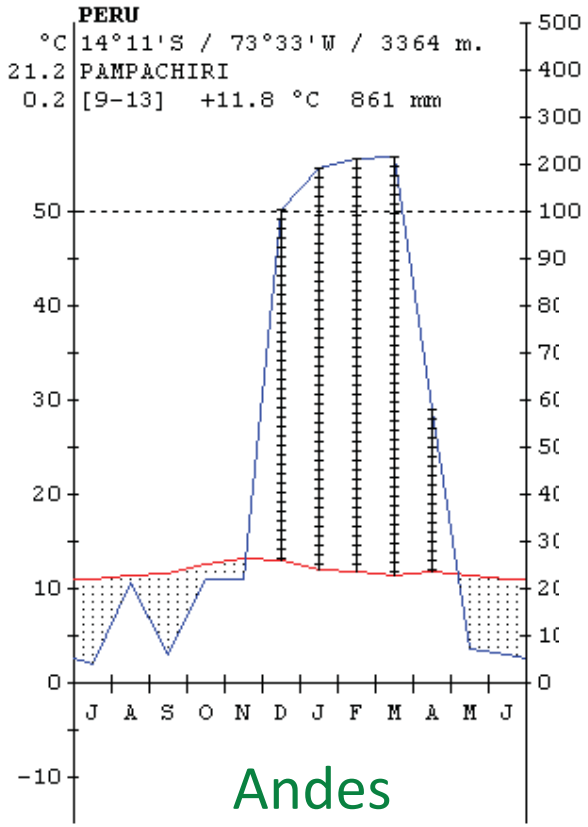
- In the tropics temperatures fall by ~5-6 °C per 1000 m of vertical ascent.
- This is equivalent to moving poleward about 800 km.
- The frost limit is often a major ecological boundary
- Oxygen decreases as you get higher.
- U.V. increases as atmosphere gets thinner.

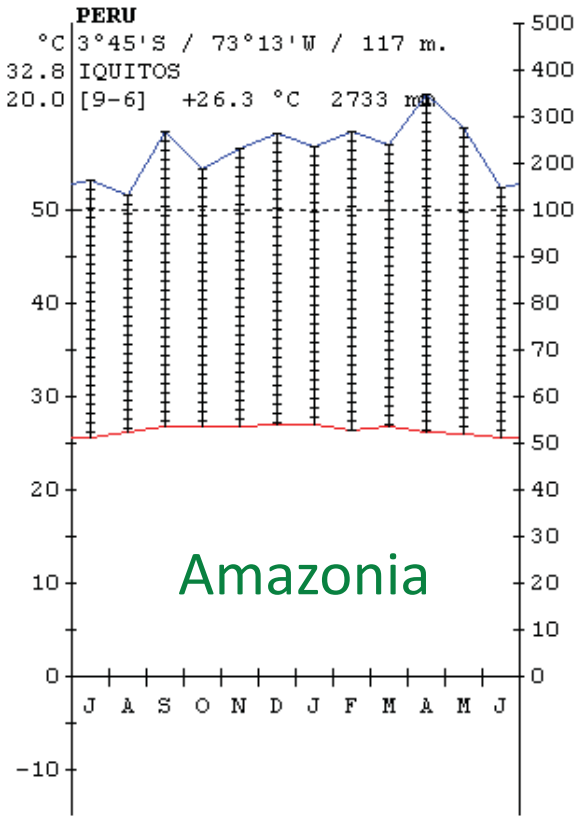
Rain-shadow effect in tropical mountains



Rain-shadow effect in the Central Andes







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Kosñipata Valley, Peruvian Andes. Photo: M.R. Silman

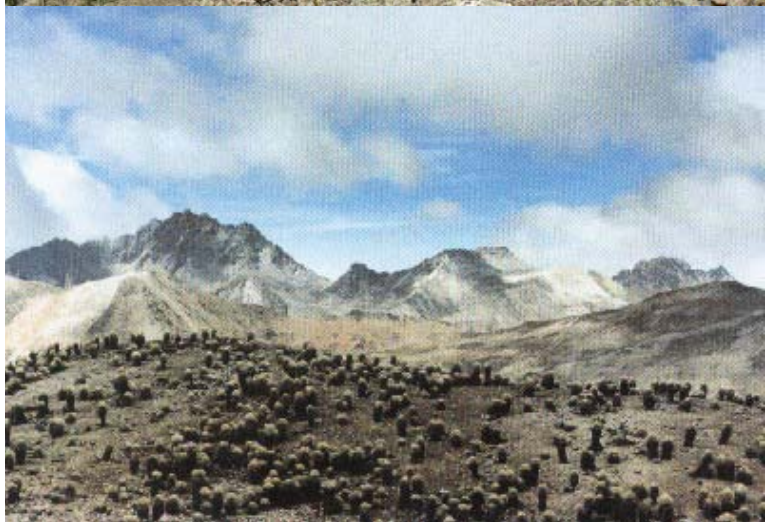
Tropical montane ecosystems

Ecological gradients

- Trees get smaller as you go up the mountain.
- Leave size decreases as elevation increases.
- Change in vine diversity with elevation.
- Some lowland tropical families replaced by temperate families of plants.
- Above mid-elevations ecosystems can be light limited.

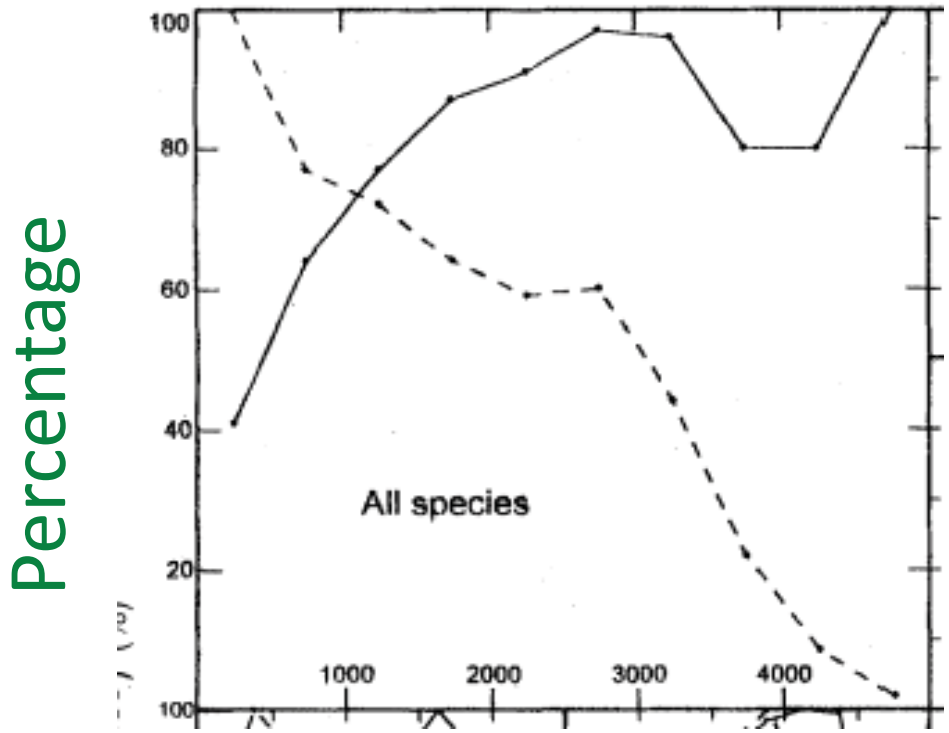
High-elevation tropical ecosystems

Puna or subparamo



- Tree line is generally about 3400 m above this is subparamo to 3800 m (shrubby grassland).
- Above 3800 m high montane grasslands. Equivalent of alpine meadows or tundra.
- Also *Polylepis*

Endemism in tropical mountains

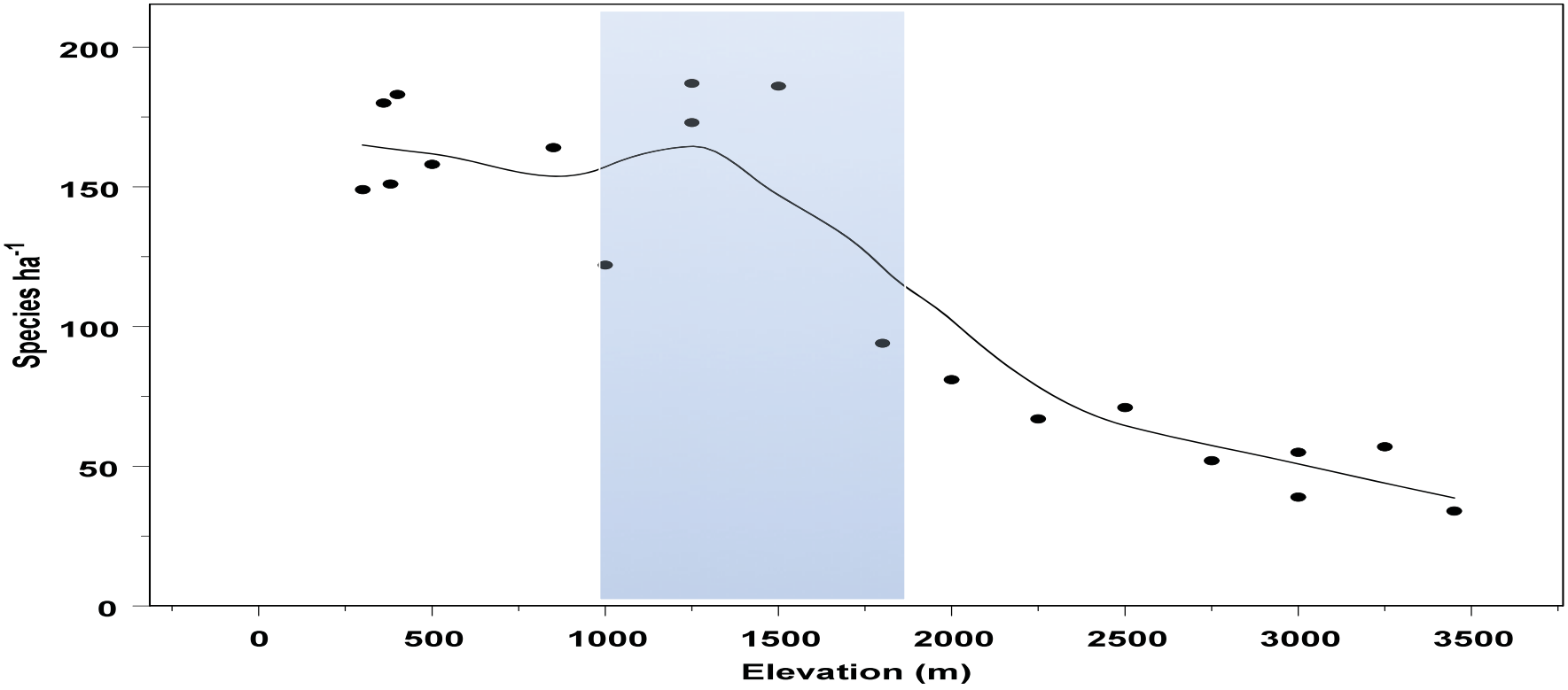


Solid: endemism

Dashed: species richness

Diversity in tropical montane ecosystems

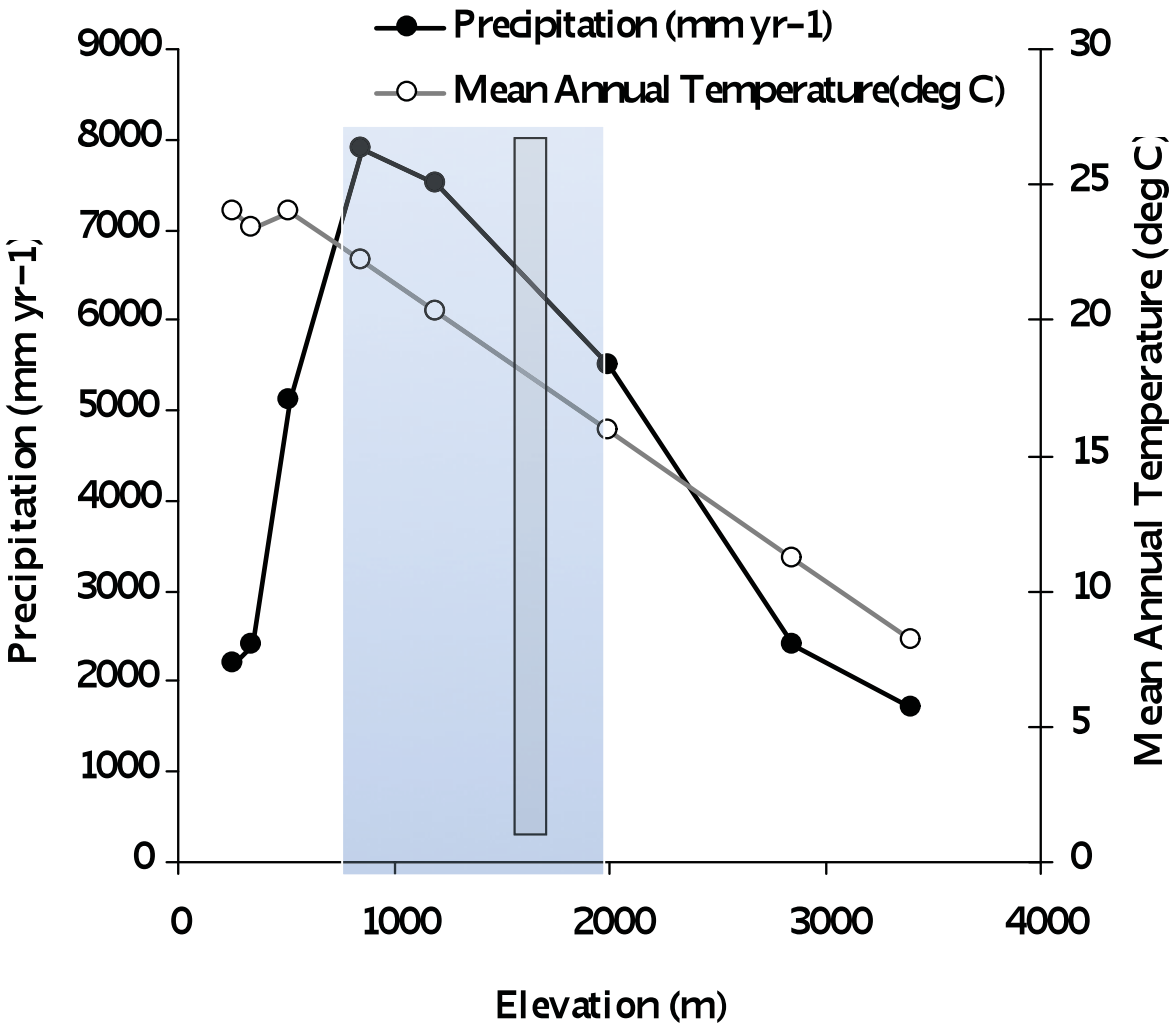
Andes transect - ABERG



Silman et al. in press. Jounal of Biogeography

Precipitation and temperature

Andes transect - ABERG



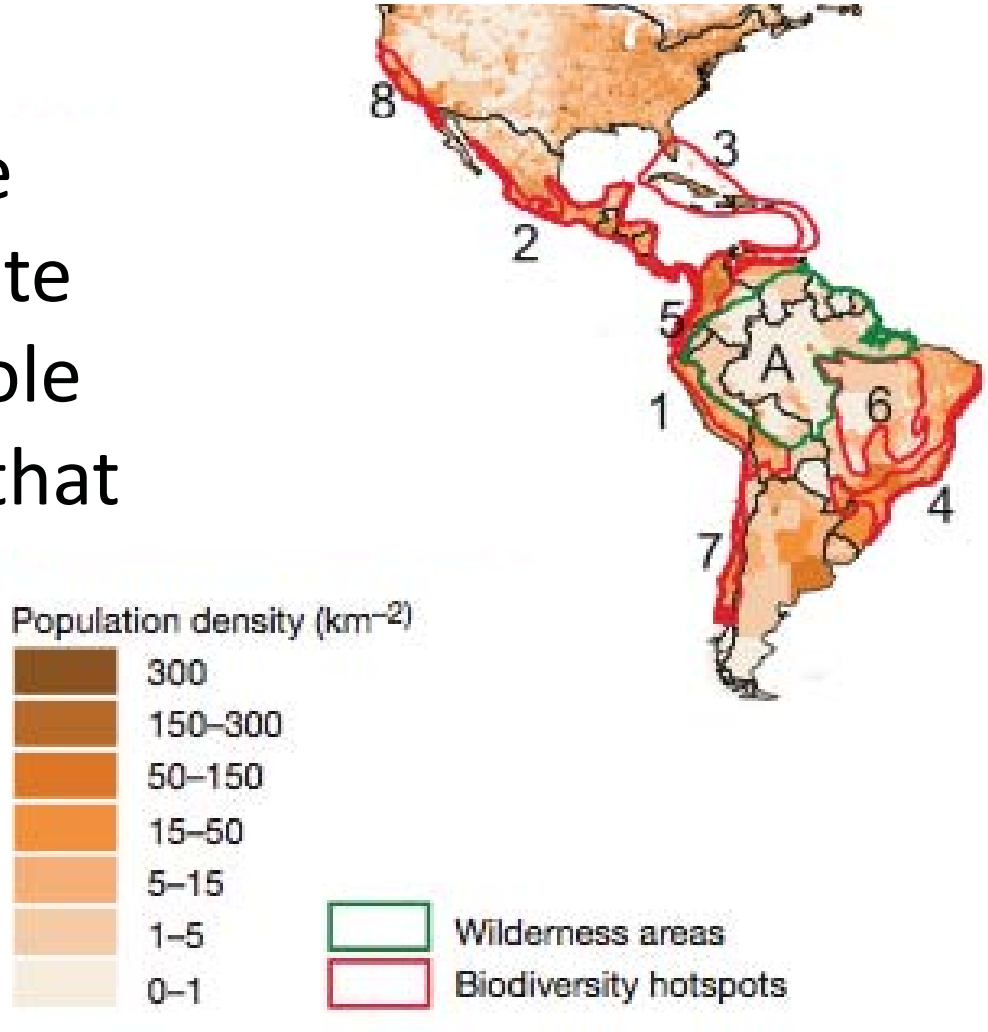
Current threats to Tropical Montane Biodiversity

- Threats
  - Increasing human occupation
  - Habitat loss - fragmentation
  - Global environmental change

- Responses to current environmental change
  - Range shifts
  - Species extinctions

Tropical montane ecosystems and human populations

Population growth is 3%yr, higher than the population growth rate of the world as a whole (1.3% yr) and above that of the developing countries (1.6% yr).



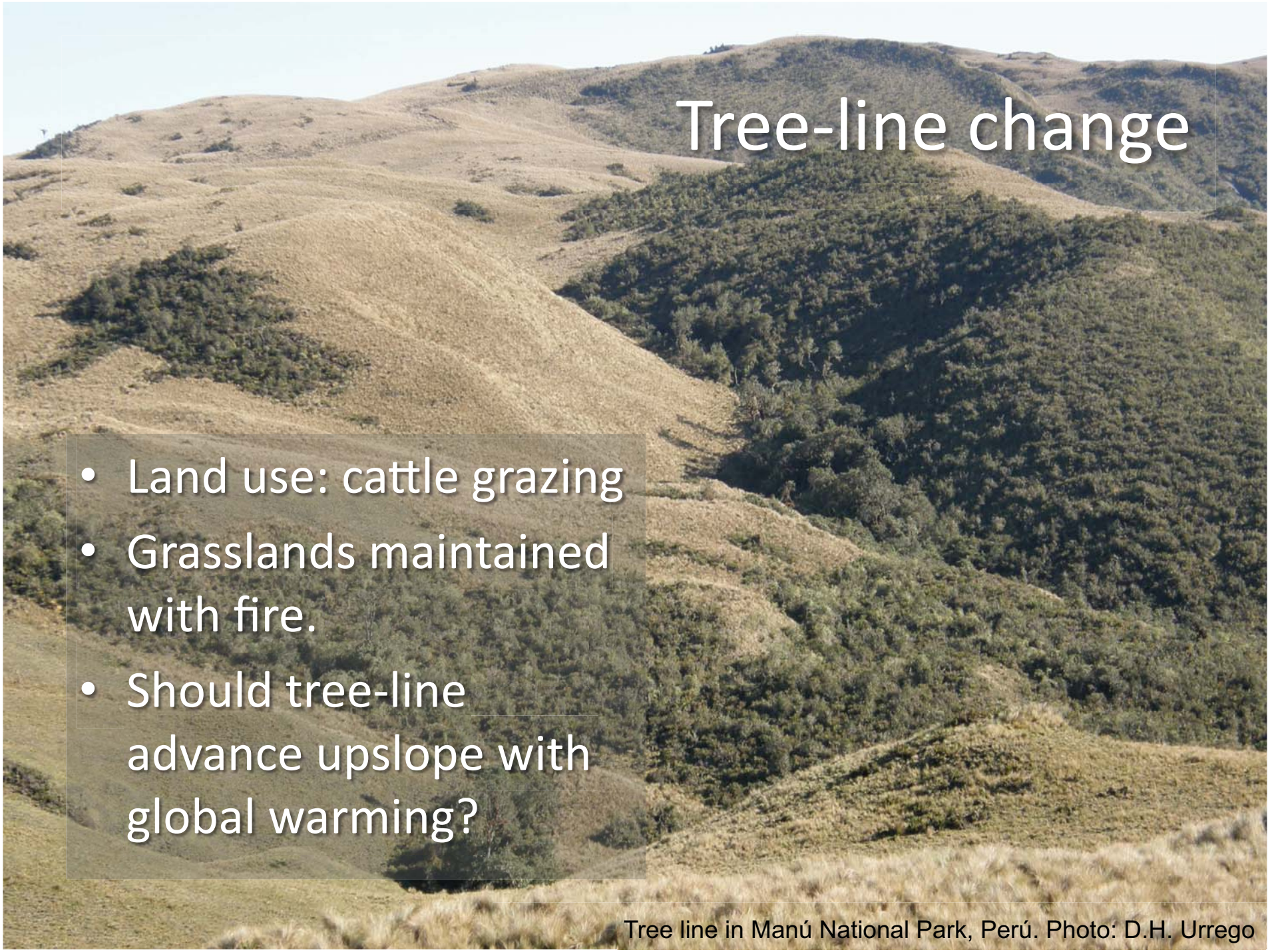
Cincotta et al 2000 *Nature*

Current treats

Habitat loss and fragmentation

Tree-line change

- Land use: cattle grazing
- Grasslands maintained with fire.
- Should tree-line advance upslope with global warming?

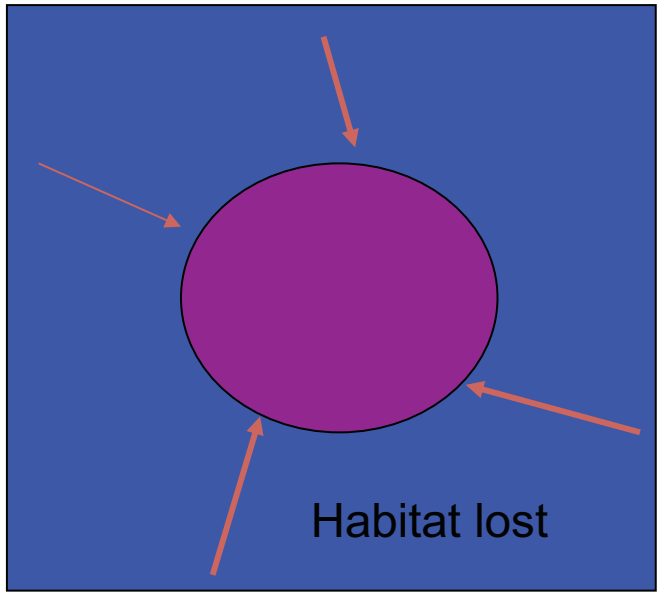


Tree line in Manú National Park, Perú. Photo: D.H. Urrego

Effects of habitat fragmentation

Supersaturation & Relaxation

- Supersaturation: species flow into remaining area as their habitat is destroyed (ark effect).
- This sets up an extinction debt (Hanski 2002) that is followed by relaxation (loss of species following isolation).



Species most vulnerable to habitat fragmentation

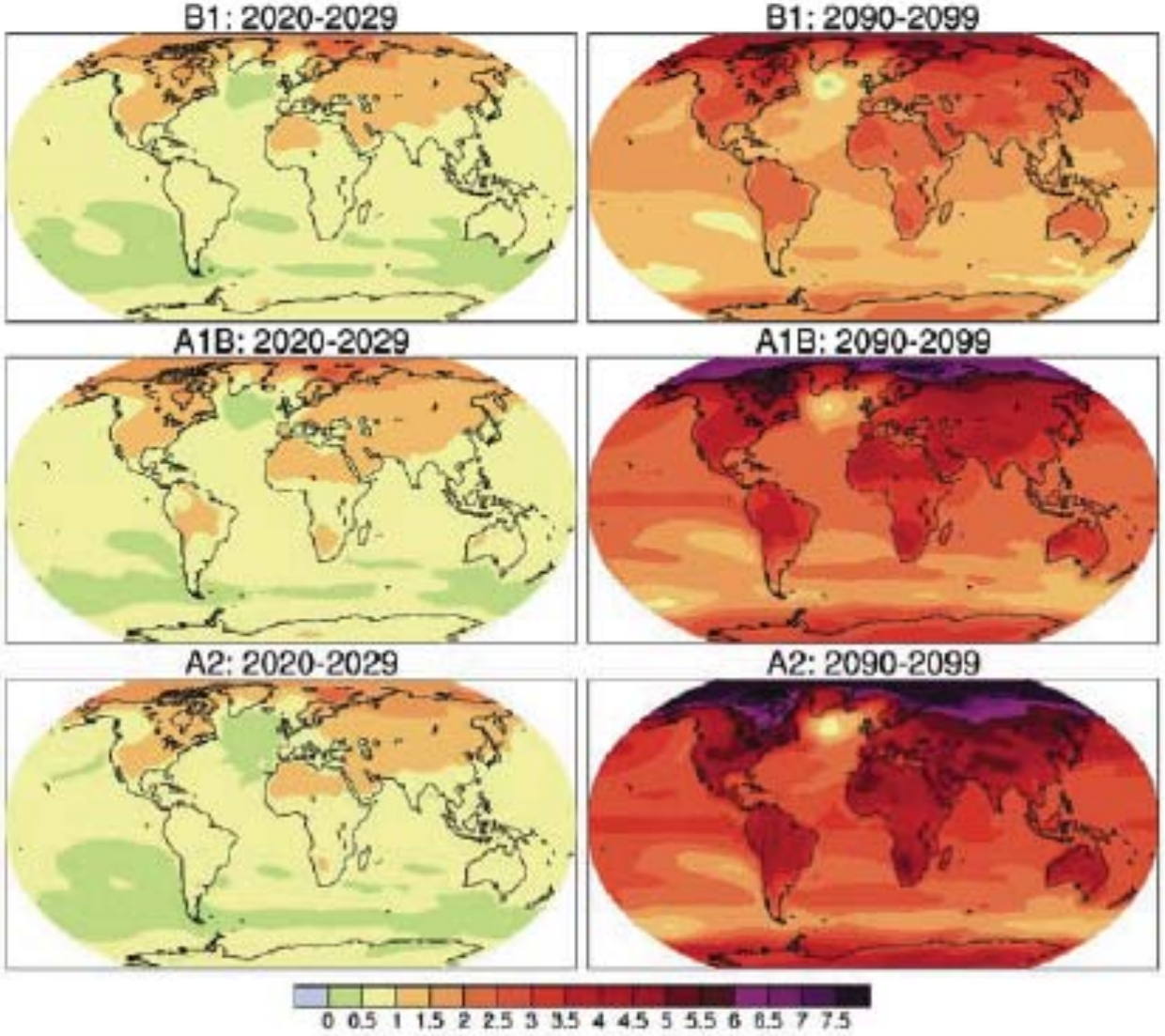
- Naturally rare or endemic
- Require large habitat areas
- Poor dispersers
- Species with fluctuating populations
- Ground nesting birds
- Game animals
- Metapopulations

Current treats

Global environmental change

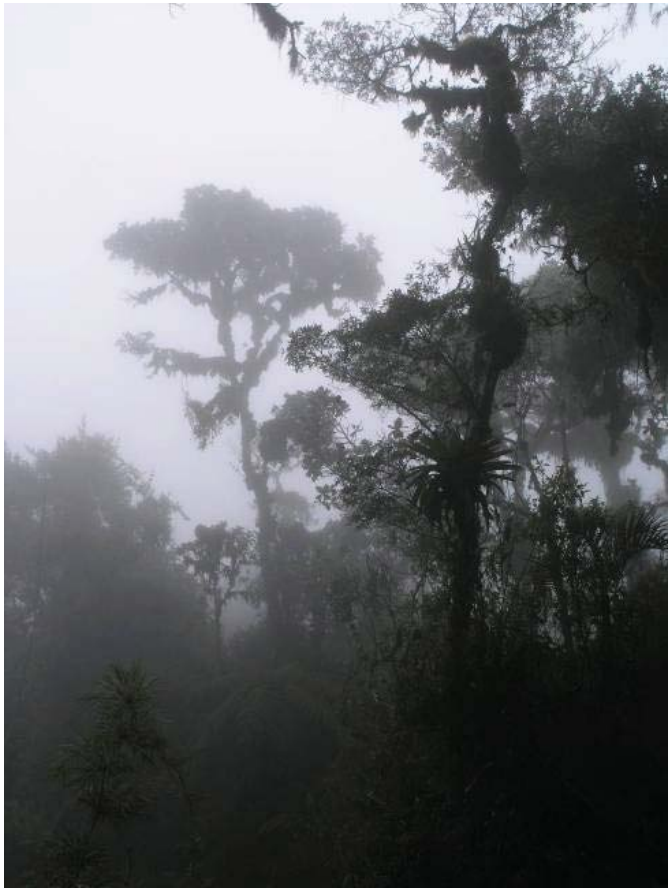
Biodiversity responses

IPCC projections



Ecological shifts resulting from current environmental change

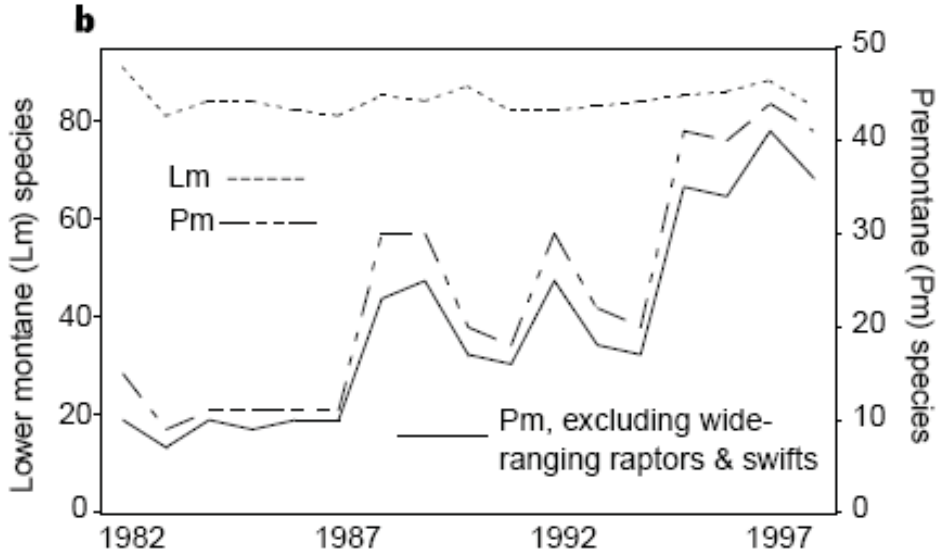
- Species invasions
- Shifts in species dominance
- Biome shifts
- Increase in diseases



Altitudinal range shifts

Monteverde, Costa Rica (Pounds et al., 1999)

- No change in lower montane bird species since 1979
- Number of premontane bird species significantly increased



Global warming and extinctions

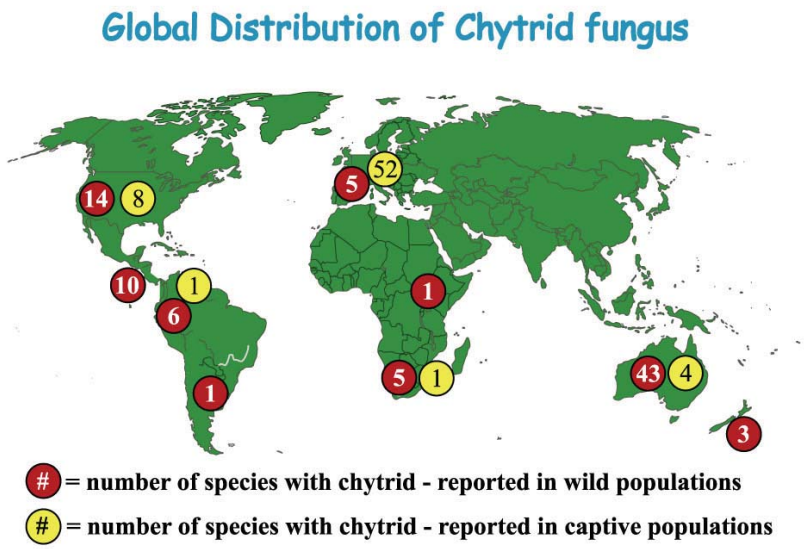
- 40% (20 of 50) of frog and toad species disappeared following synchronous population crashes in 1987 in Monte Verde, Costa Rica.
- This extinction included an endemic species: the golden toad (*Bufo periglenes*)

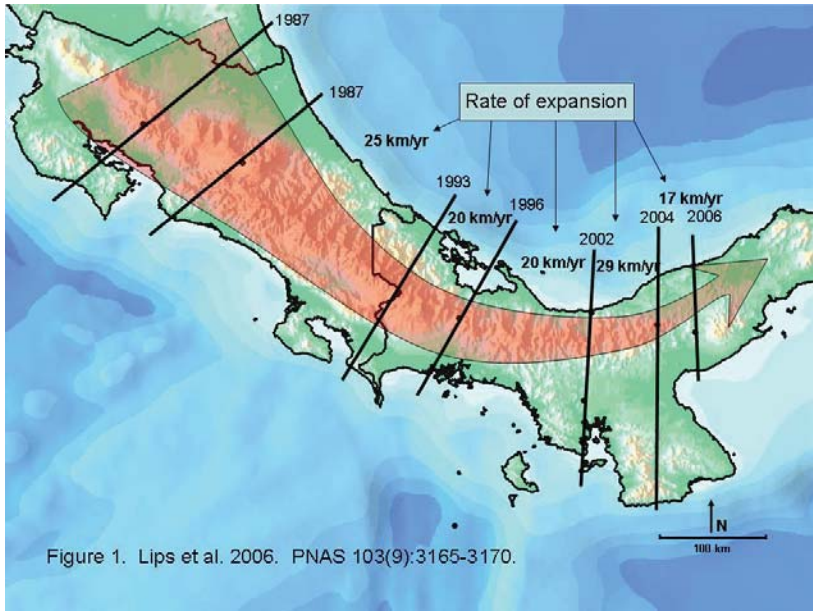
Pounds et al 2006 *Nature*

Warming and amphibian decline

- Costa Rican amphibian crash in the 1980s linked to changes in air and SSTs, & believed linked to chytrid fungus outbreak

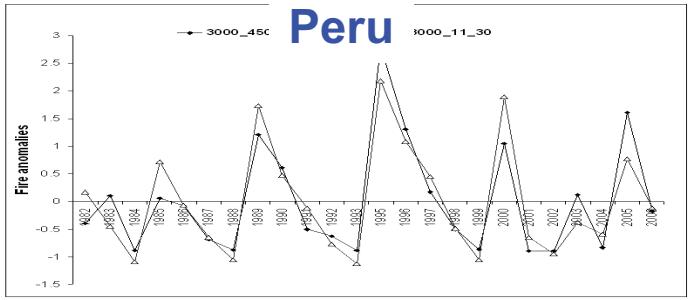
- Warming increases clouds (lower day temp & higher night temp) = Favorable conditions for chytrid fungus (Pounds et al., 2006)

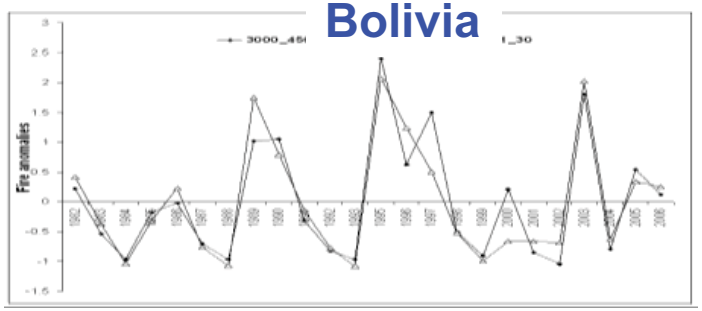


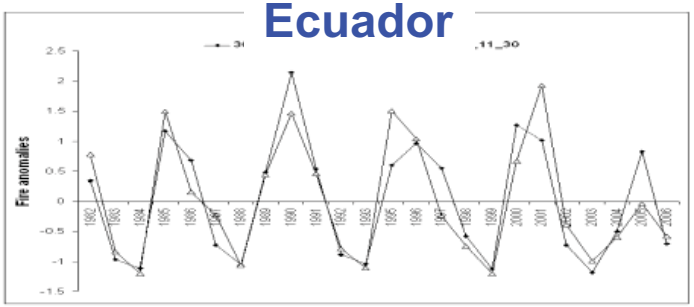


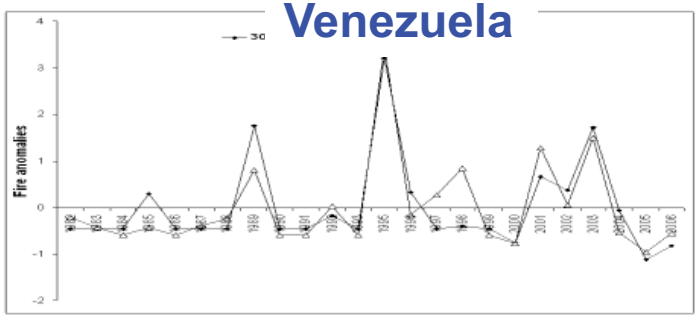
Effects of global environmental change

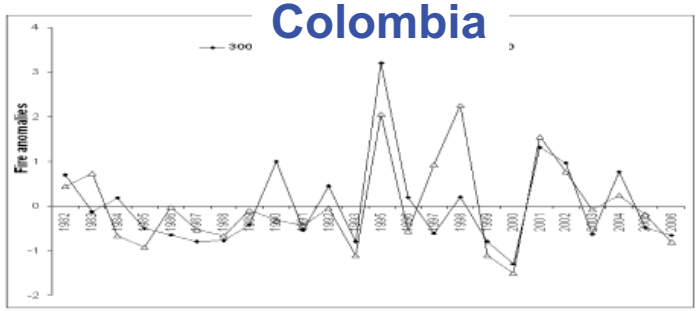
Fire trends in the Tropical Andes 1982-2005 at high elevations (2000-4500)











Roman-Cuesta et al. in press

Effects of global environmental change

Fire trends in the Tropical Andes 1982-2005 at high elevations (2000-4500)

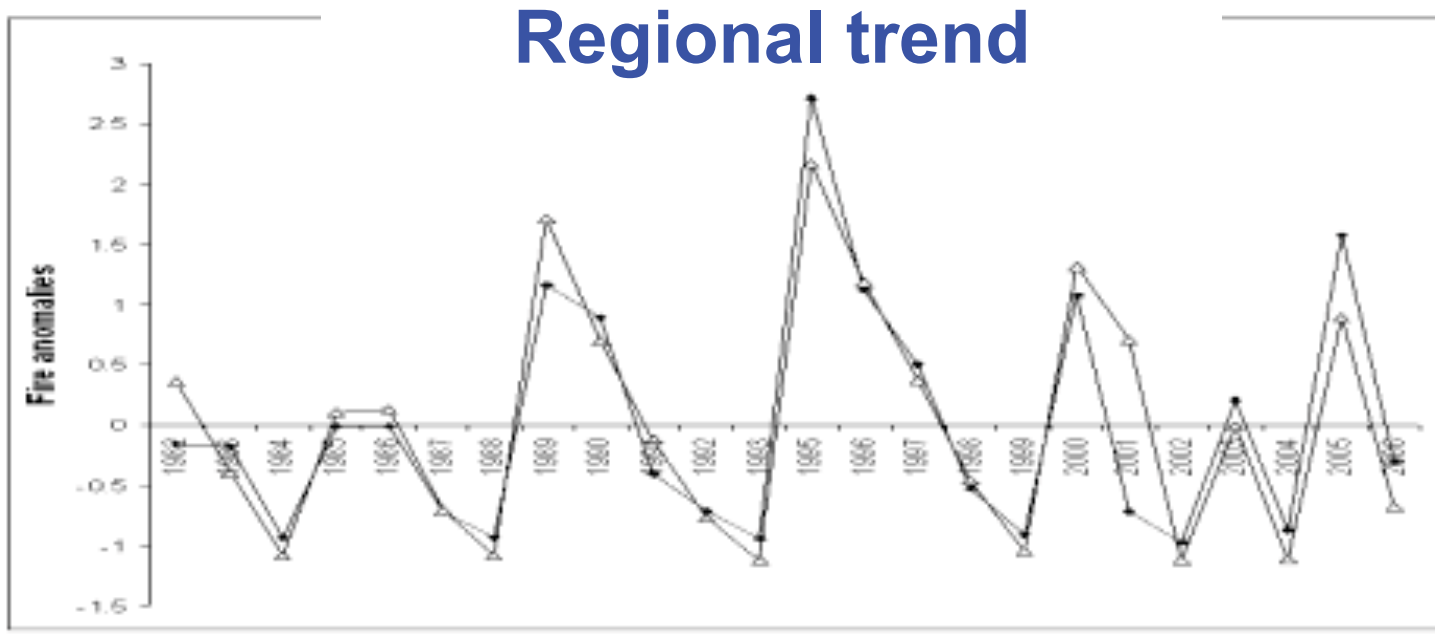
1) Strong synchronicity in regional fire peaks: climate-driven events

2) Fire can jeopardize tree migration by tree-line retreats

3) Fire should be taken into account for conservation

drier + warmer

wetter + colder



Roman-Cuesta et al. in press

Conclusions

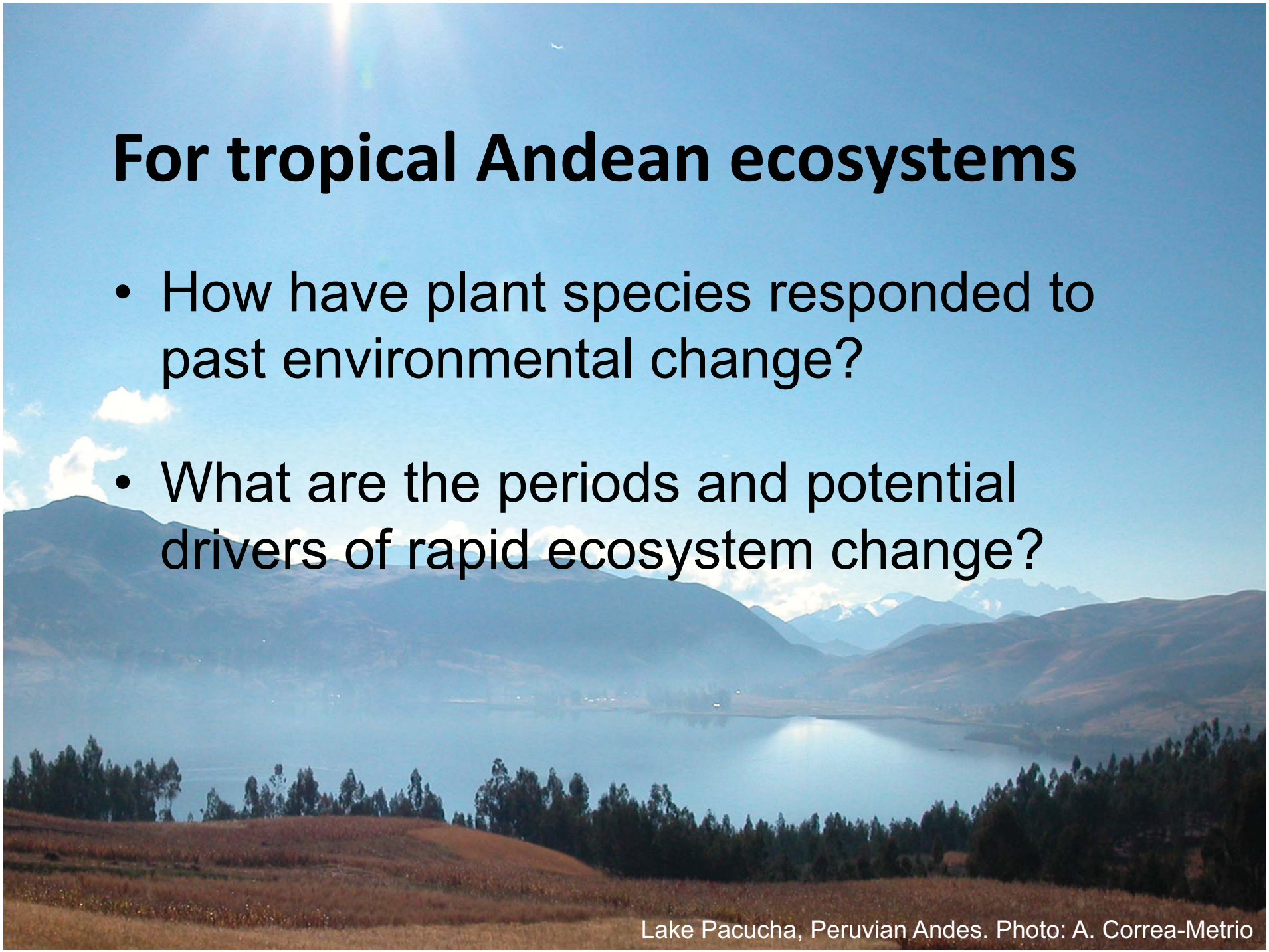
- High environmental and ecological variability foster this diversity
- Harbor high levels of biodiversity and endemism
- Classified as conservation hotspots
- Highly threatened ecosystems due to increasing human pressure and resulting land-use changes and habitat fragmentation
- Already experiencing increased fires, species range shifts and extinctions due to global environmental change

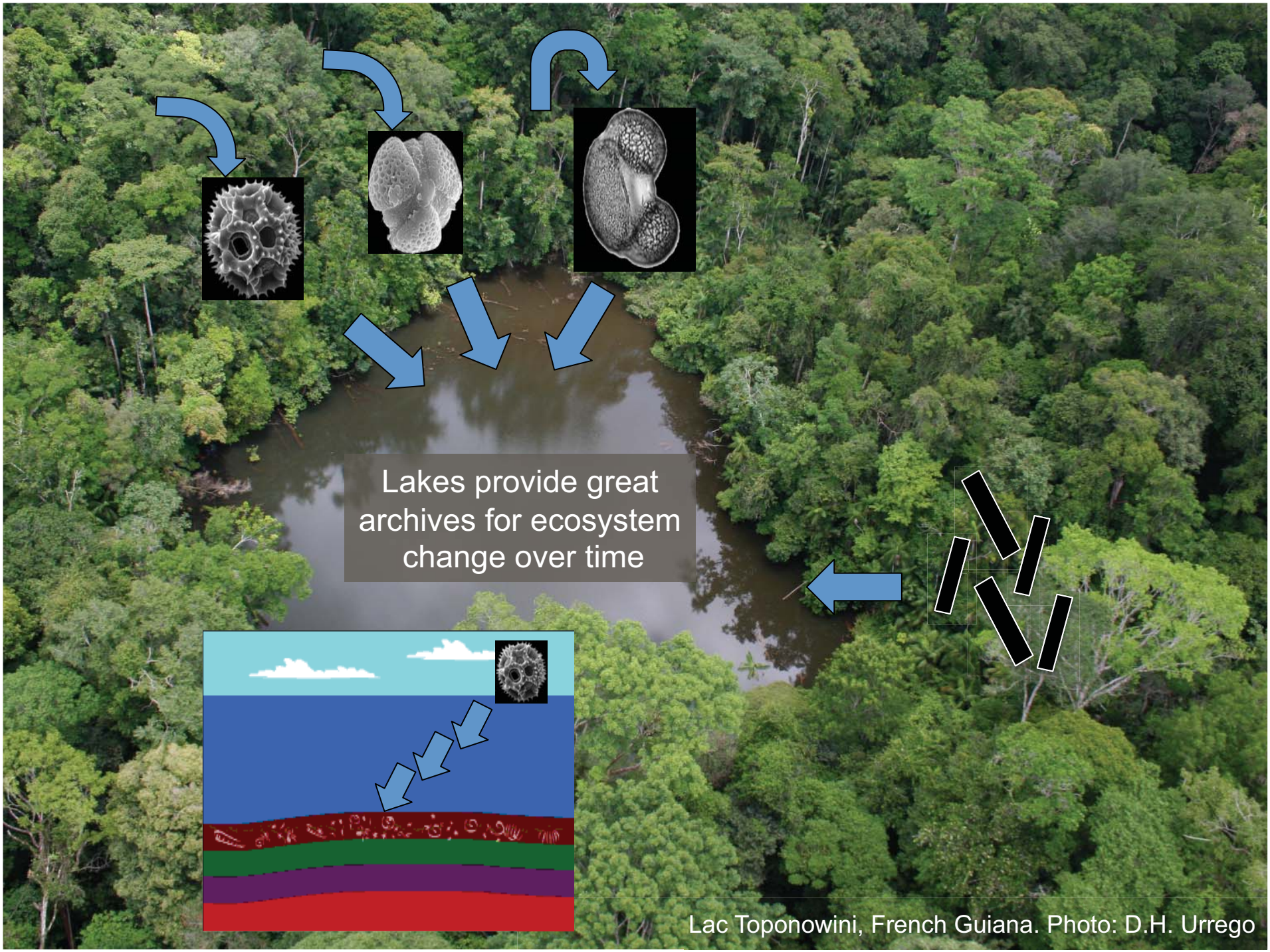
BREAK

Quick introductions

PAST: History tropical montane ecosystems

Species migrations in the central Andes, an example.


For tropical Andean ecosystems
• How have plant species responded to past environmental change?
• What are the periods and potential drivers of rapid ecosystem change?
Lake Pacucha, Peruvian Andes. Photo: A. Correa-Metrio


Lakes provide great archives for ecosystem change over time
Lac Toponowini, French Guiana. Photo: D.H. Urrego

Lakes are rare and remote in Amazonia

Selection of coring site and anchoring

Rig and platform setup

Rig manually driven

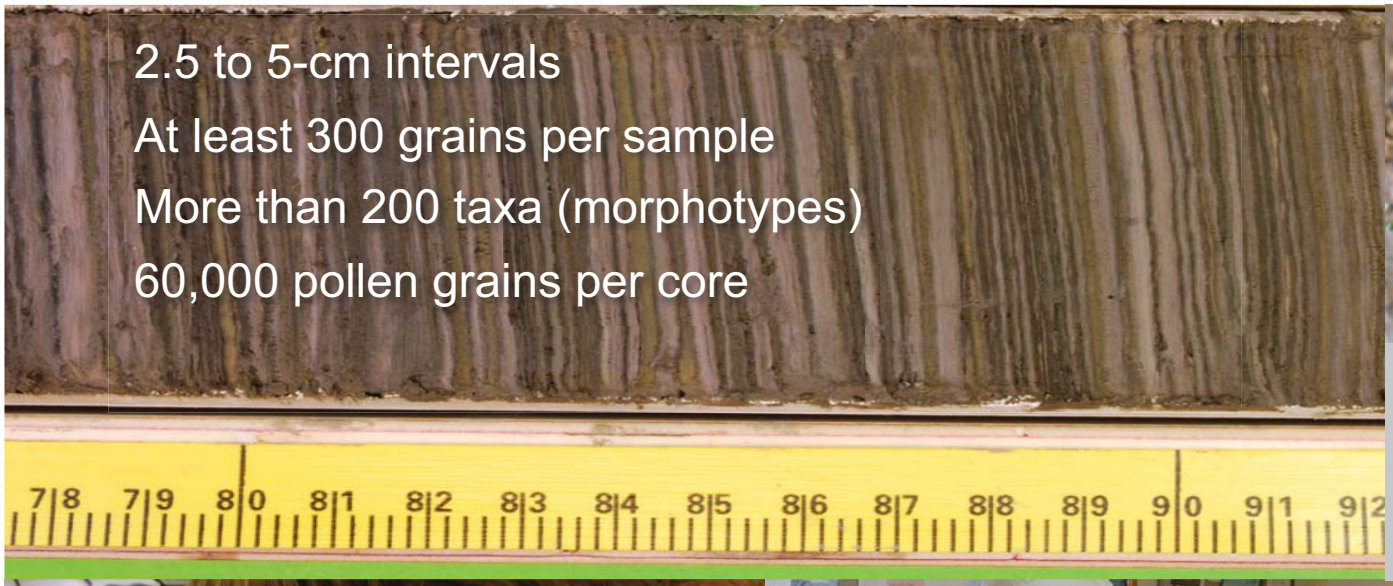
Cores transported in
1.3-m aluminum tubes

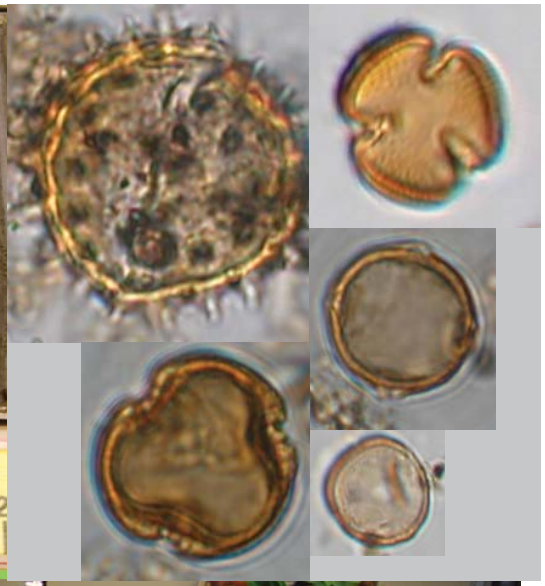
2.5 to 5-cm intervals

At least 300 grains per sample

More than 200 taxa (morphotypes)

60,000 pollen grains per core

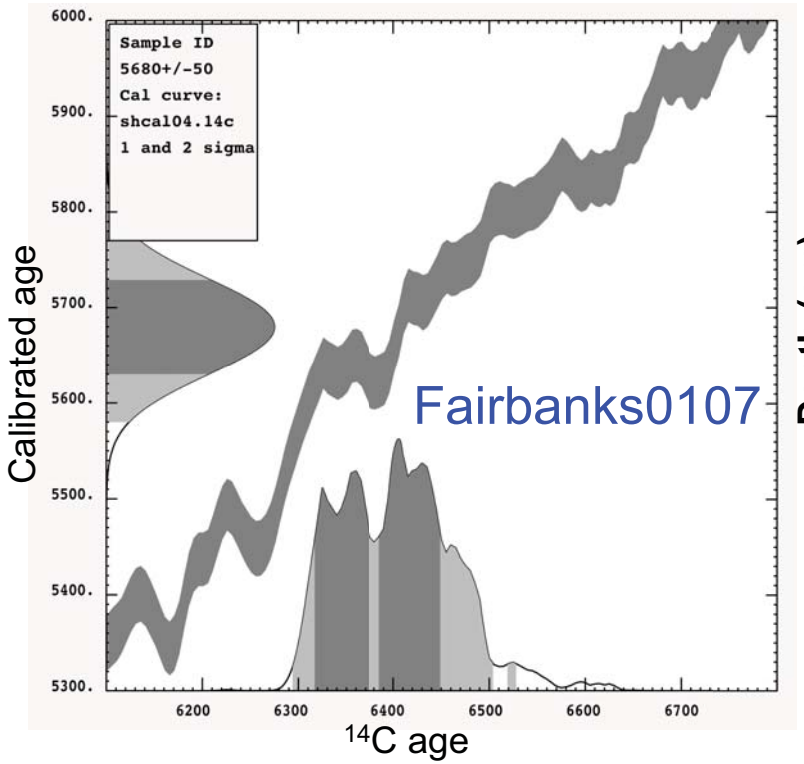


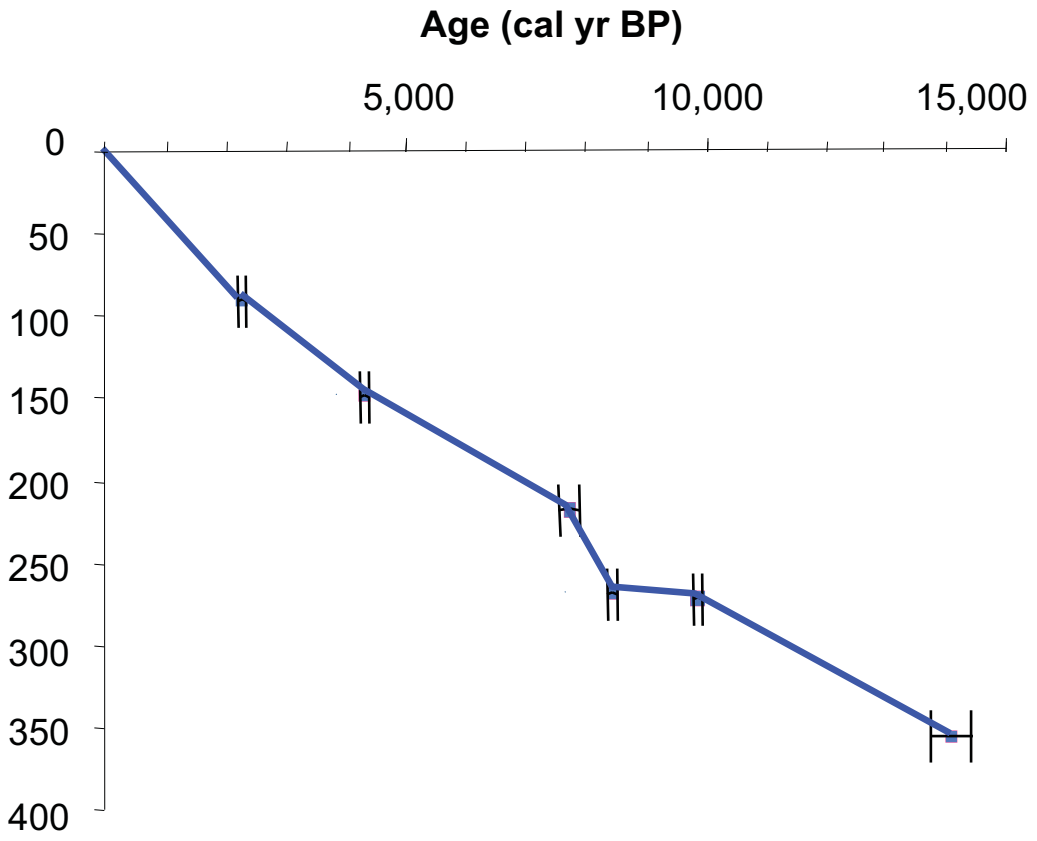


Chronologies

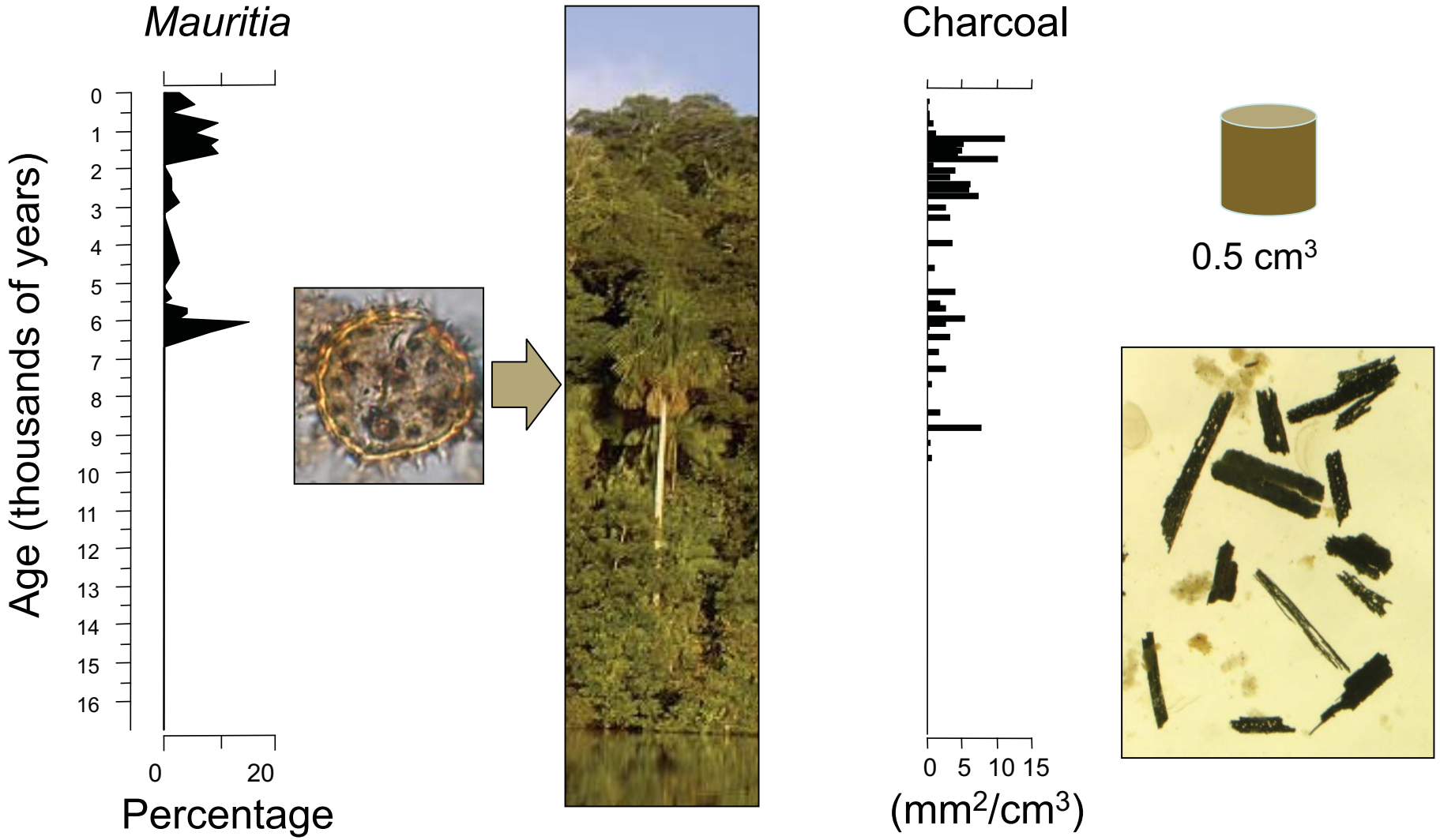
Bulk Macrofossil

^{14}C dating

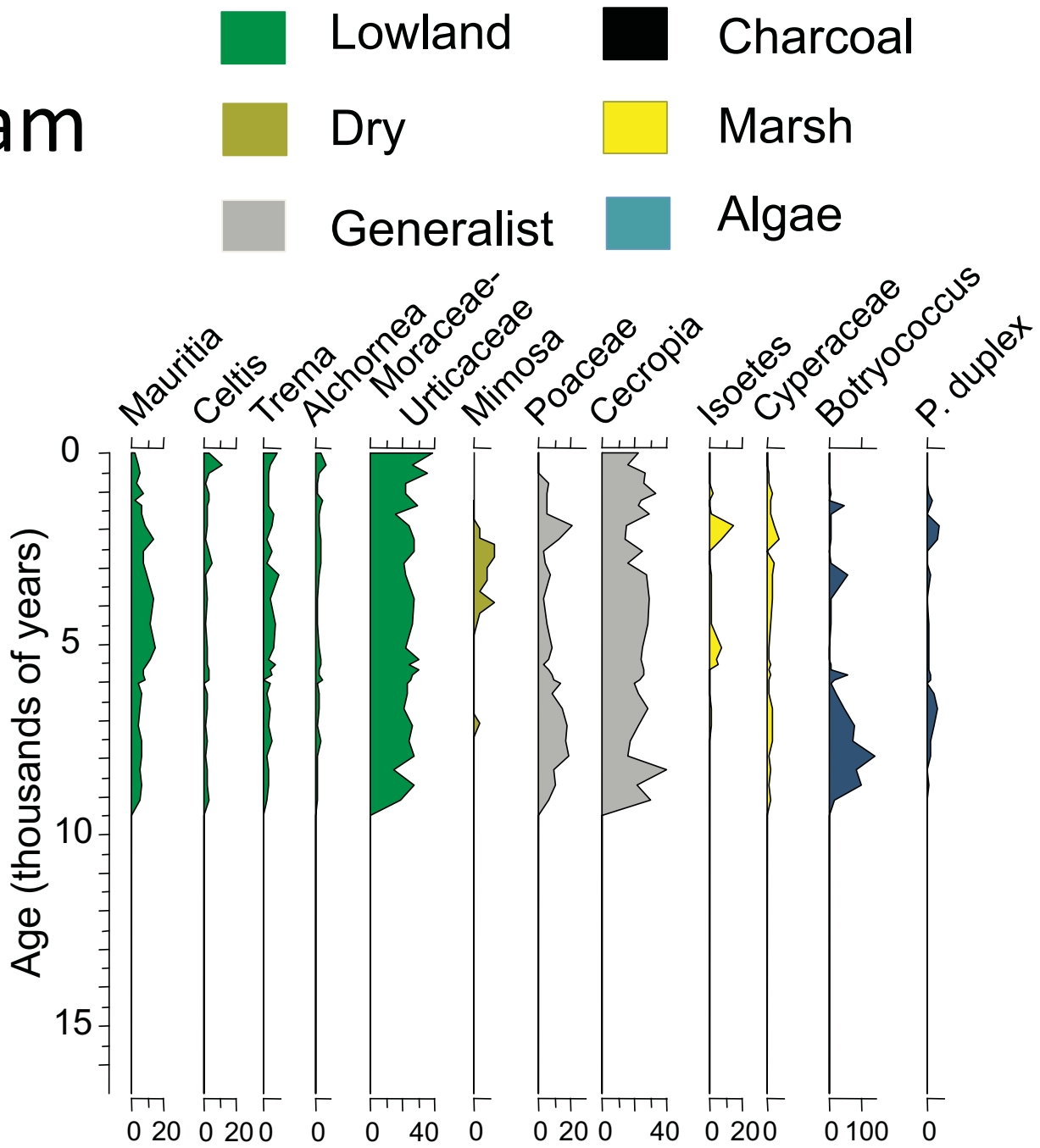




Pollen diagram



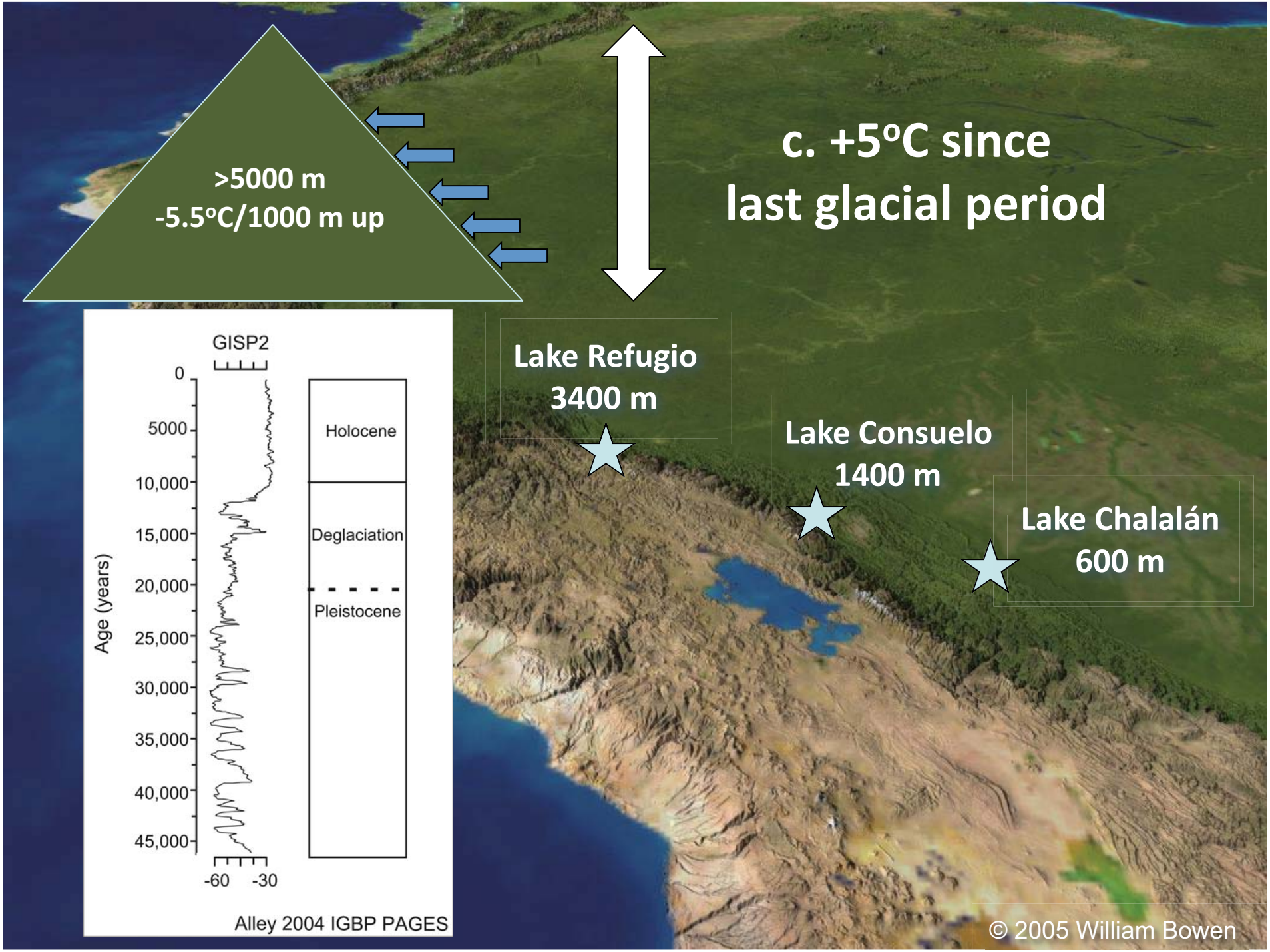
Pollen diagram

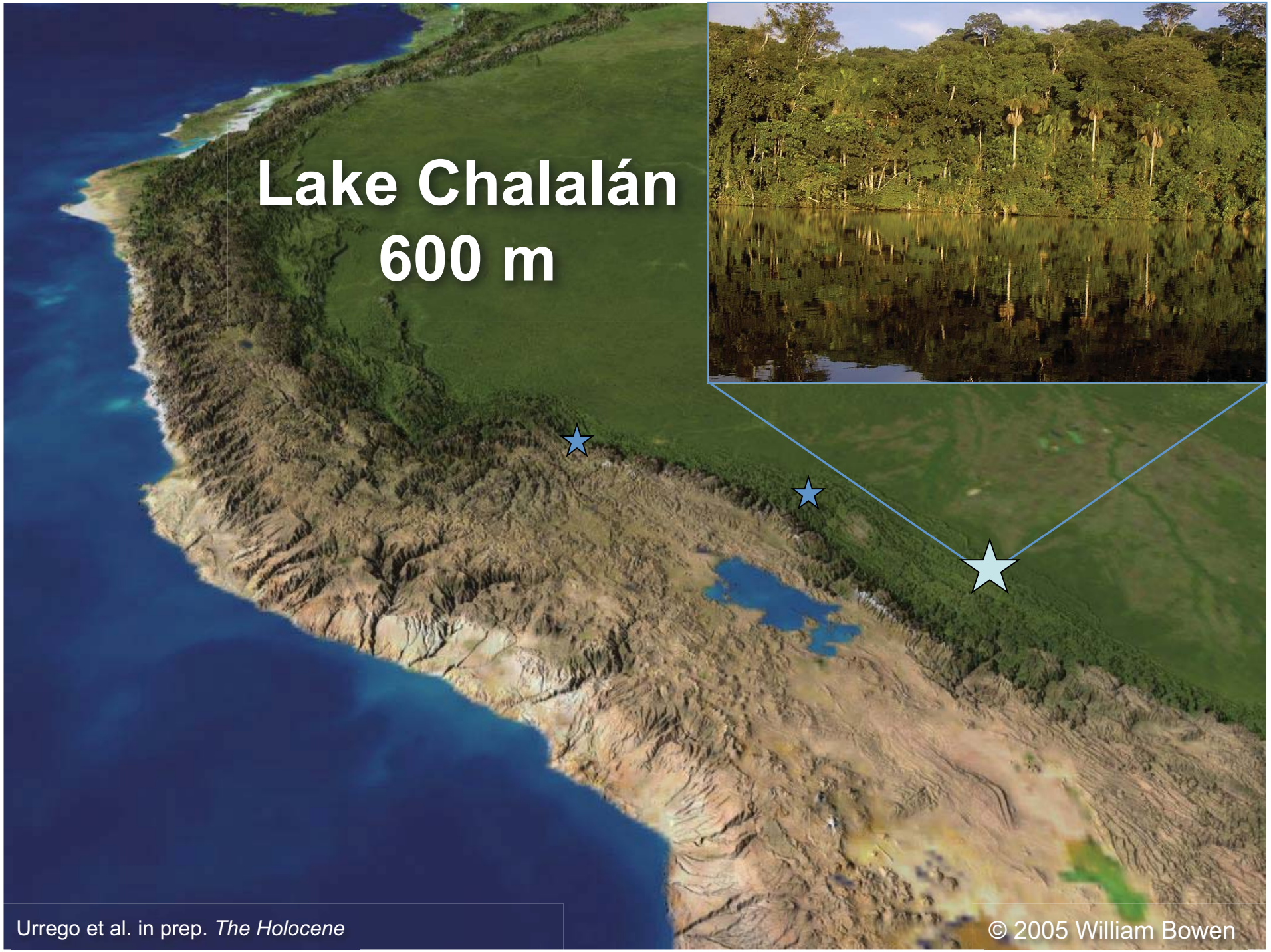


Questions?

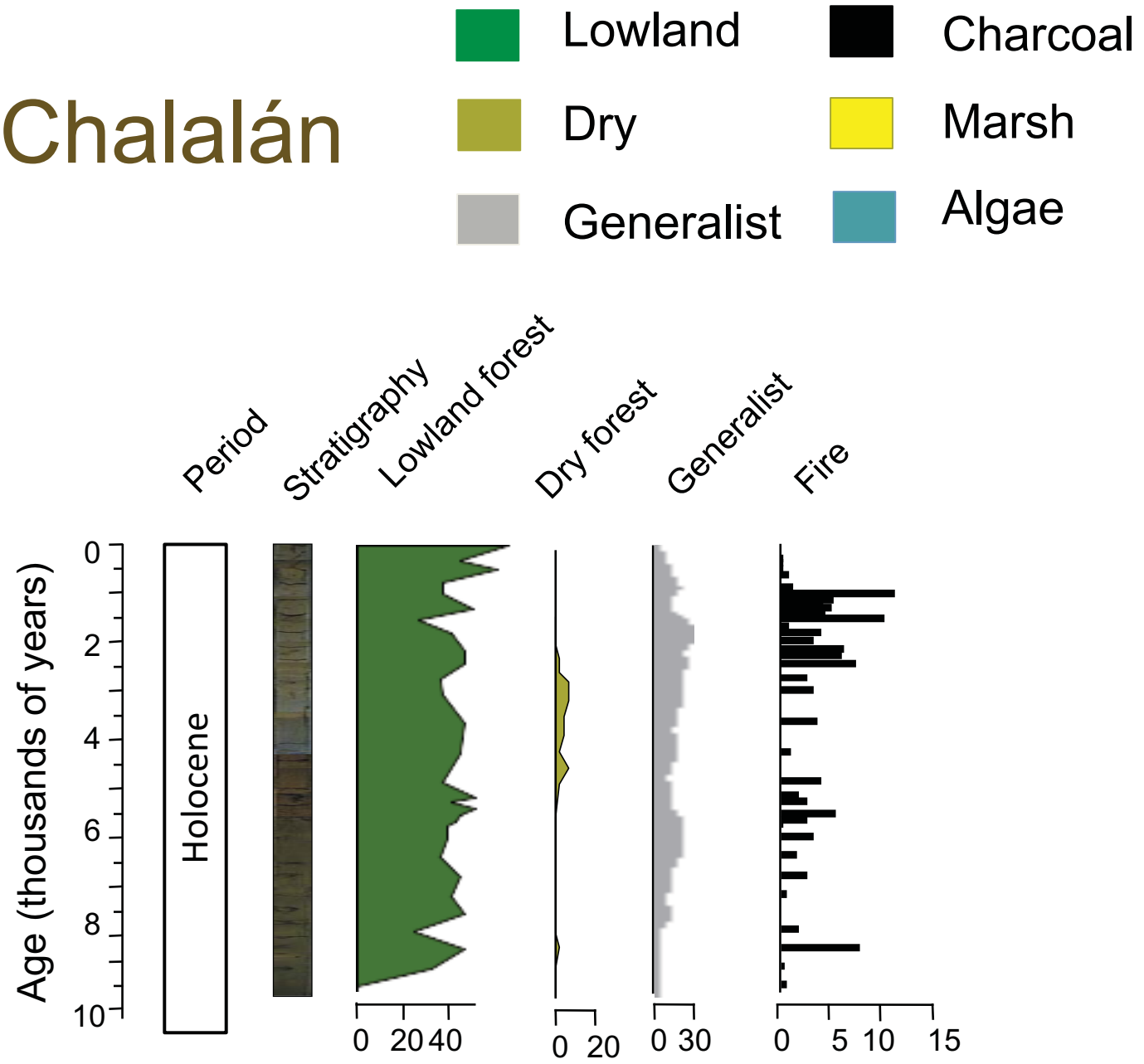
PAST: History tropical montane ecosystems

Species migrations in the central Andes, an example.

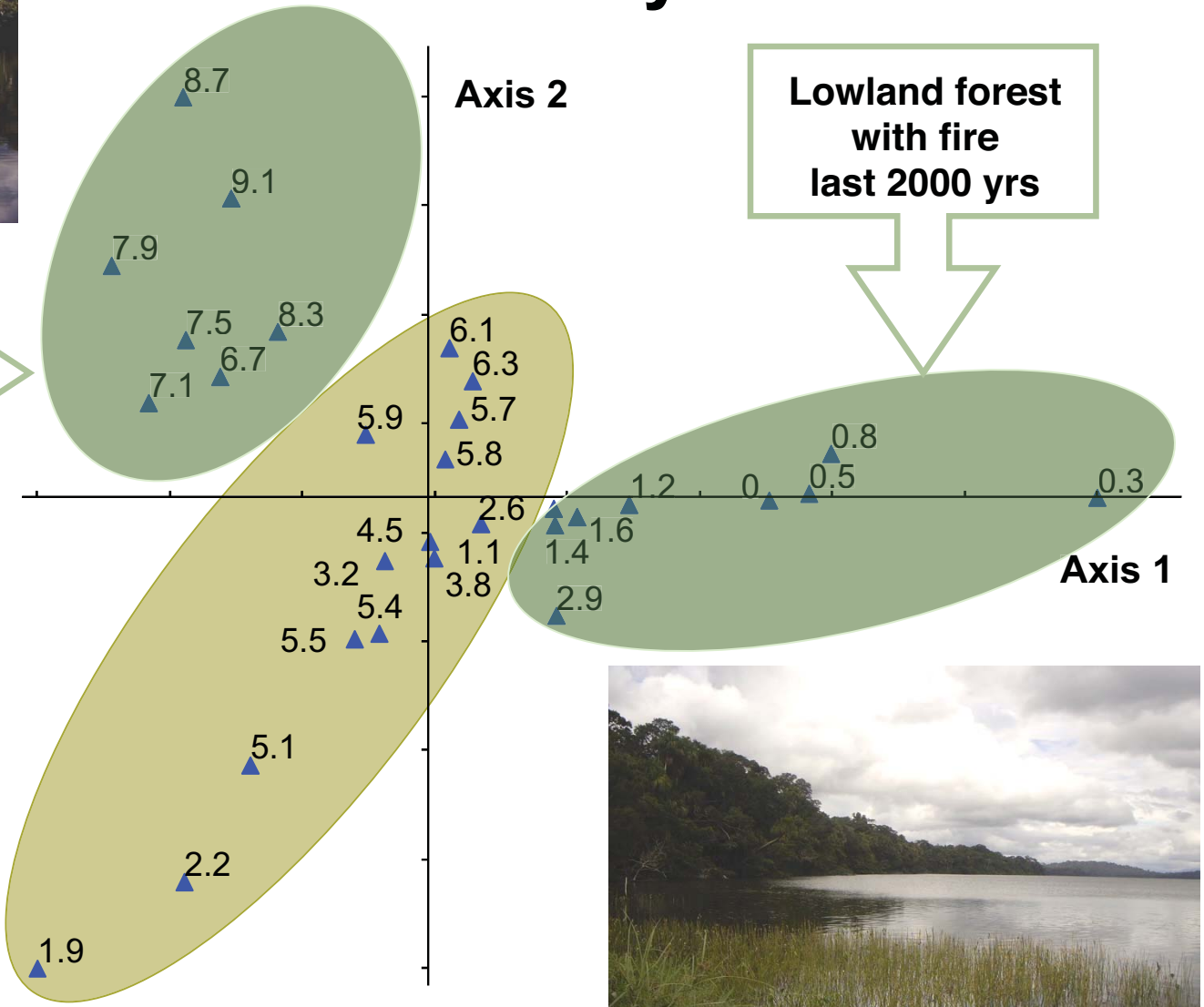

>5000 m
-5.5°C/1000 m up
c. +5°C since
last glacial period
Lake Refugio
3400 m
Lake Consuelo
1400 m
Lake Chalalán
600 m
GISP2
0
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
Age (years)
Holocene
Deglaciation
Pleistocene
-60
-30
Alley 2004 IGBP PAGES
© 2005 William Bowen


Lake Chalalán
600 m
Urrego et al. in prep. *The Holocene*
© 2005 William Bowen

Lake Chalalán



Ordination analysis



Lowland forest from 9000 to 7000 yrs

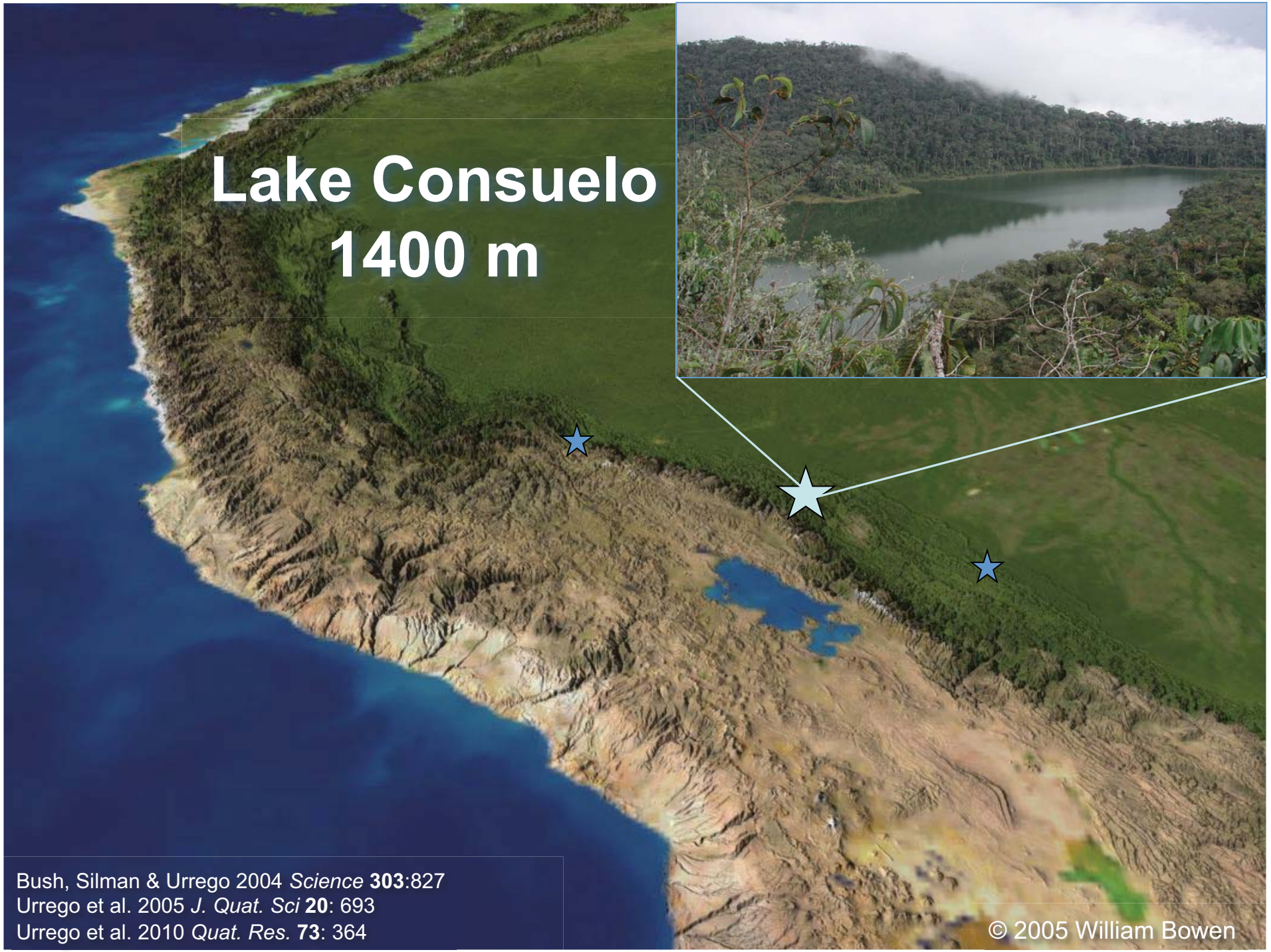
Lowland forest with fire last 2000 yrs

Dry forest elements from 7000 to 2000 yrs

Ecosystem change at 600 m

Lake Chalalán

- Continuous forest throughout the Holocene.
- Increase in dry forest elements synchronous with with regional drought between c. 7000 and 2000 years ago.
- Forest fires increase around 2000 years.
- During the last 2000 years, reverts back to lowland forests with a different composition.

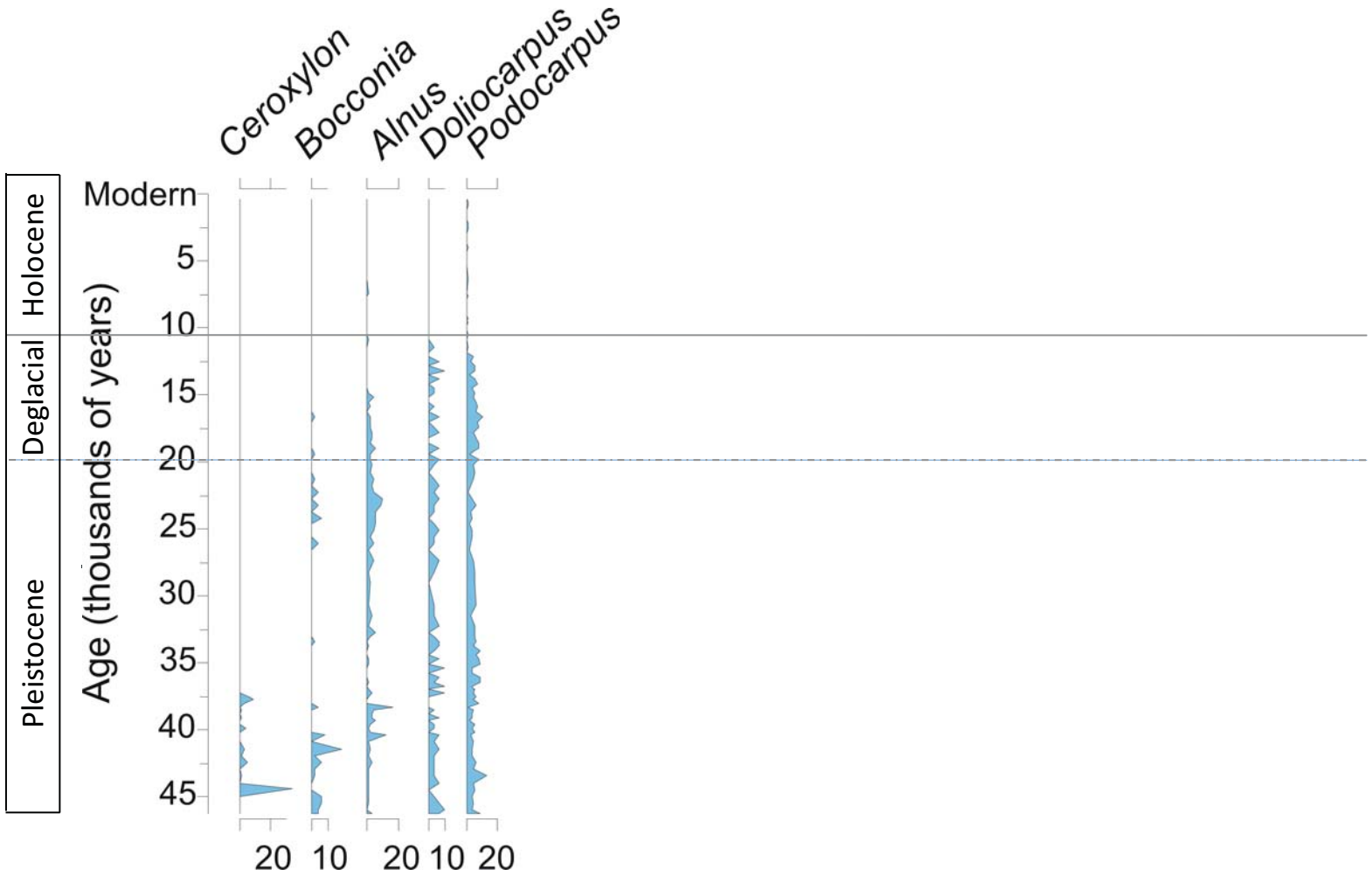


Bush, Silman & Urrego 2004 *Science* **303**:827
Urrego et al. 2005 *J. Quat. Sci* **20**: 693
Urrego et al. 2010 *Quat. Res.* **73**: 364


Lake Consuelo
1400 m

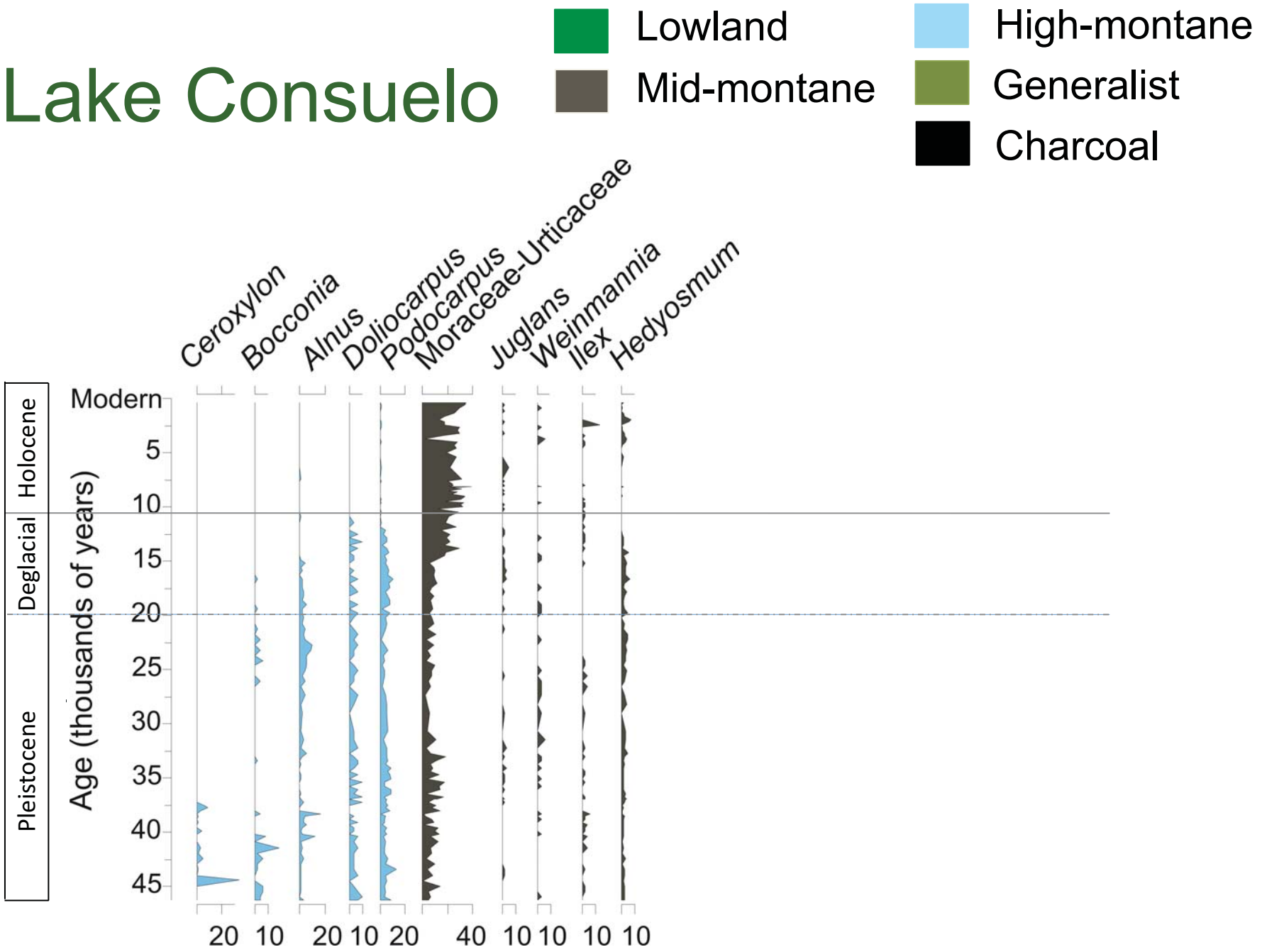
Lake Consuelo

Lowland
Mid-montane
High-montane
Generalist
Charcoal



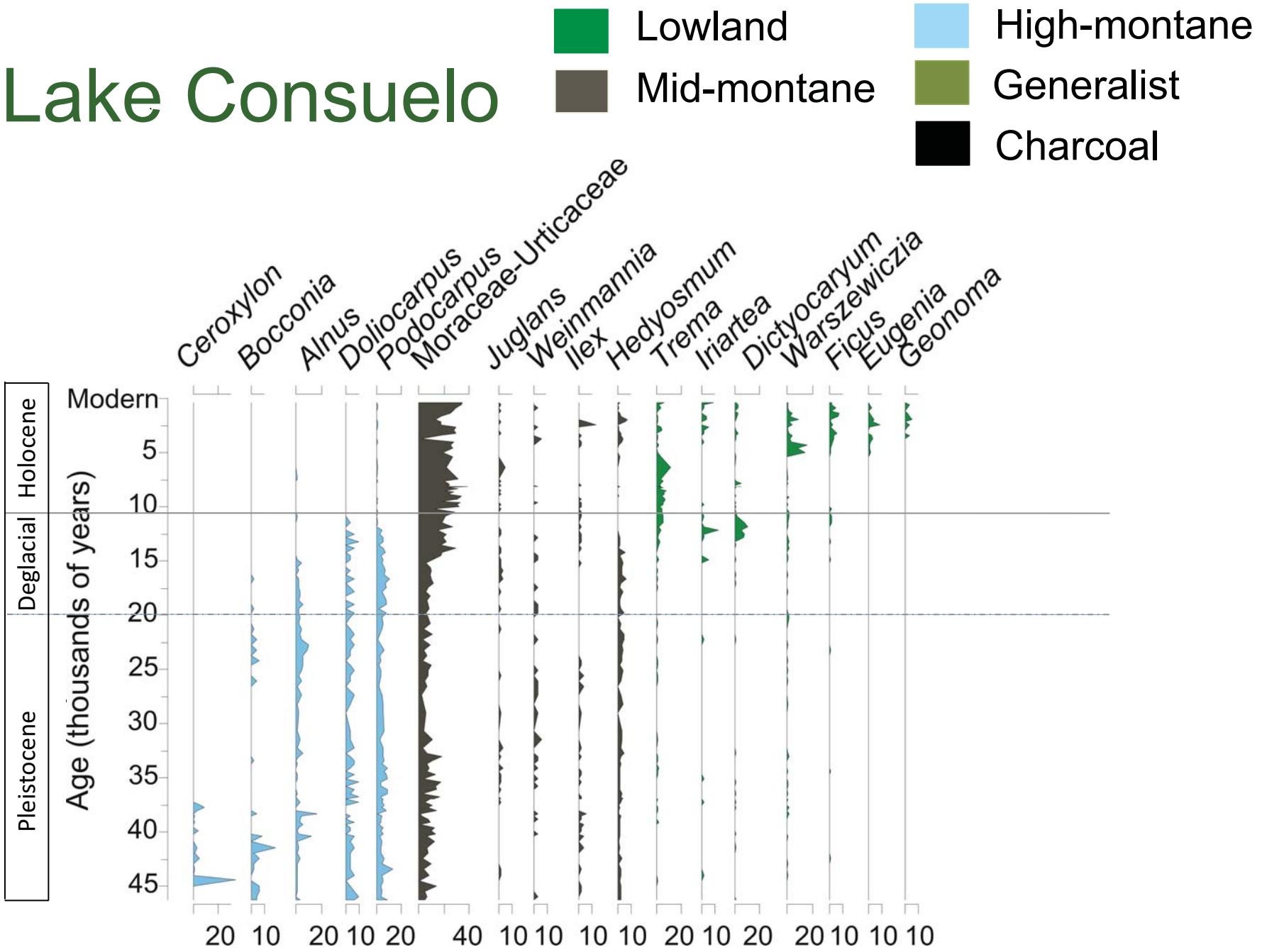
Urrego et al. 2010 *Quat. Res.* **73**: 364

Lake Consuelo



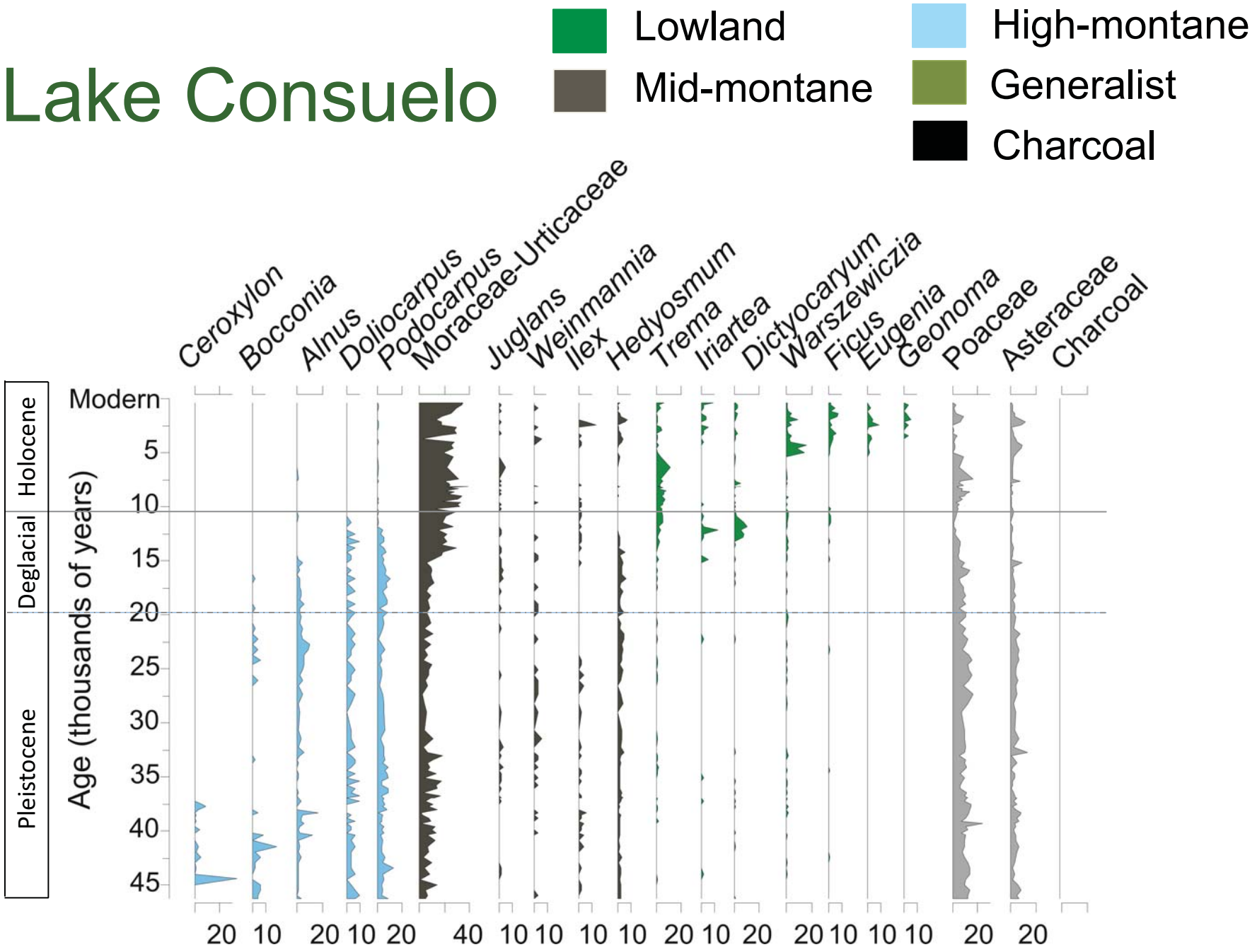
Urrego et al. 2010 *Quat. Res.* **73**: 364

Lake Consuelo



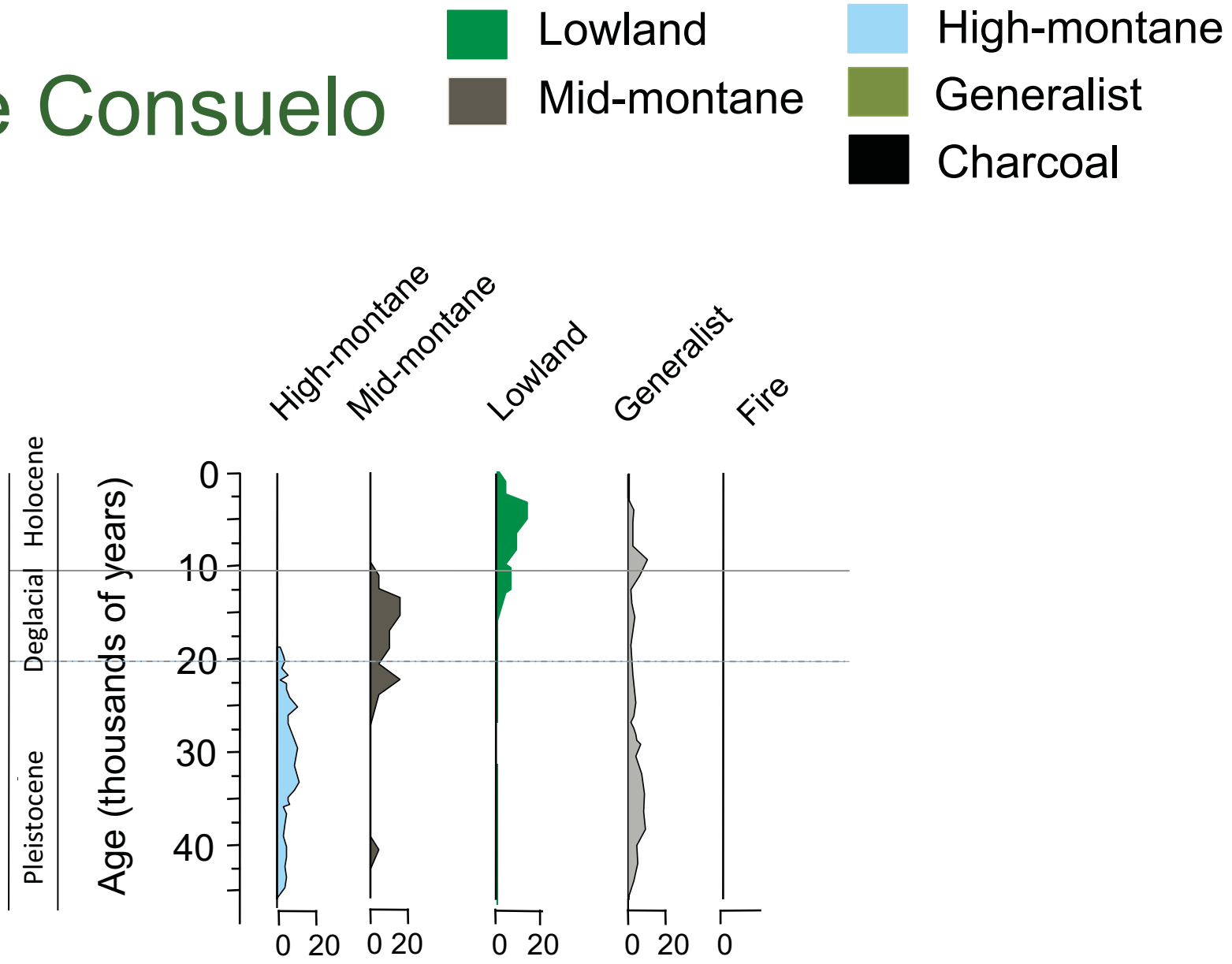
Urrego et al. 2010 *Quat. Res.* **73**: 364

Lake Consuelo



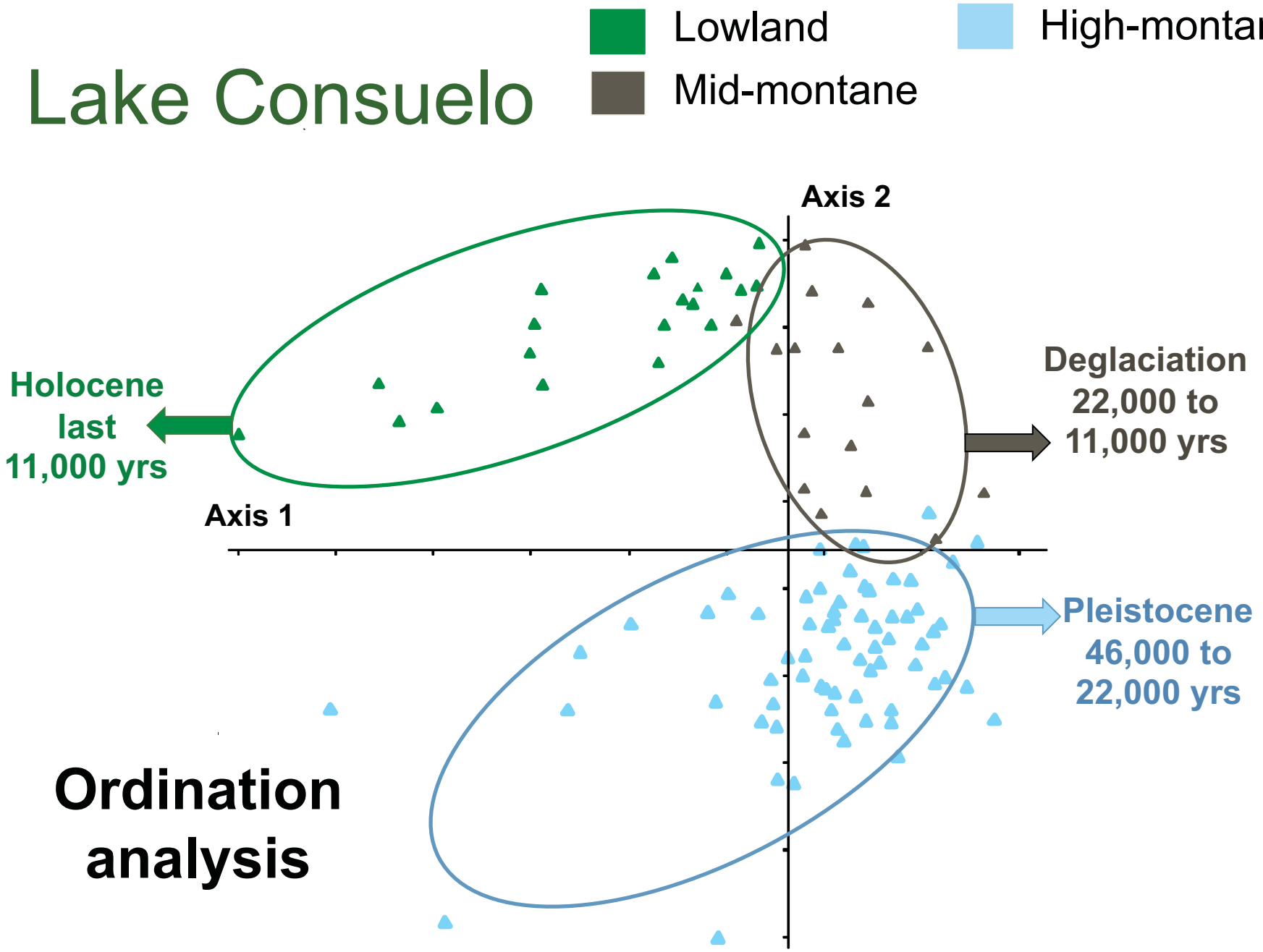
Urrego et al. 2010 *Quat. Res.* **73**: 364

Lake Consuelo



Urrego et al. 2010 *Quat. Res.* **73**: 364

Lake Consuelo



Ordination analysis

Urrego et al. 2010 *Quat. Res.* **73**: 364

Ecosystem change at 1400 m

Lake Consuelo

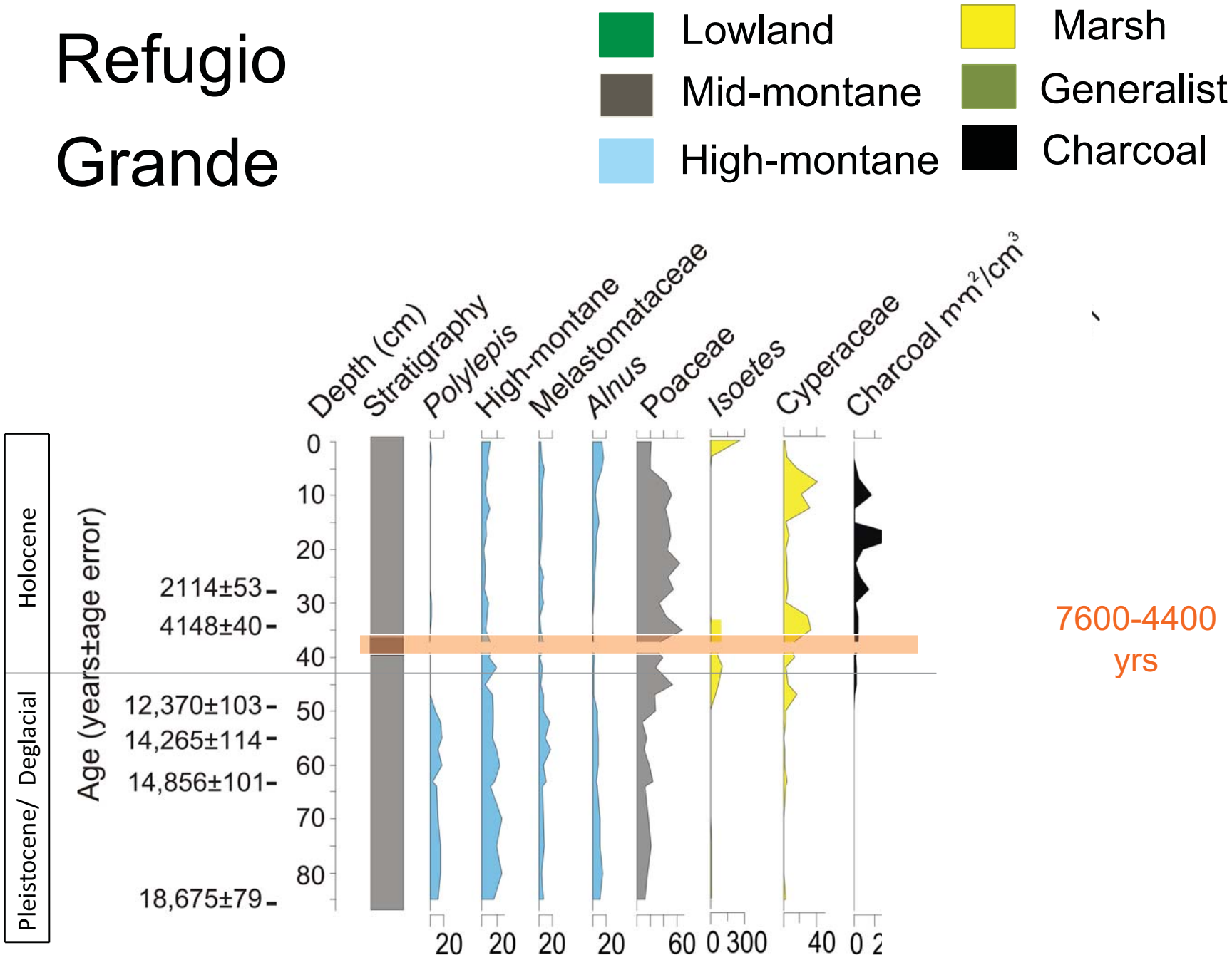
- Large species turnover from Pleistocene to Holocene (from high montane and low montane).
- Gradual ecosystem change during deglaciation (5^{o}C warming over c. 10,000 yr).
- No history of fire or human occupation at this site.

Urrego et al. accepted. *J. Quat. Sci*

Refugio Lakes

Landsat TM sensor, P. Zelazowski

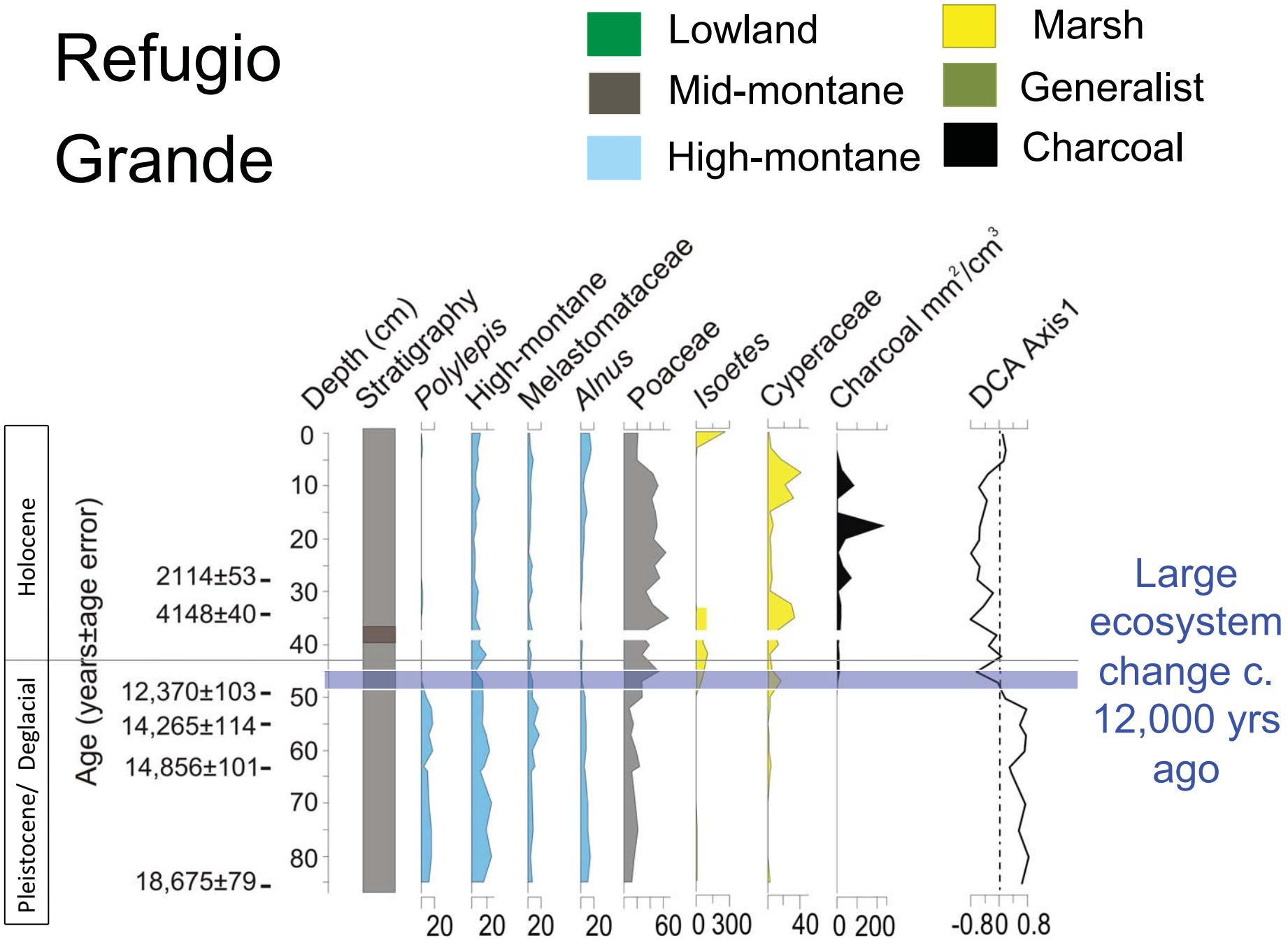
Refugio Grande



7600-4400 yrs

Urrego et al. accepted. *J. Quat Sci*

Refugio Grande



Large ecosystem change c. 12,000 yrs ago

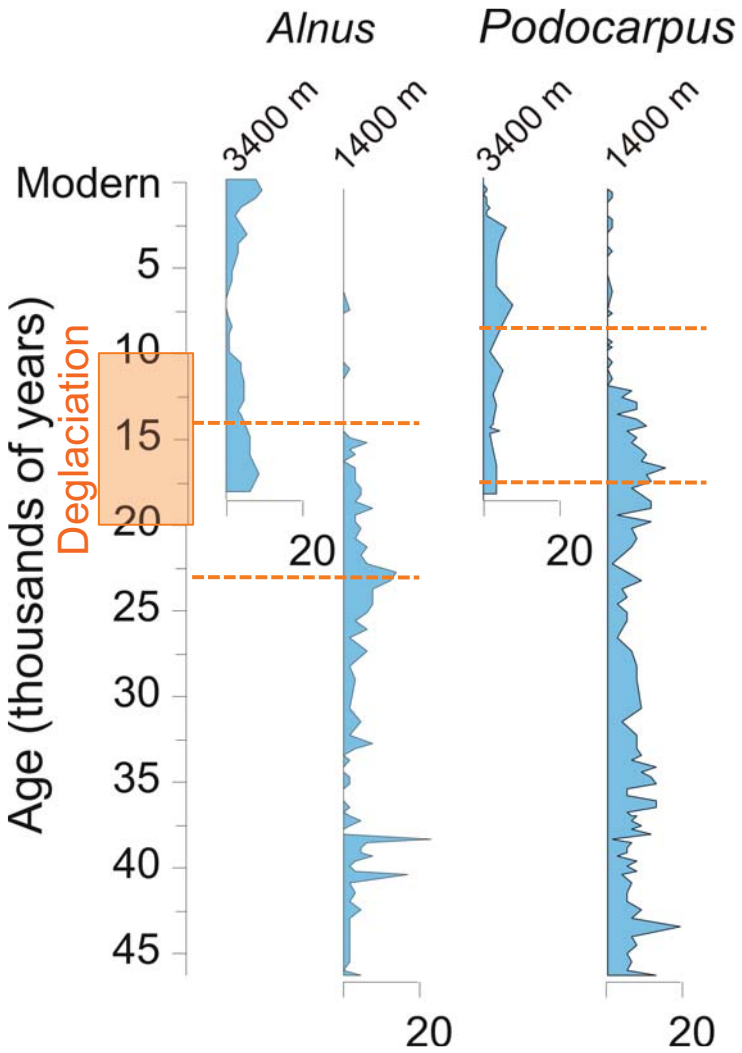
Urrego et al. accepted. *J. Quat Sci*

Ecosystem change at 3400 m

Lakes Refugio

- Tree line lay close to Refugio lakes between 16,000 and 12,000 years ago.
- Largest vegetation change occurred around 12,000, and coincided with onset of fire.
- Increase in grasslands 12,000 years ago were associated with increase in fire.
- Lakes dried out during mid-Holocene (c. 7600 and 4400 years ago).

Responses to post-glacial warming: +5°C



Migration rate

c. 1000 meters in 10,000 years

c. 10 cm/year

Current rate: c. 3m/yr
(Feeley et al. 2009 PNAS)

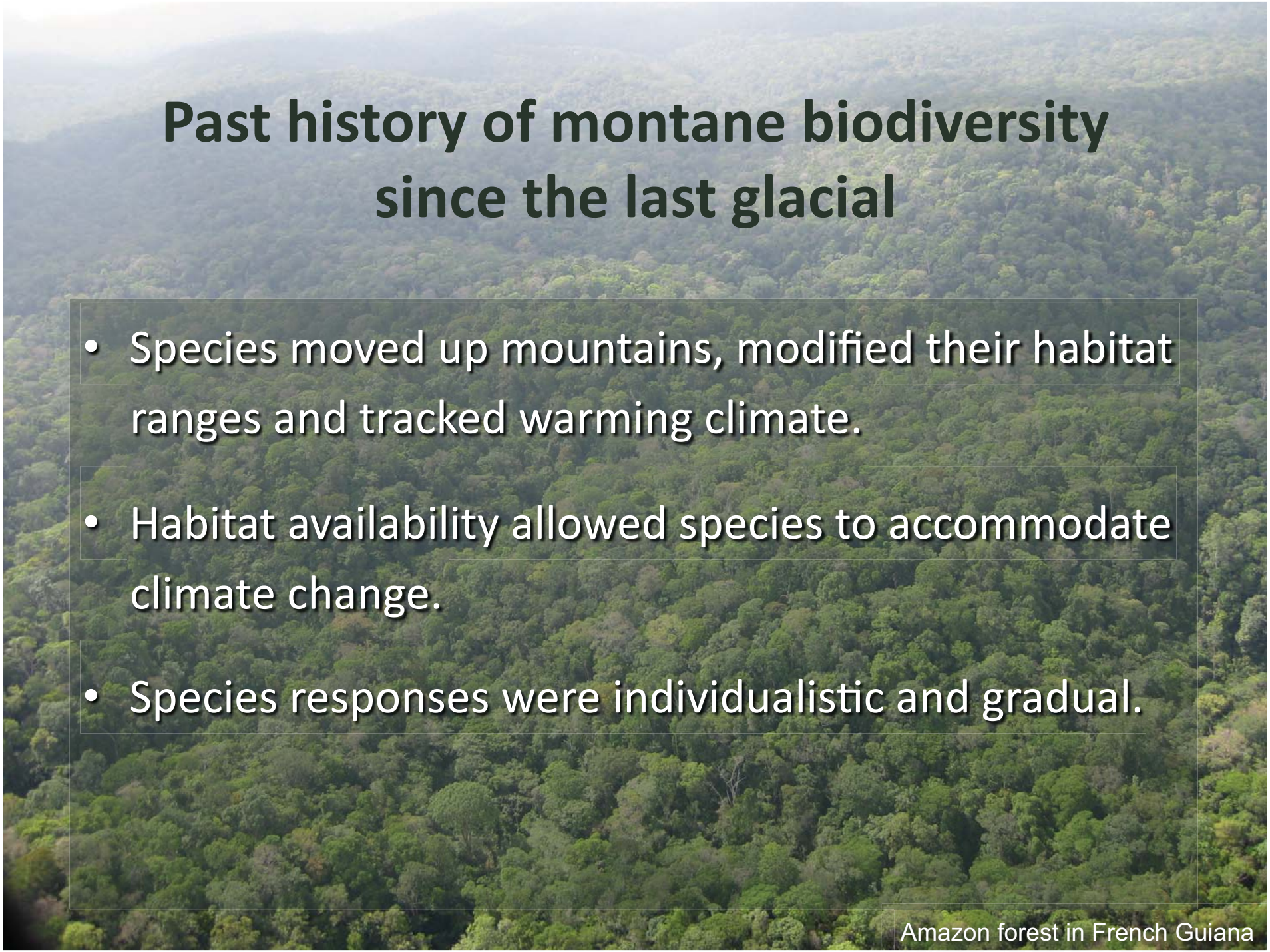
Projected speed of current temperature change is
3°C/100 years
Necessary rate of migration: 6m/yr

Species responses since the last glacial period in the tropical Andes

- Individualistic migrations.
- Slow rate of migration during the past: **10cm/yr**. Current rate is 3m/yr (Feeley et al. 2009 PNAS).
- Under current climate change, species need to migrate at 6m/yr (3^{o}C/100 yrs). Would they be able to cope?
- Habitat availability decreases with altitude in the montane systems. This will probably hinder migrations upslope.

Past history of montane biodiversity since the last glacial

- Species moved up mountains, modified their habitat ranges and tracked warming climate.
- Habitat availability allowed species to accommodate climate change.
- Species responses were individualistic and gradual.



Amazon forest in French Guiana

Past history of montane biodiversity since the last glacial

- Rates of migration c. 10 cm/year since the last glacial period.
- Current rate of migration in the tropical Andes 3 m/yr (Feeley et al. 2009 PNAS).
- Predicted speed of global climate change (3^{o}C/100 yrs = 6m/yr).
- Would current speed of environmental change, coupled with reduction of habitat availability, surpass any change experienced since the last glacial period?

Some bold predictions

- Given the speed of current environmental change, it is unlikely that species will be able to cope.
- It is likely that many species will be lost given the speed of current climate change.
- Most vulnerable species will likely be those with narrow ranges and specialized niches.
- Few species will likely take over empty niches.
- Ecosystems are likely to become less diverse.

Amazon forest in French Guiana. Photo: D.H. Urrego

Questions?

FUTURE: Striving for conservation of tropical montane ecosystems

- Reserve design
- A practical exercise

What is the best strategy for conservation of tropical montane biodiversity?

A million-dollar question

Identify threats!

Reserve design for tropical montane biodiversity

- Big or small?
- Connected or not?
- Optimum shape to maximize conservation?

Conservation Biology

Corridors and reserve design

- Purpose determines decision making
- Preliminary studies should be the baseline
- What works well in an region (or for a species) doesn't necessarily apply to other cases

Conservation Exercise

1. Develop a conservation plan for a montane region described below that would **maximize** diversity conservation, **minimize** social pressure, and remain within **budget.**

Location:	Tropical Andes
Budget:	USD$1'000 000
Current land use:	70% Primary and secondary forest
	12% above-treeline savannas
	10% fire-maintained cattle pastures
	8% active agricultural land
Price of land:	USD$15/ha of mildly eroded cattle land
	USD$20/ha of high-elevation agricultural land
	USD$8/ha of inaccessible primary forest
	USD$10/ha of primary forest

Conservation Exercise

2. List potential current and future threats to biodiversity on your reserve.
3. Discuss how you would address potential threats.
4. Prepare a 5-minute presentation to justify your conservation plan to the rest of the participants.

Questions…

Above the clouds, Peruvian Amazon. Photo: D.H. Urrego