

# The Future of Biodiversity: Science and Solutions

Dr. Andrew Gonzalez



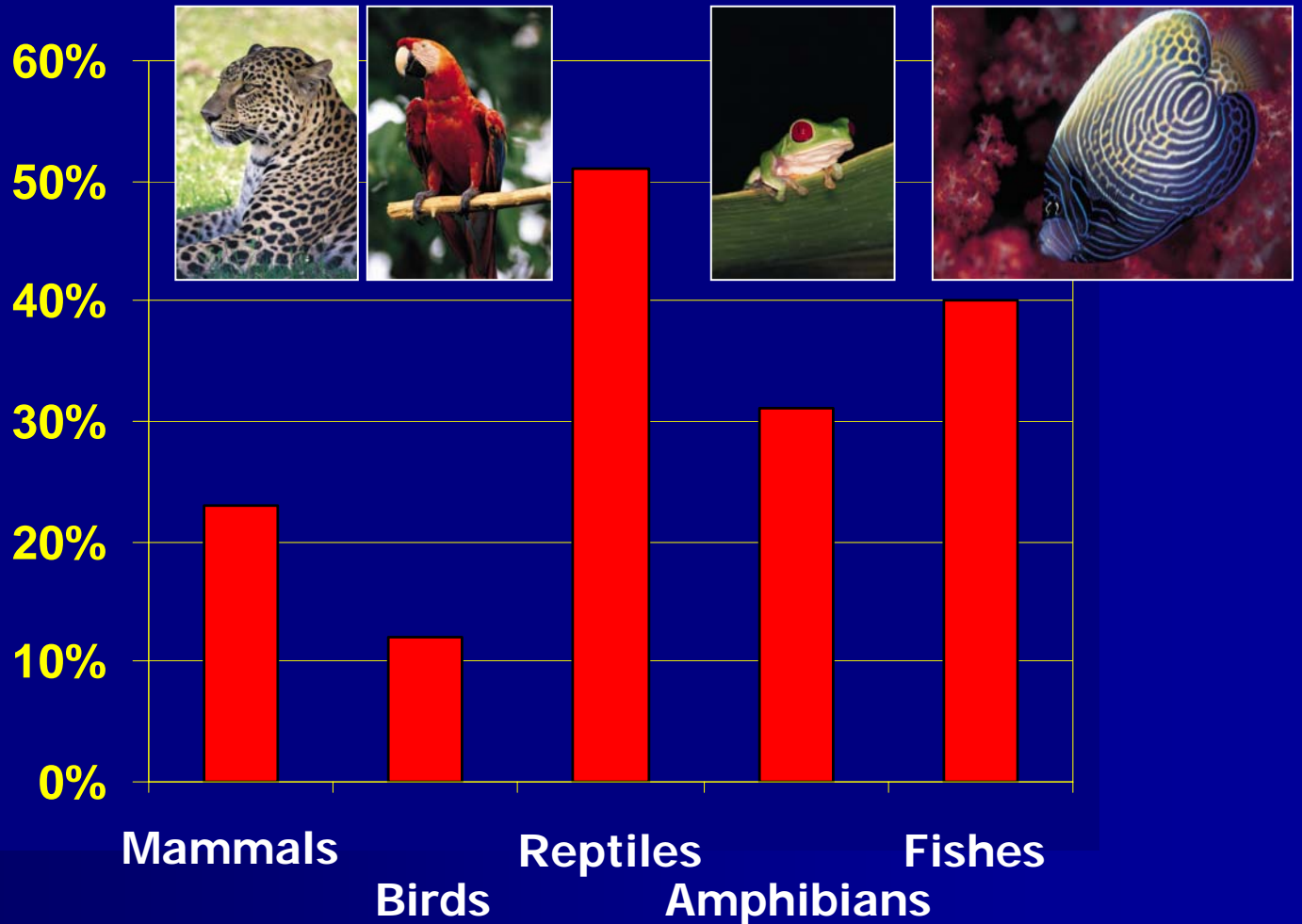
Department of Biology

***“Human actions are fundamentally, and to a significant extent irreversibly, changing the diversity of life on Earth, and most of these changes represent a loss of biodiversity.”***

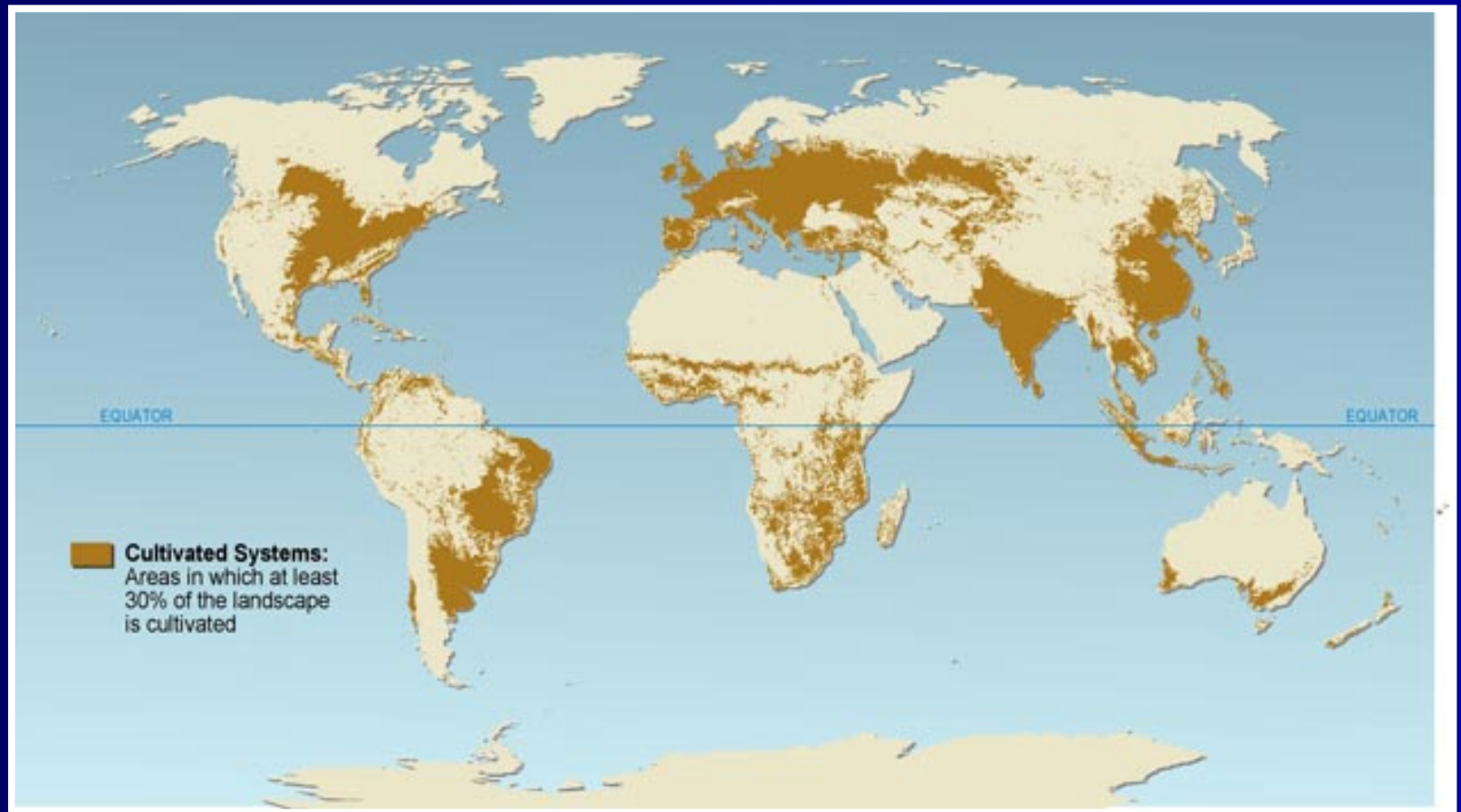
**Millenium Ecosystem Assessment (2006)**

# Species globally threatened with extinction as a proportion of total described (2006)

Data from: IUCN Red List

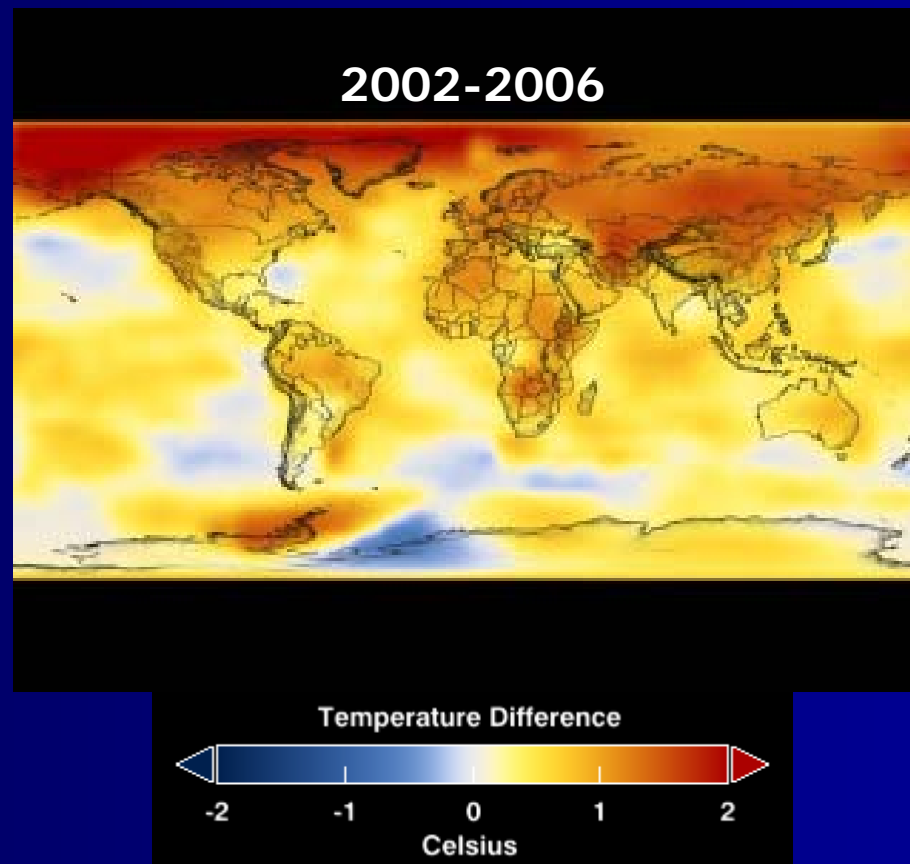


# Global Impact of Human Agriculture



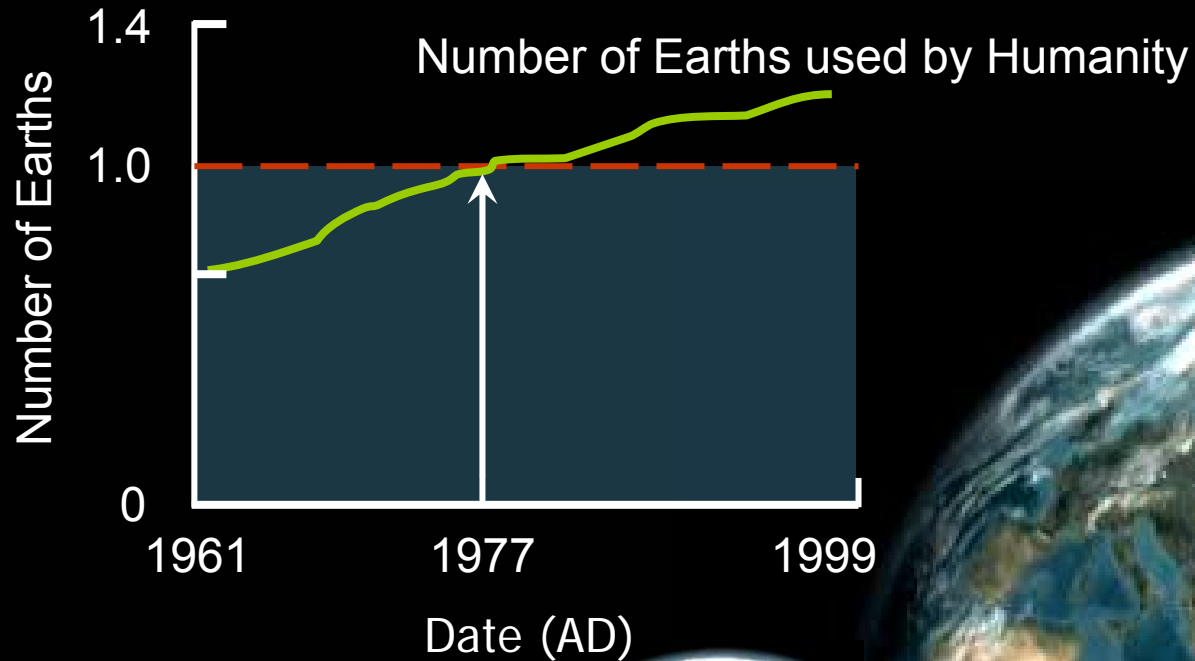
# Climate Warming and Shifting Habitat

Temperature anomalies over the last 127 years



Video: <http://svs.gsfc.nasa.gov/vis/a000000/a003300/a003375/index.html>

# We left sustainability behind in the late 70s





Human  
modification  
of the  
Biosphere



Climate  
Change

Land Use

Pollution



Speciation



Adaptation



Extinction



**Biodiversity**

# Plan

- 1) What do we know about biodiversity?
- 2) What do we know about extinction?
- 3) How do we predict future extinction?
- 4) What are the solutions?

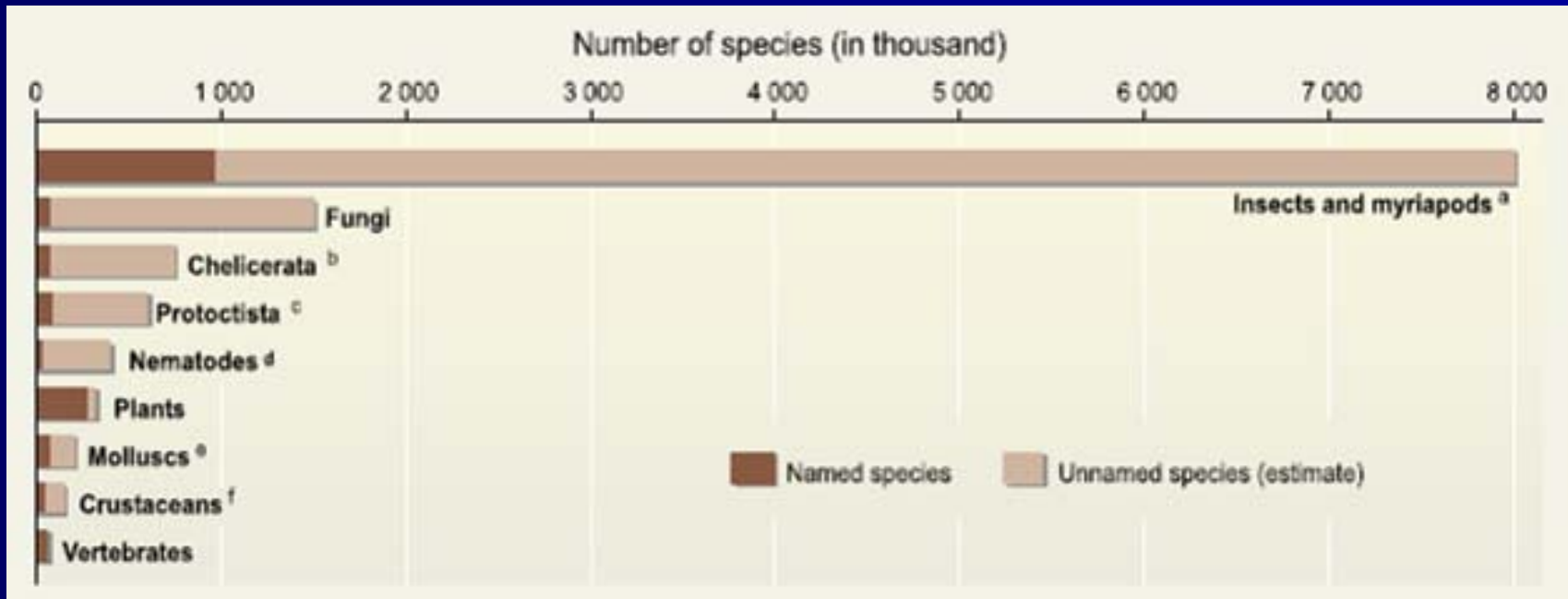


# What is Biodiversity?

*"The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems of which they are part; this includes diversity within species, between species and ecosystems."*  
*Convention for Biological Diversity (1992)*



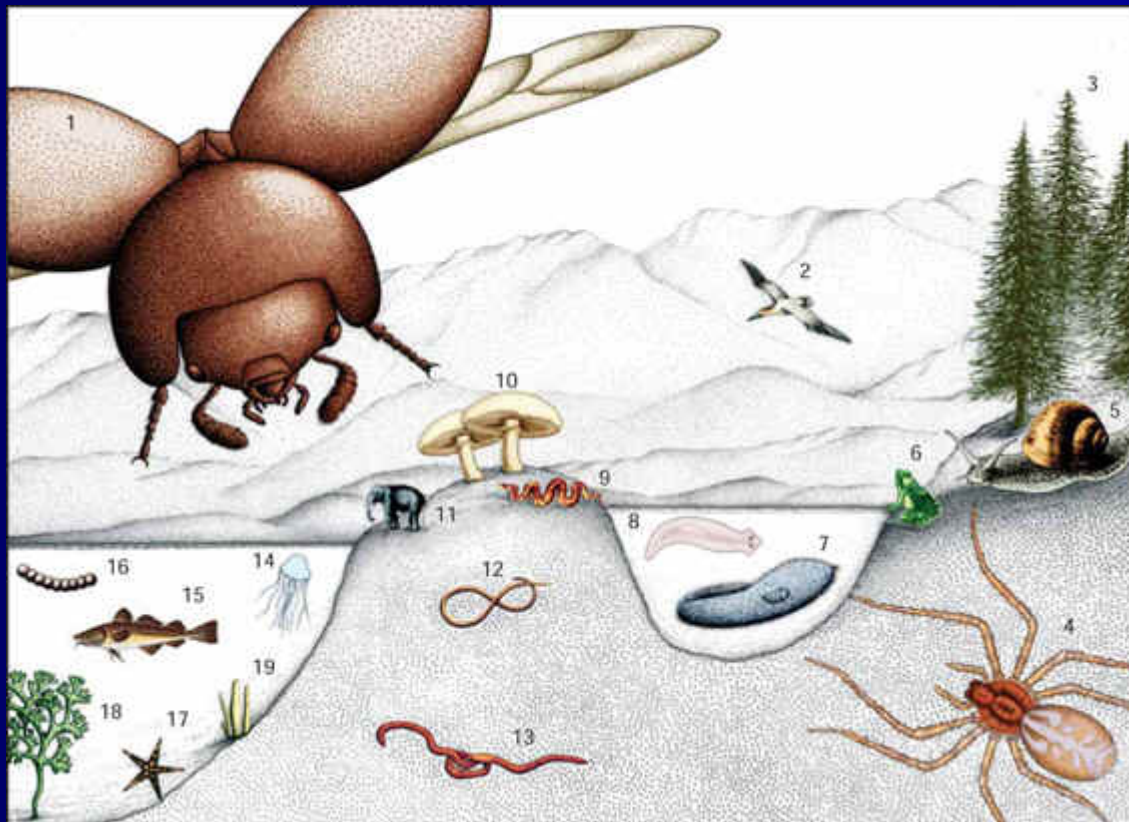
# The Majority of Earth's Biodiversity remains undescribed



Roughly 1.5 million species have been described out of an estimated total of ~10 million species.

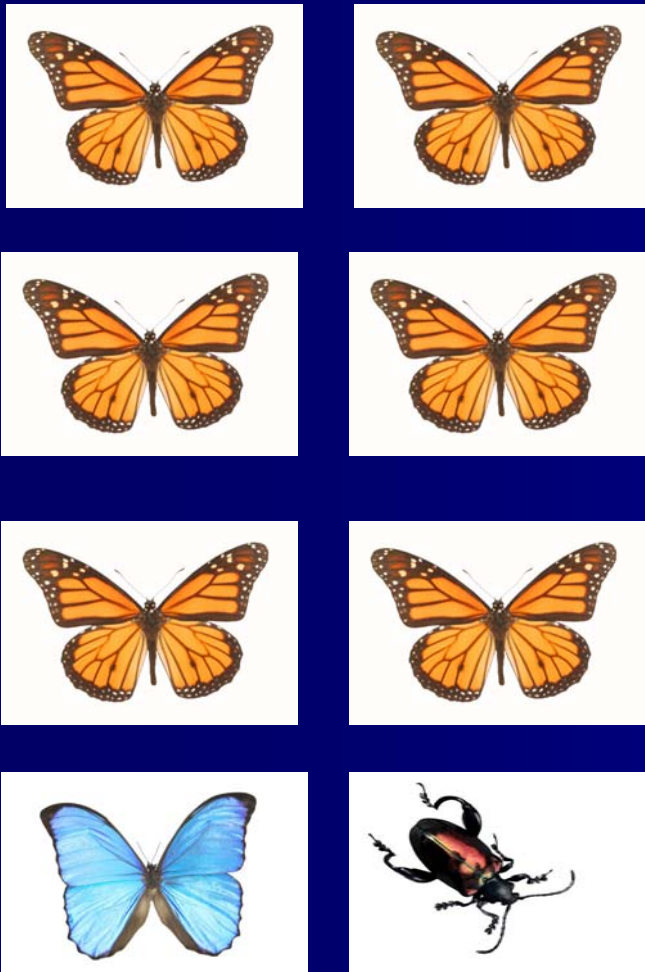
# The Species-scape

The size of the organism corresponds to the relative diversity of each group.

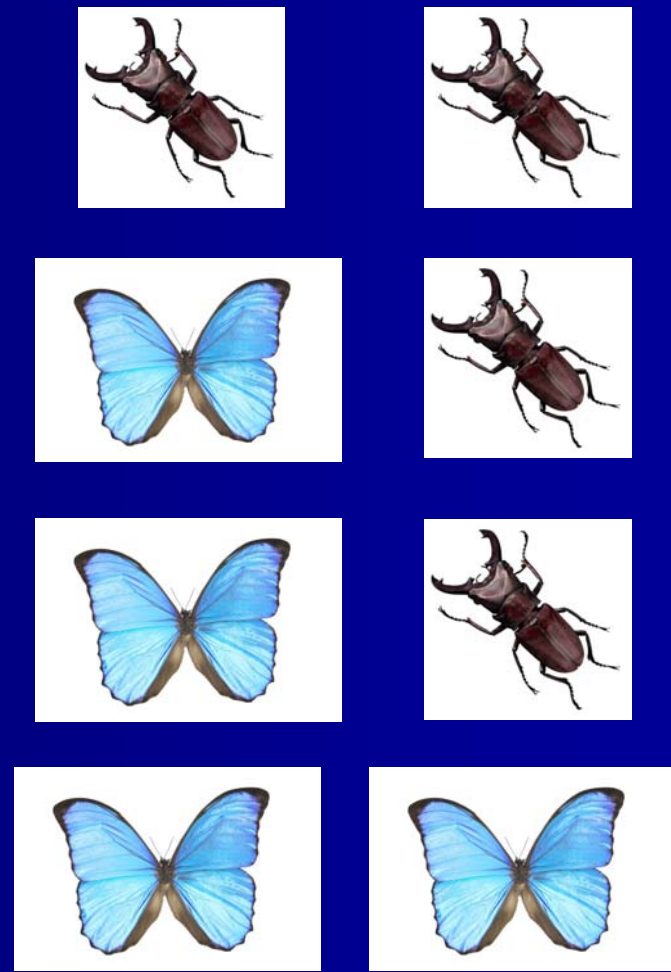


# Measuring Biodiversity

Sample A



Sample B



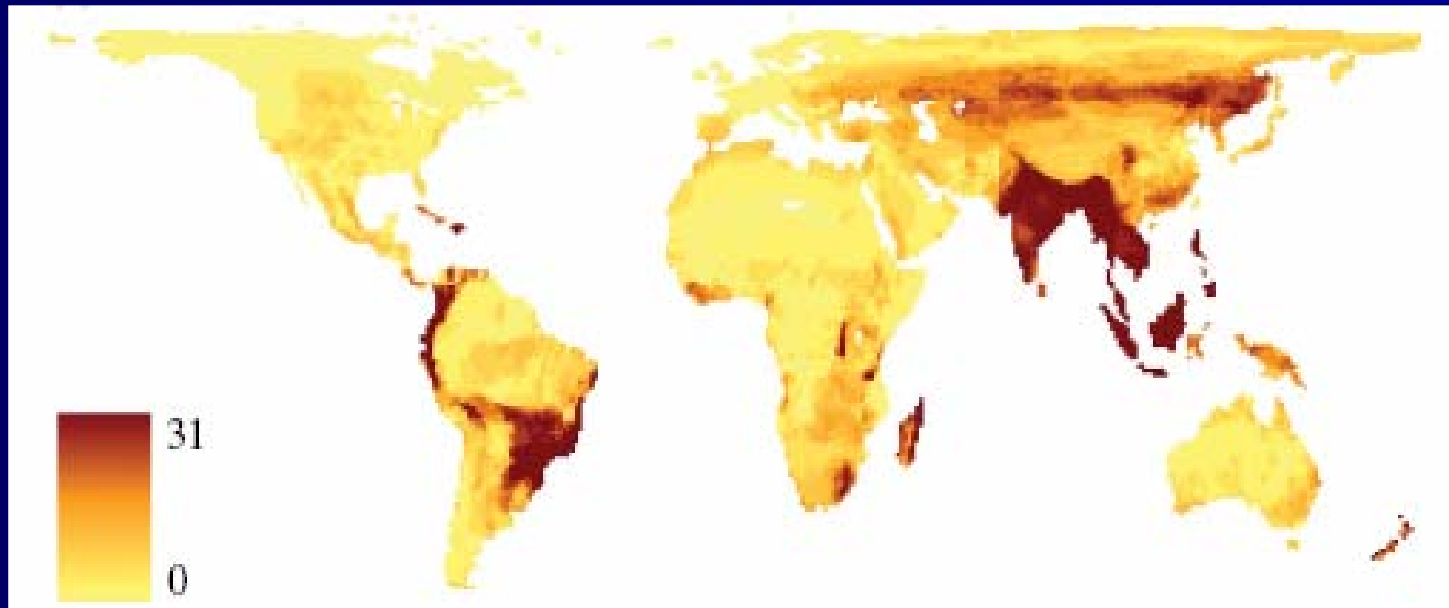


# Hotspots of Biodiversity

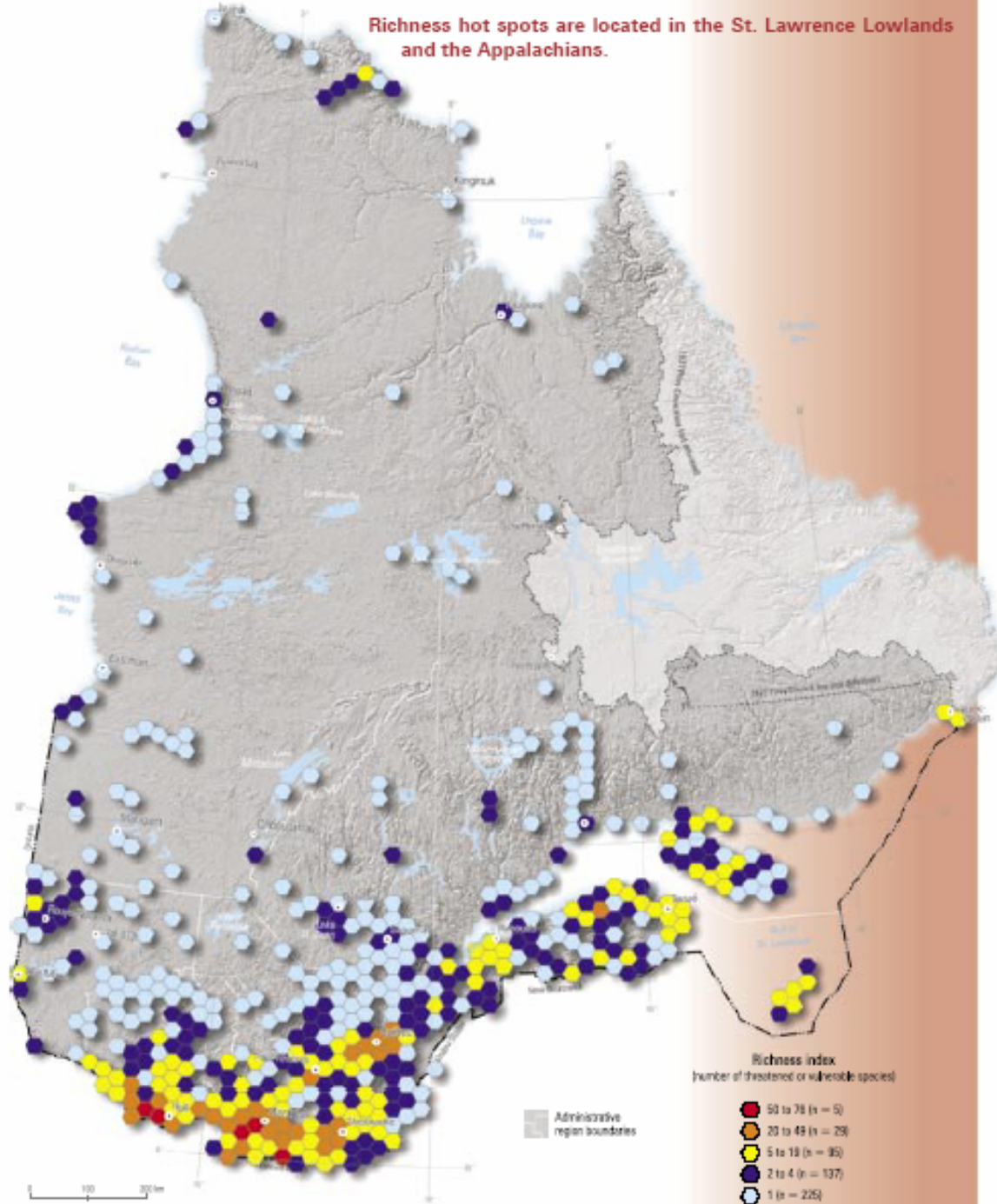
25 regions contain 44% of plant and 35% of terrestrial vertebrate biodiversity in 1.4% of land area.



# Hotspots of Threatened Biodiversity



Areas with high numbers of threatened bird species:  
partial but not complete overlap with diversity hotspots  
(Grenyer et al. 2006)



Distribution of richness in threatened or vulnerable species

# Quebec's hotspots of threatened diversity

From: Québec biodiversity Atlas



# Biodiversity Loss

Includes not just the loss of species, but any change in the mix of genotypes, populations, species and ecosystems that compromises their structure and function.





# **What do we know about Extinction?**

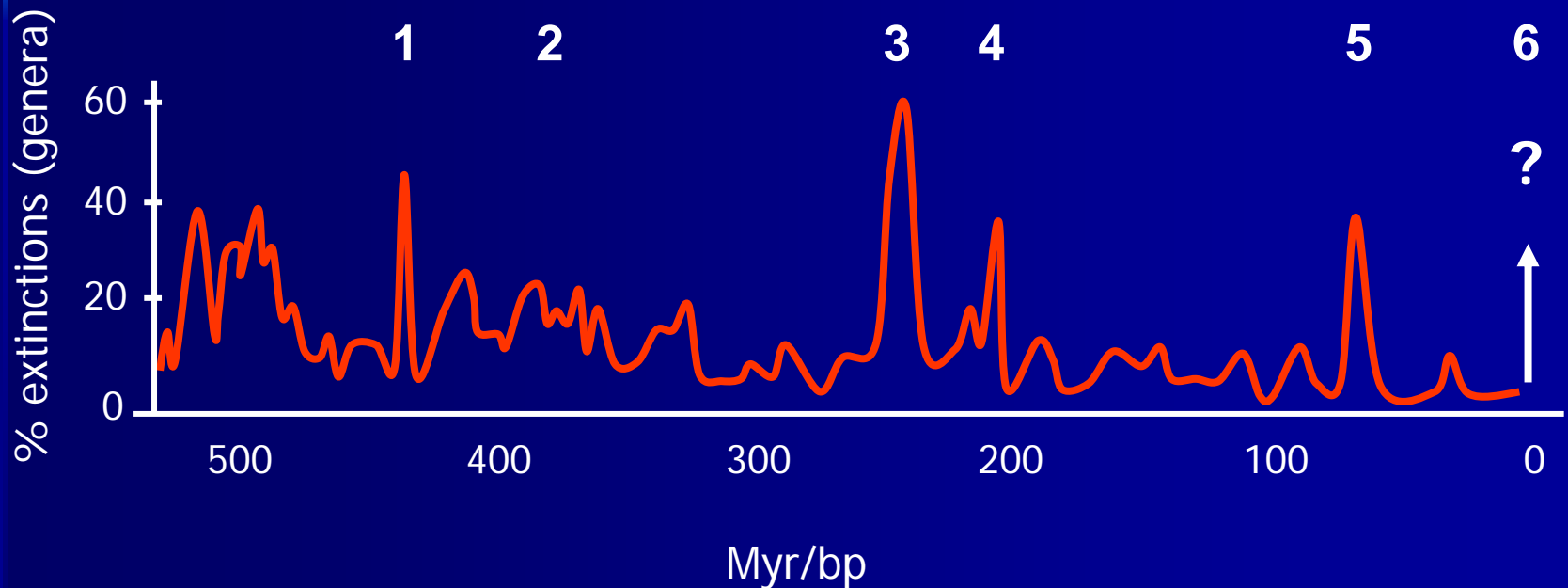
# Extinction: a concept invented by Georges Cuvier



The modern concept of  
extinction is only 200 years old!

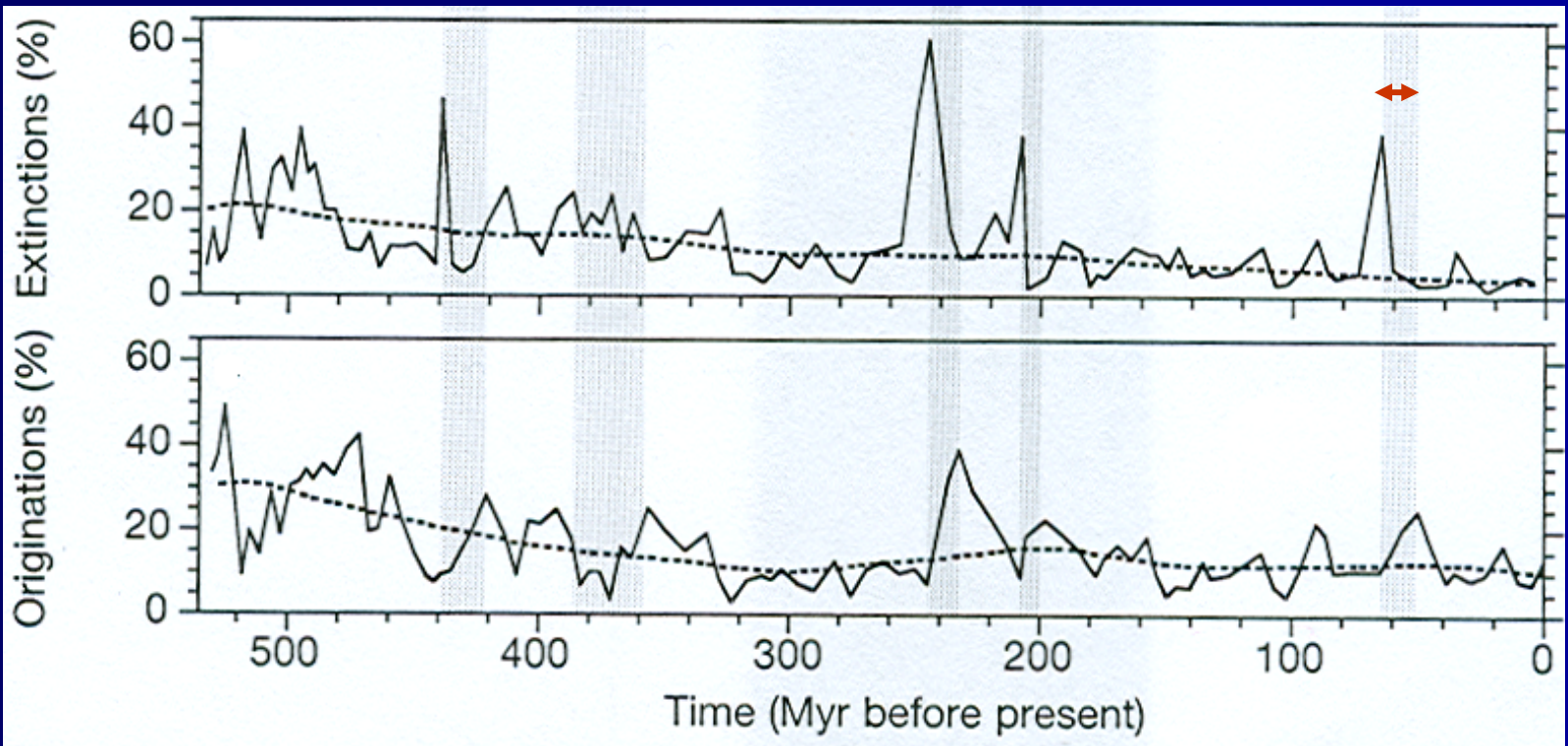
“Discours sur les révolutions de la surface du globe, et sur les  
changements qu'elles ont produits dans le règne animal.” (1825)

# Life on earth: ever present extinction



**The background extinction rate in the fossil record is 0.1-10 species per year.**

# Recovery from Extinction is Slow



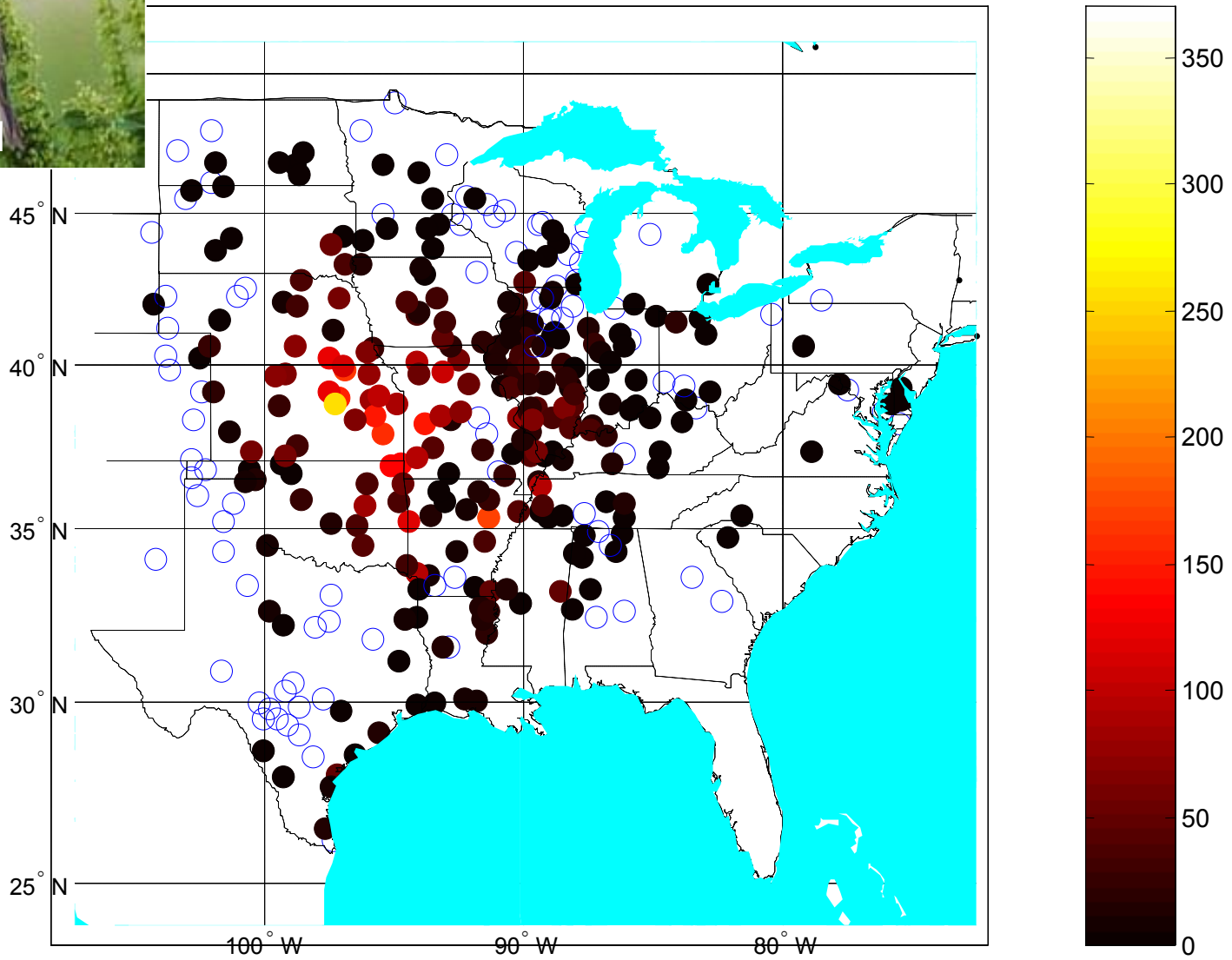
# Extinction: Essential Ideas

**Extirpation:** The loss of a population from part of a species' range.

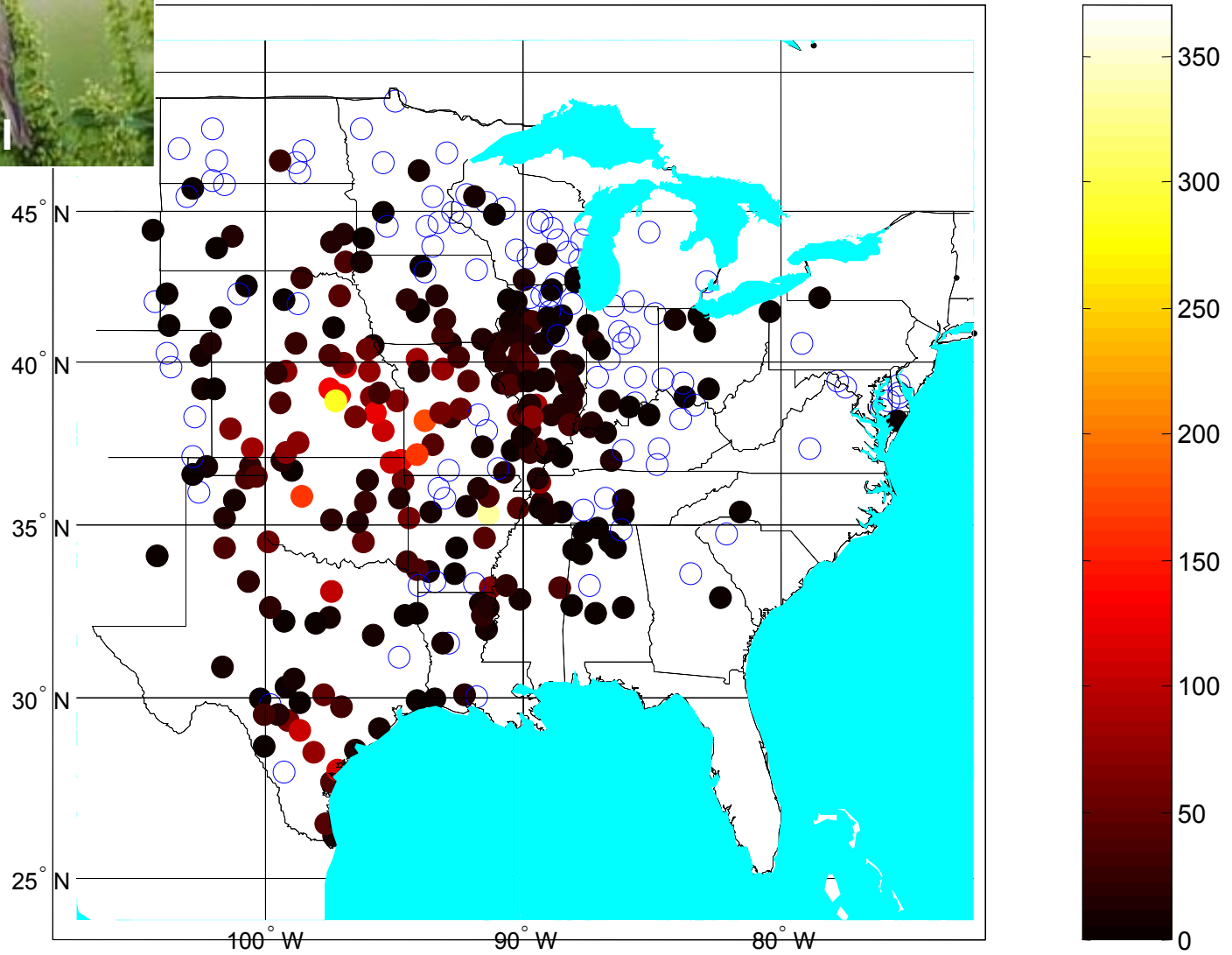
**Extinction:** The loss of all the populations of a species across its' global range.



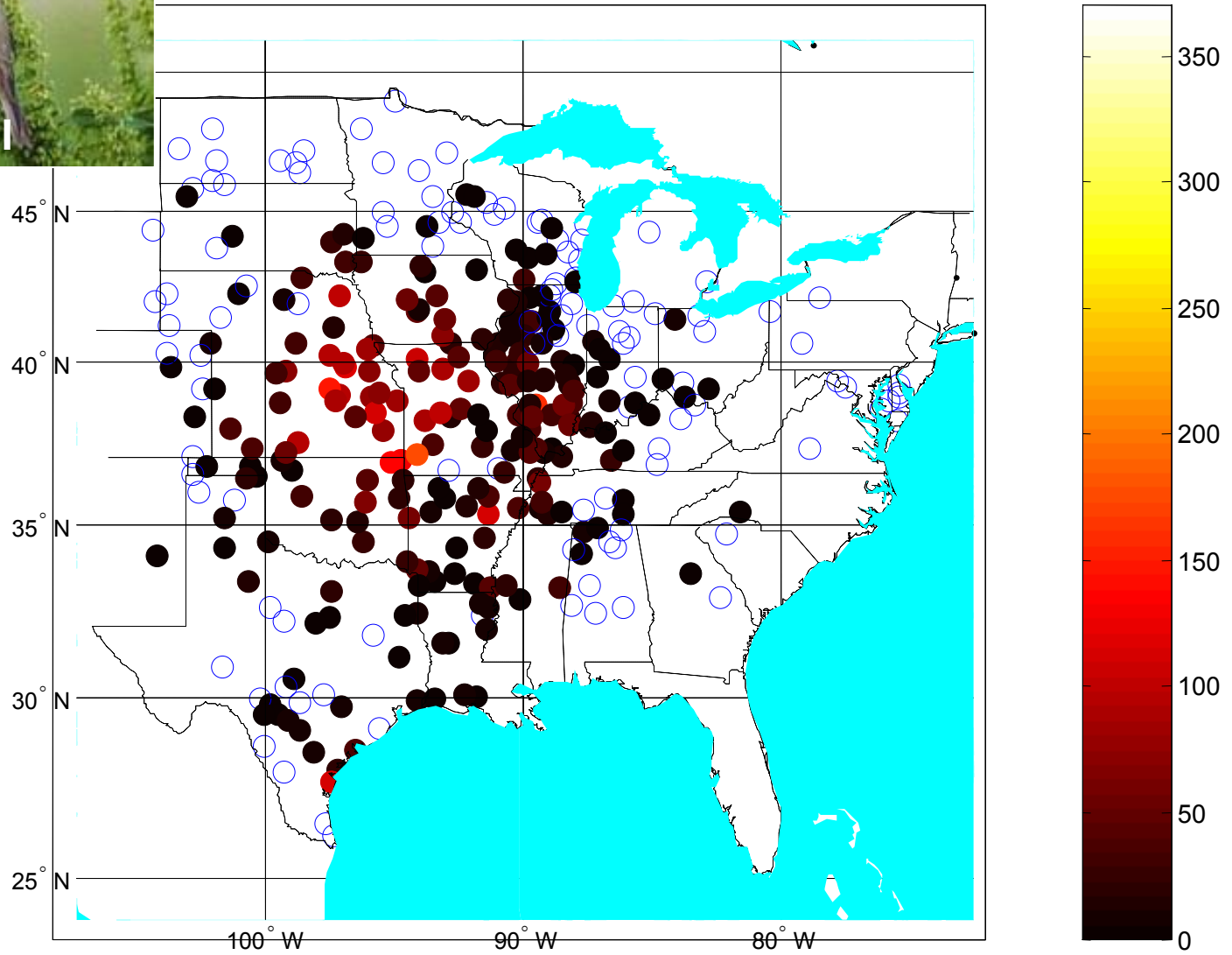
Year = 1996



Year = 1997



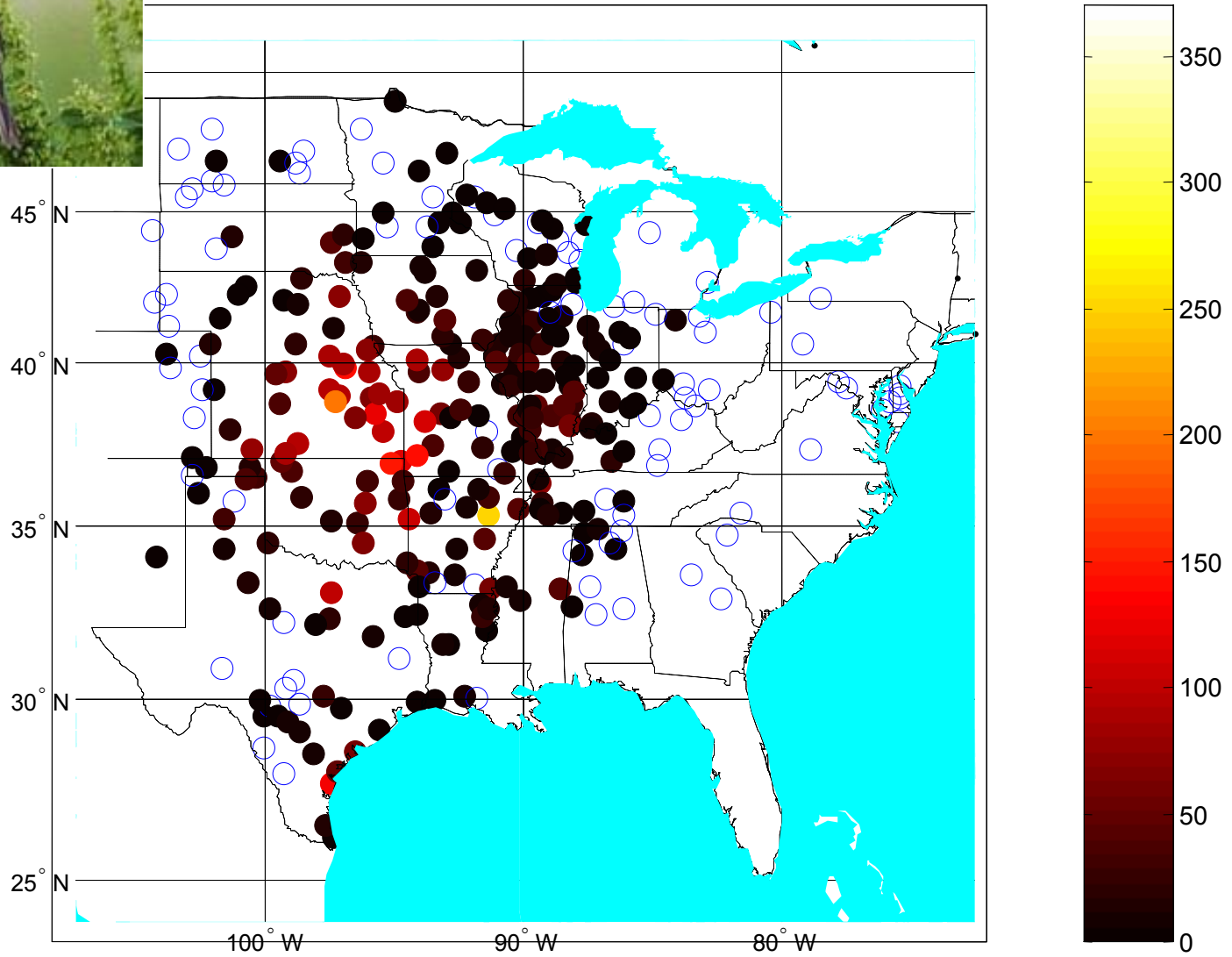
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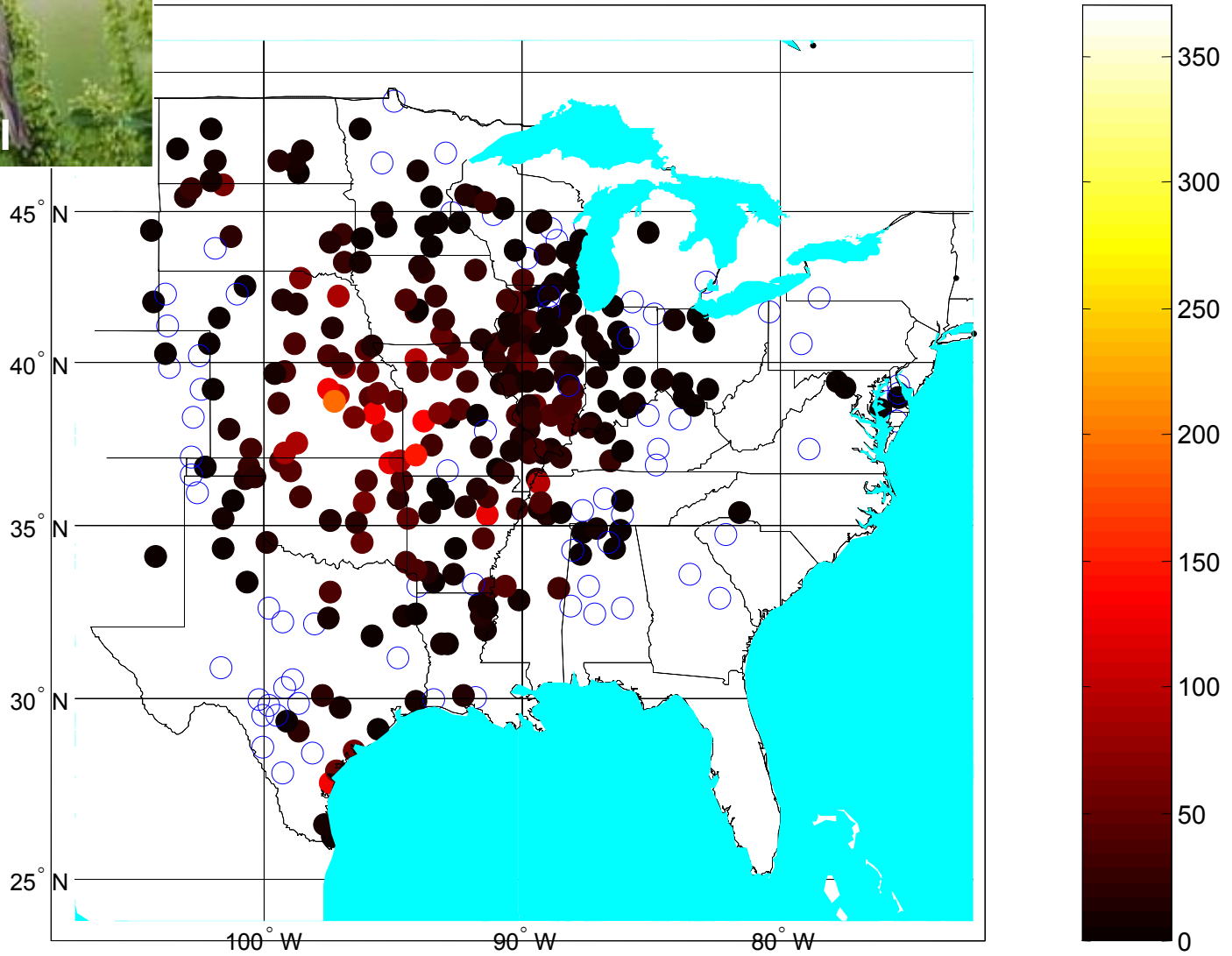




Year = 1999

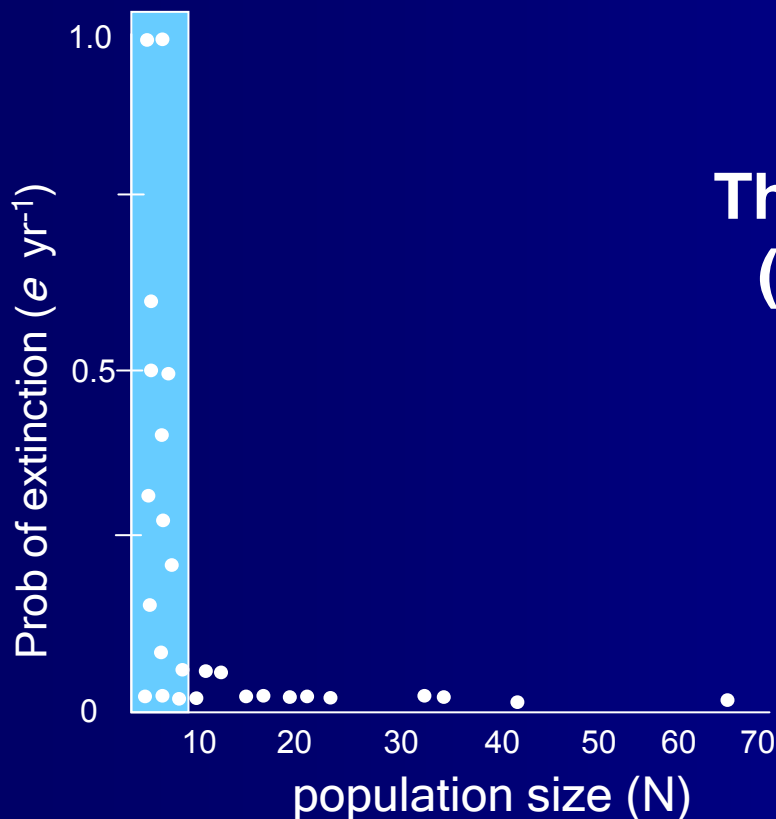


Year = 2000



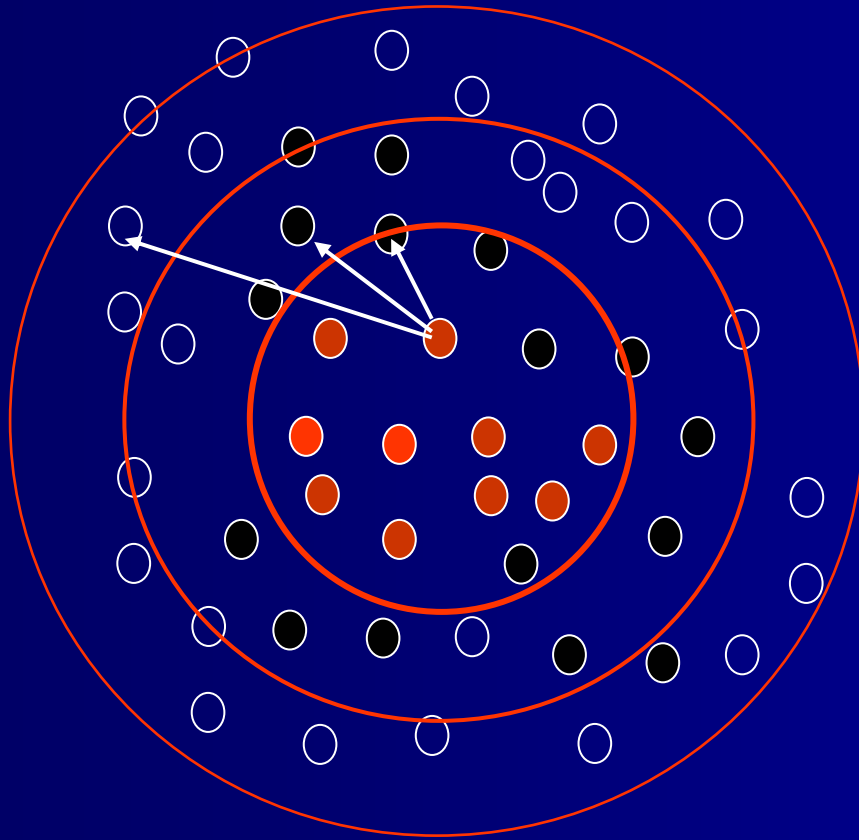
Courtesy of Dr. Brian McGill

# Population Size Predicts Extirpation



**The probability of extinction (per year) of a population increases inversely with population size.**

# Linking Extirpation to Extinction

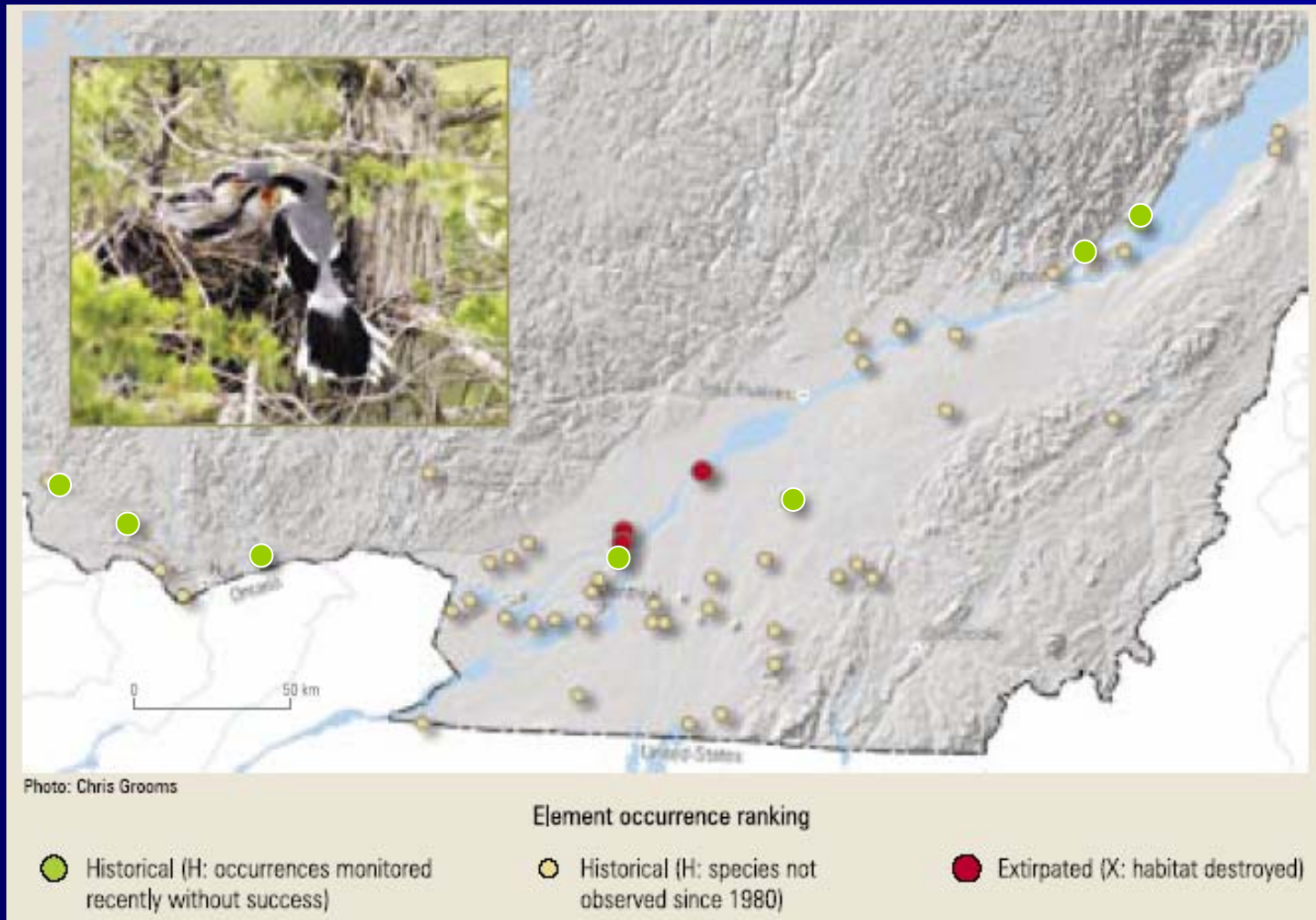


**Emmigration from large populations in the centre, sustains small populations at the periphery.**

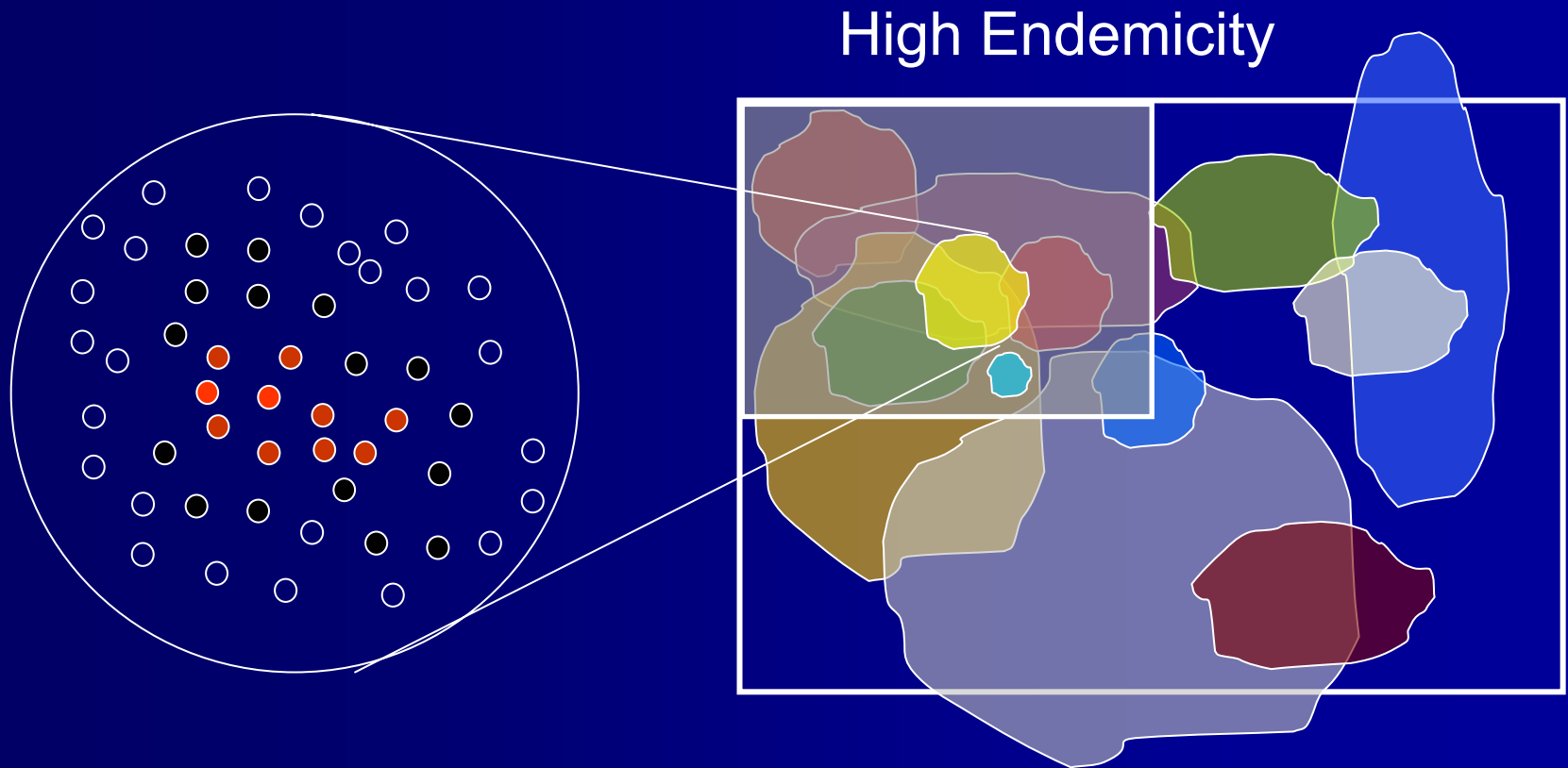
**There are on average ~200 populations per species**

# Decline and Extirpation of the Loggerhead Shrike in Québec

From: Québec biodiversity Atlas

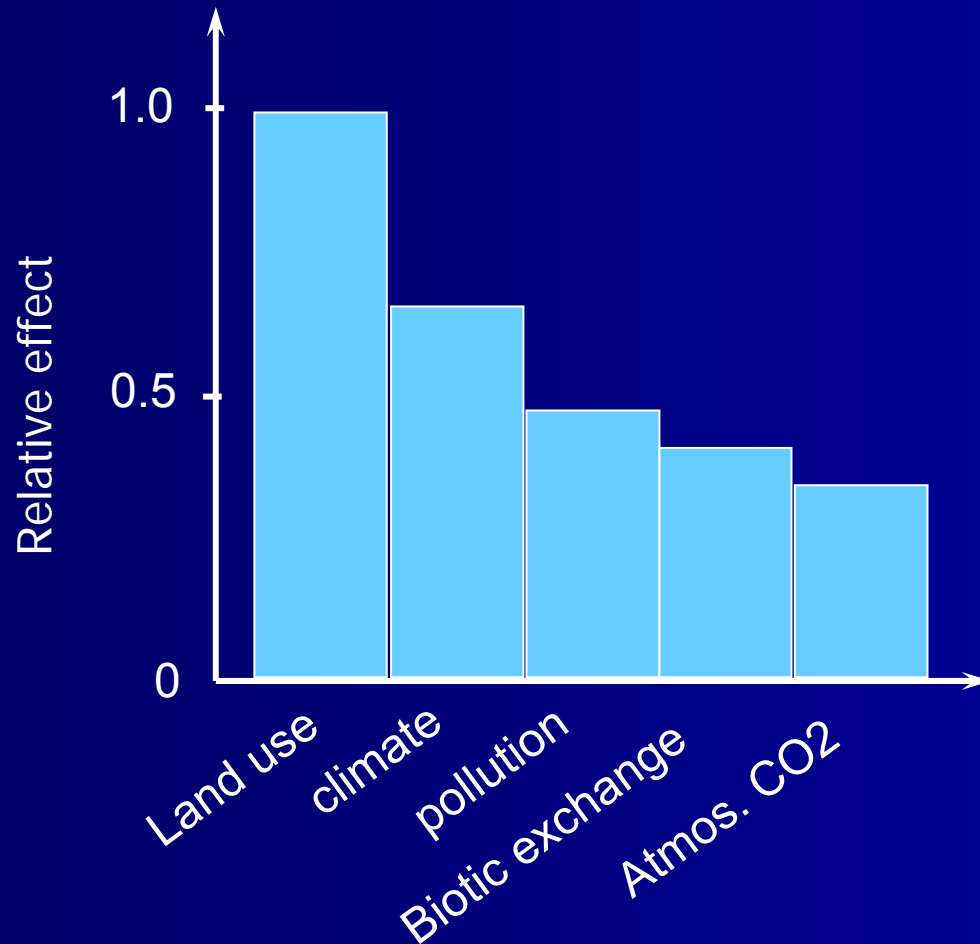


# Range Size and Endemicity



**Species with small ranges have higher risk of extinction**

# 5 Major Causes of Extinction



# Deforestation

**Landsat images of forest loss (60%) over a 25 year period in Rondonia state, Brazil.**



Video: <http://svs.gsfc.nasa.gov/vis/a000000/a002100/a002116/index.html>

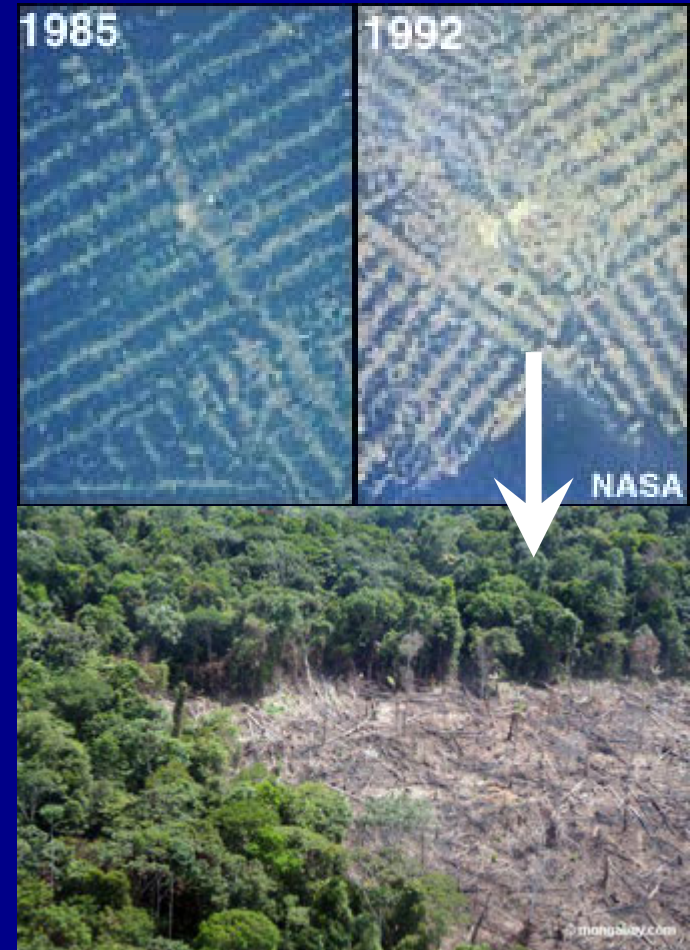


# Deforestation

50% of the world's 14-18 million km<sup>2</sup> of tropical rainforest have fallen.

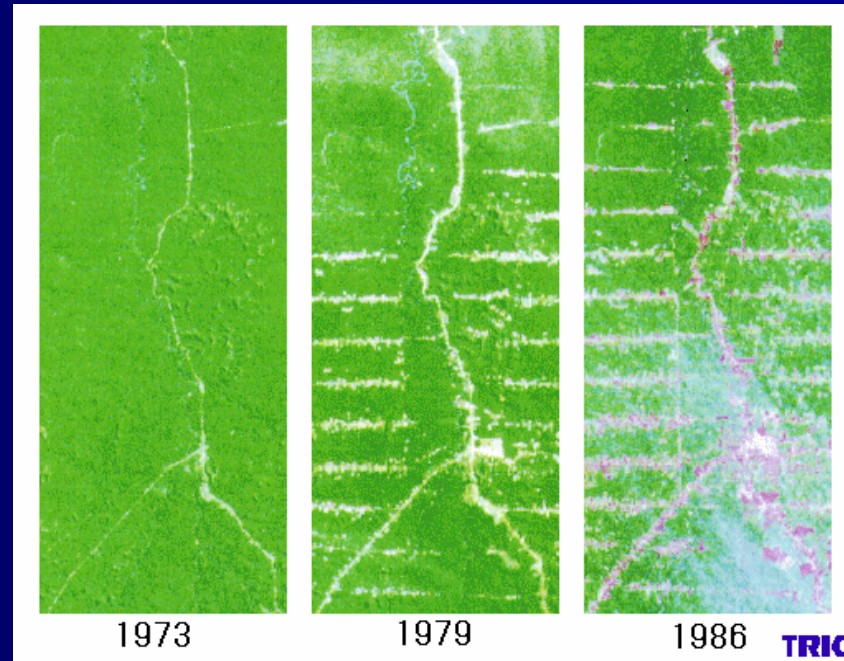
Estimates of deforestation of tropical forest for the 1990s range from 55,630 km<sup>2</sup> to 120,000 km<sup>2</sup> each year.

At this rate, all tropical forests may be gone within 100 years.



**How do we predict extinction  
in the future?**

# Forest Destruction & Fragmentation



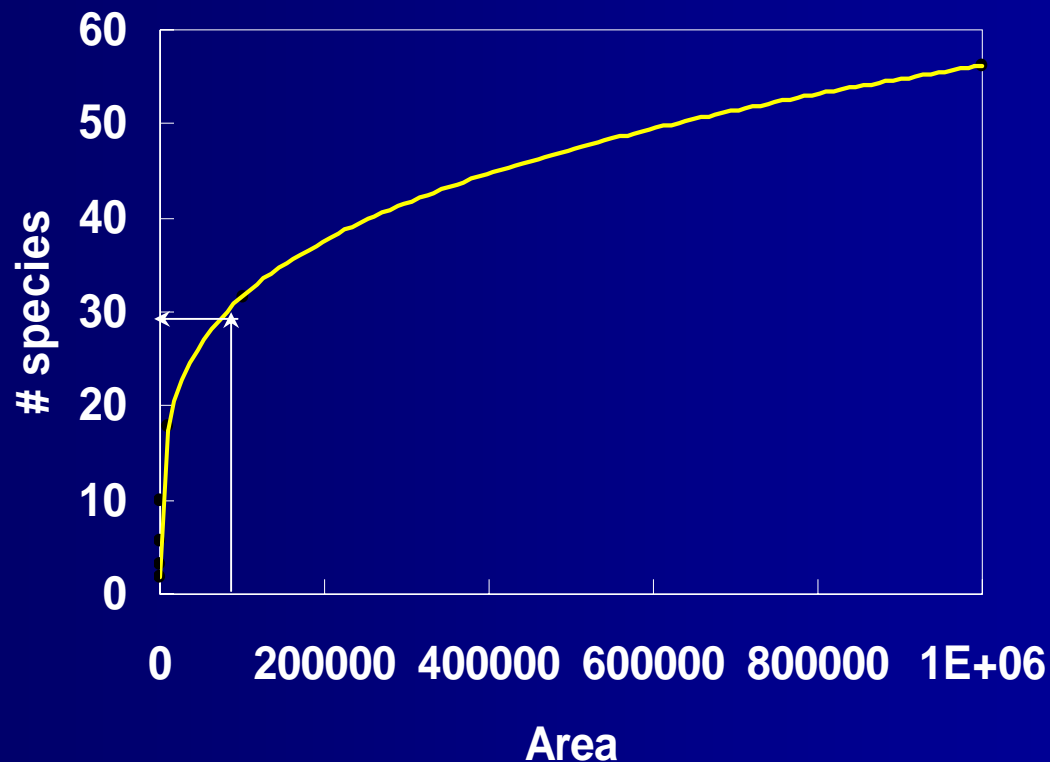
- 1) Loss of original habitat area
- 2) Reduction in size of fragments
- 3) Increasing isolation of fragments

**CHOPPING DOWN ALL OF THE TREES GIVES YOU  
A CLEAR VIEW OF THE DEVASTATION CAUSED  
BY CHOPPING DOWN ALL OF THE TREES.**

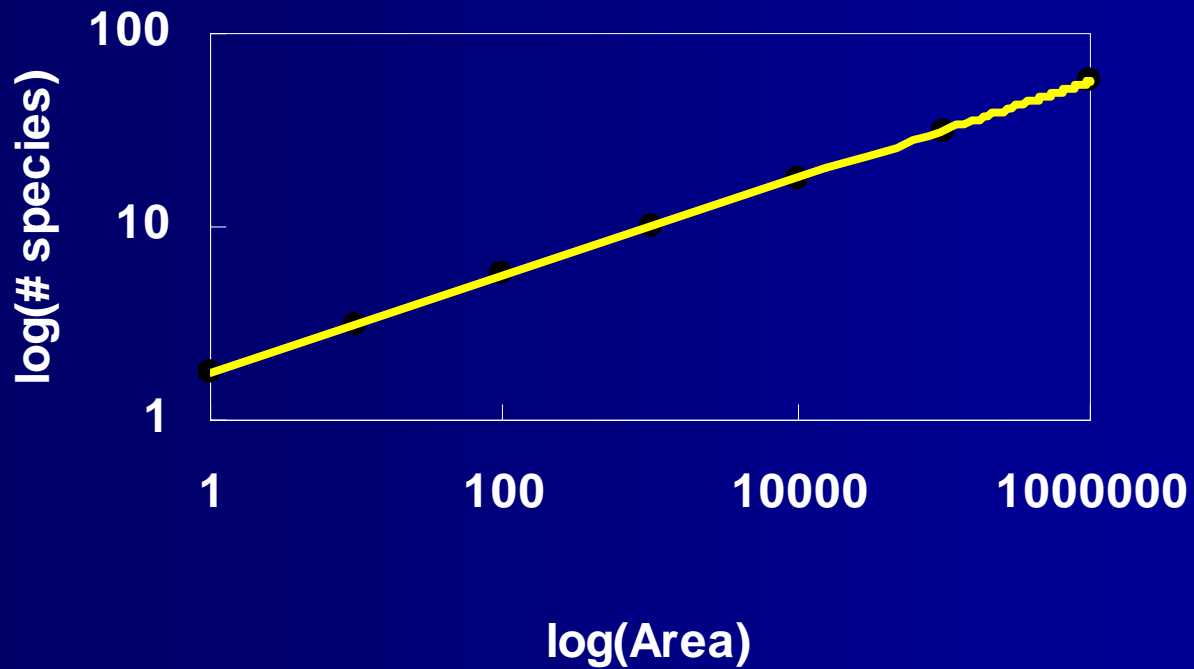


# The Number of Species Increases with Habitat Area

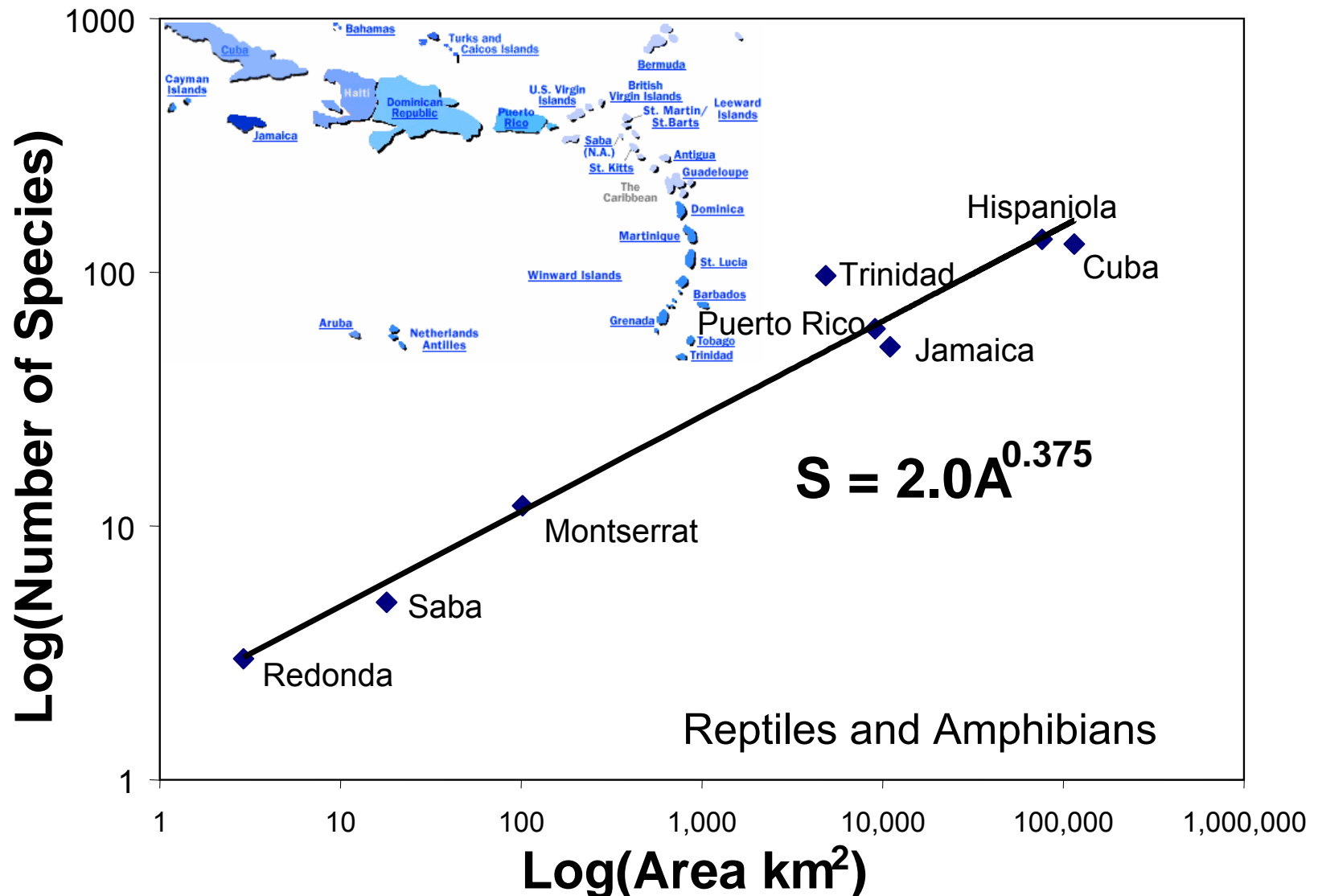
$$Species = c(Area)^z$$



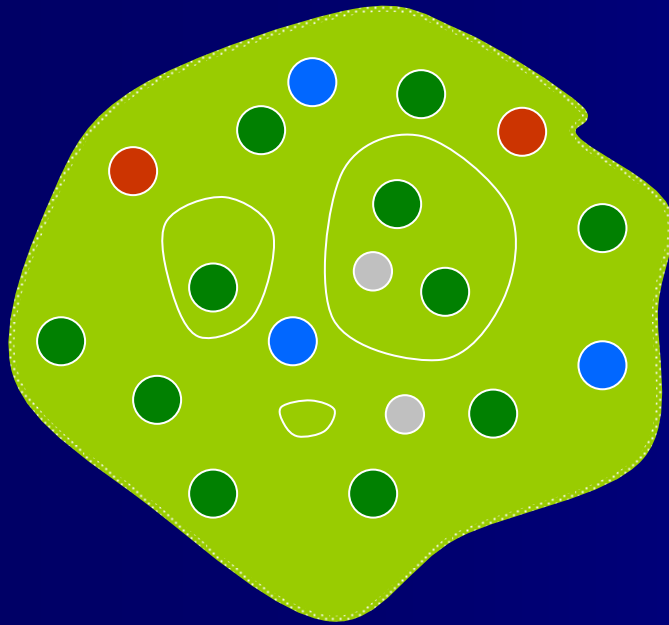
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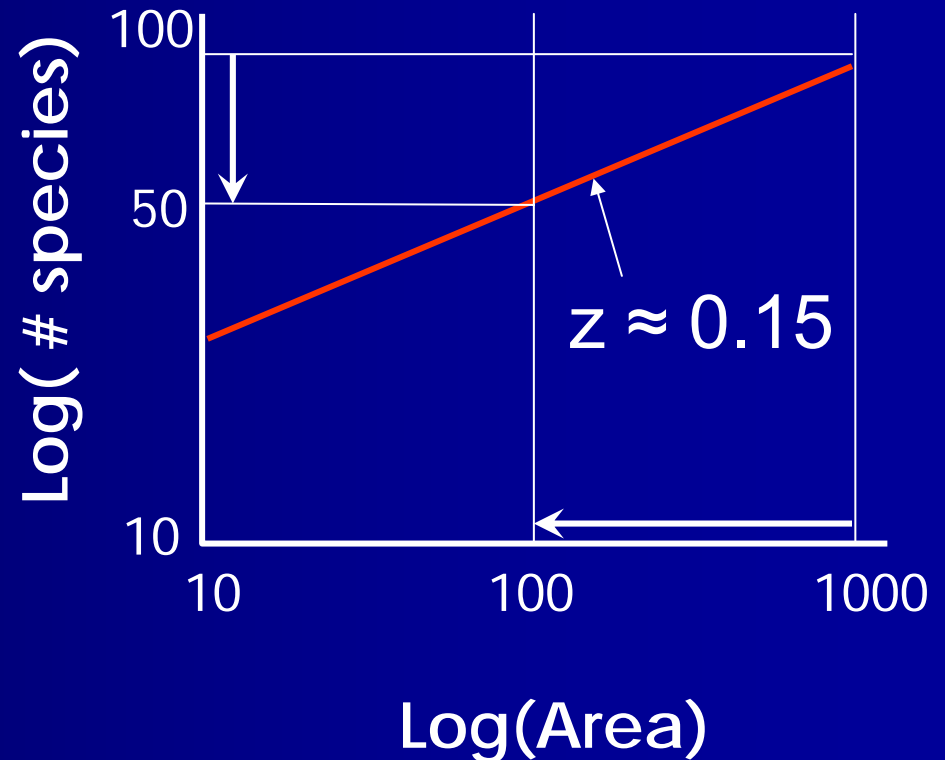
# The Species-Area Relationship



# Predicting Extinctions With The Species-Area Relationship

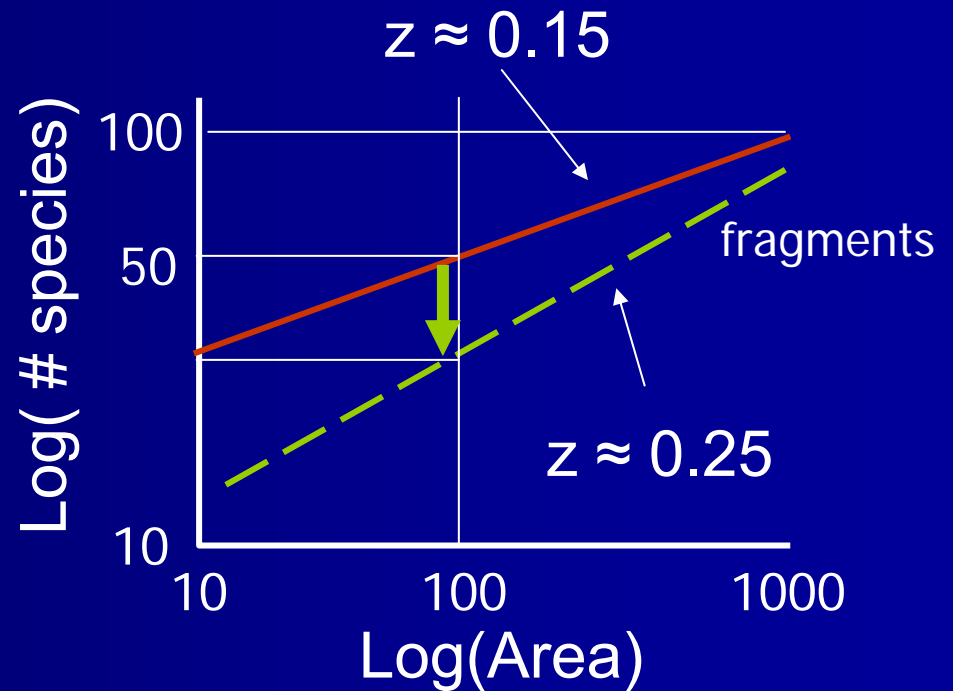
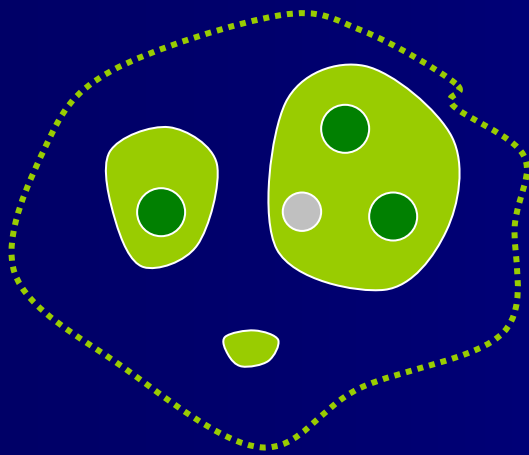


$$\text{species} = cA^z$$



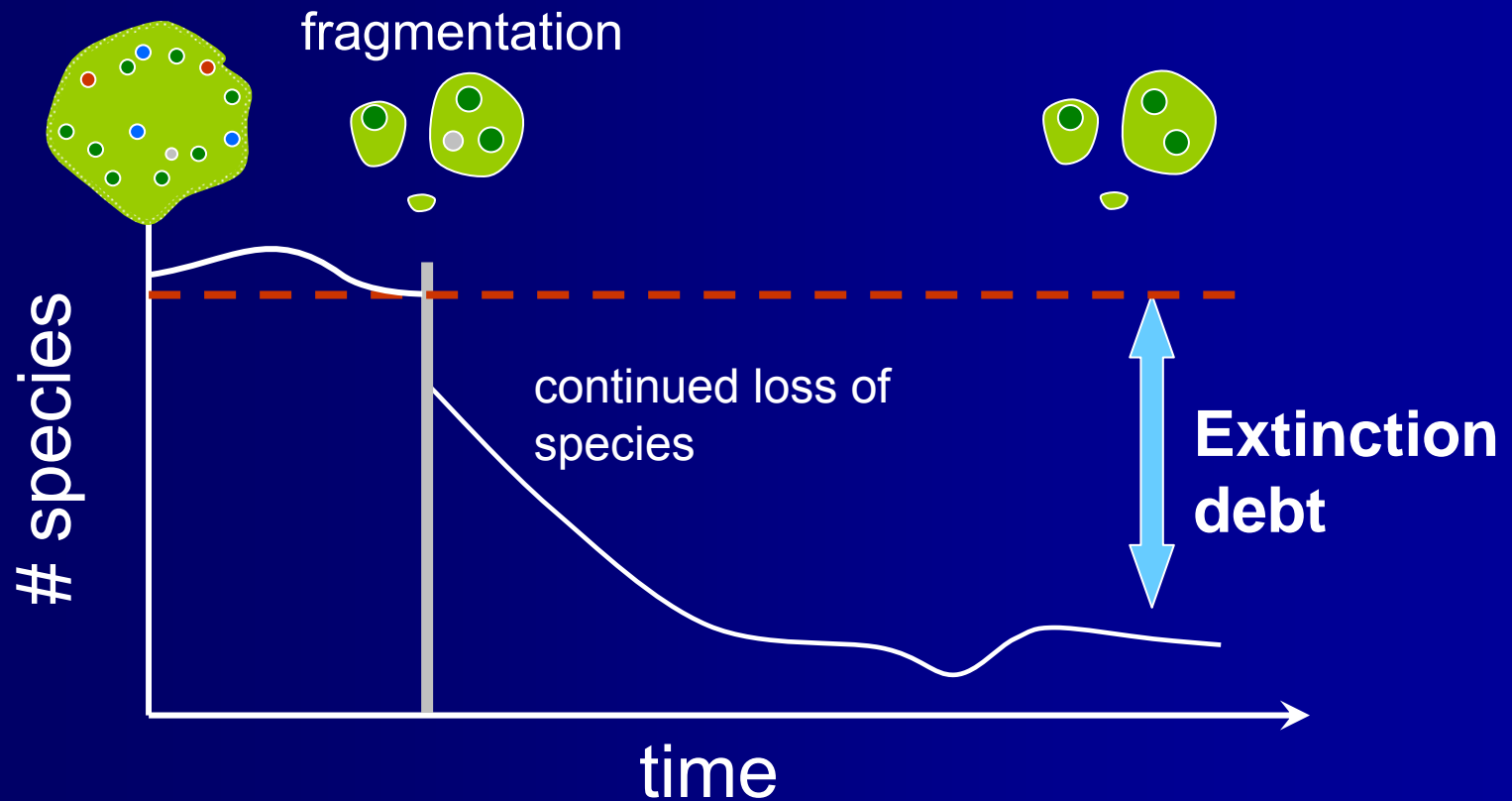


**But it is not so simple...**



**Delayed increase in the slope ( $z$ ) of the species-area relation reflects loss of species in small forest fragments.**

# Delayed loss = Extinction "Debt" in Fragmented Habitats



# Calculating Extinction

Expression for original species richness:

$$S_0 = cA_0^z$$

Expression for new species richness:

$$S_n = cA_n^z$$

A little algebra:

$$\frac{S_n}{S_0} = \frac{cA_n^z}{cA_0^z} = \left( \frac{A_n}{A_0} \right)^z$$

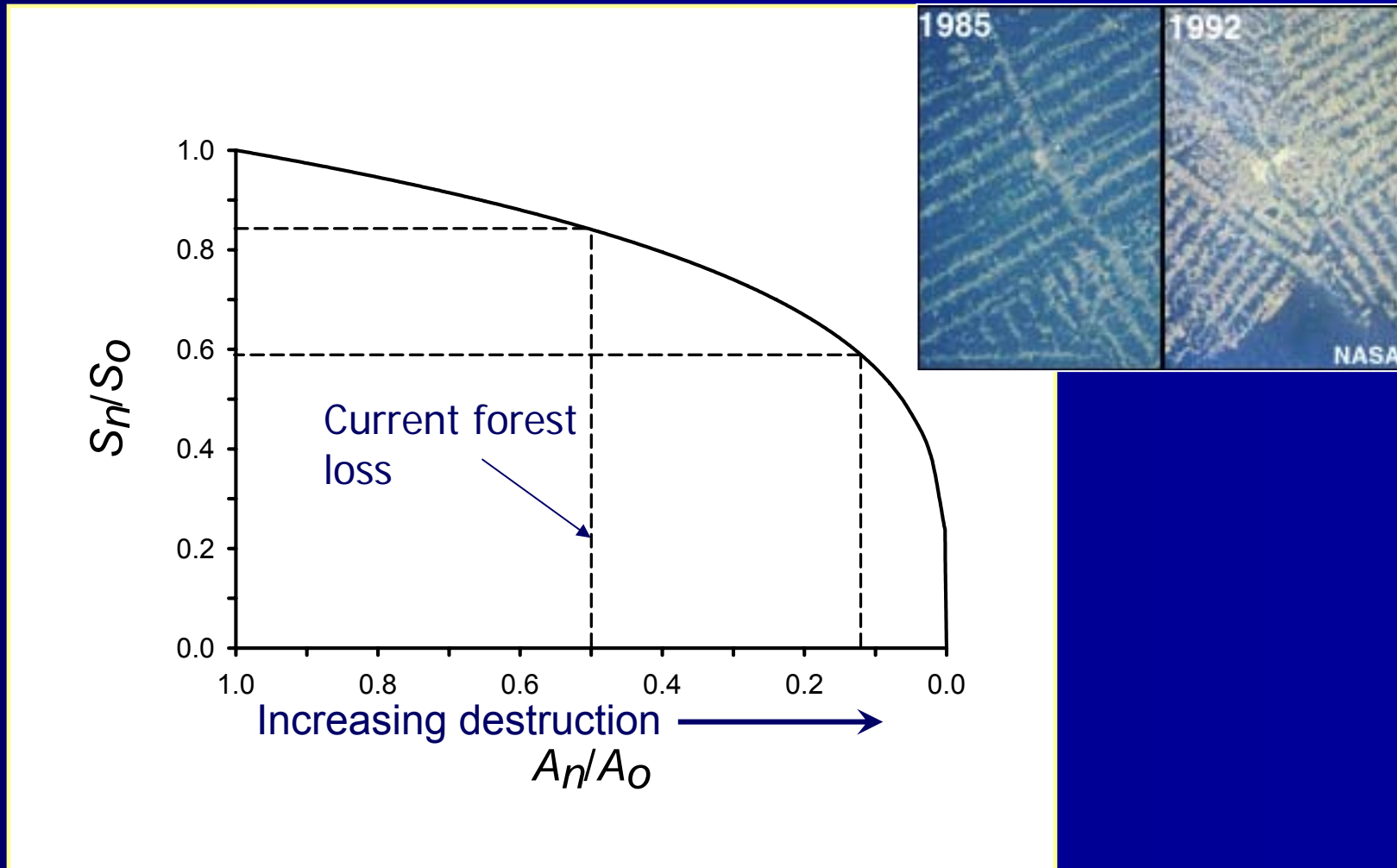
# Impact of Deforestation to Date

8 of 16 million km<sup>2</sup> (50%) of tropical forest removed.

$$\frac{S_n}{S_o} = \left( \frac{A_n}{A_o} \right)^z = (0.5)^{0.25} = 0.84$$

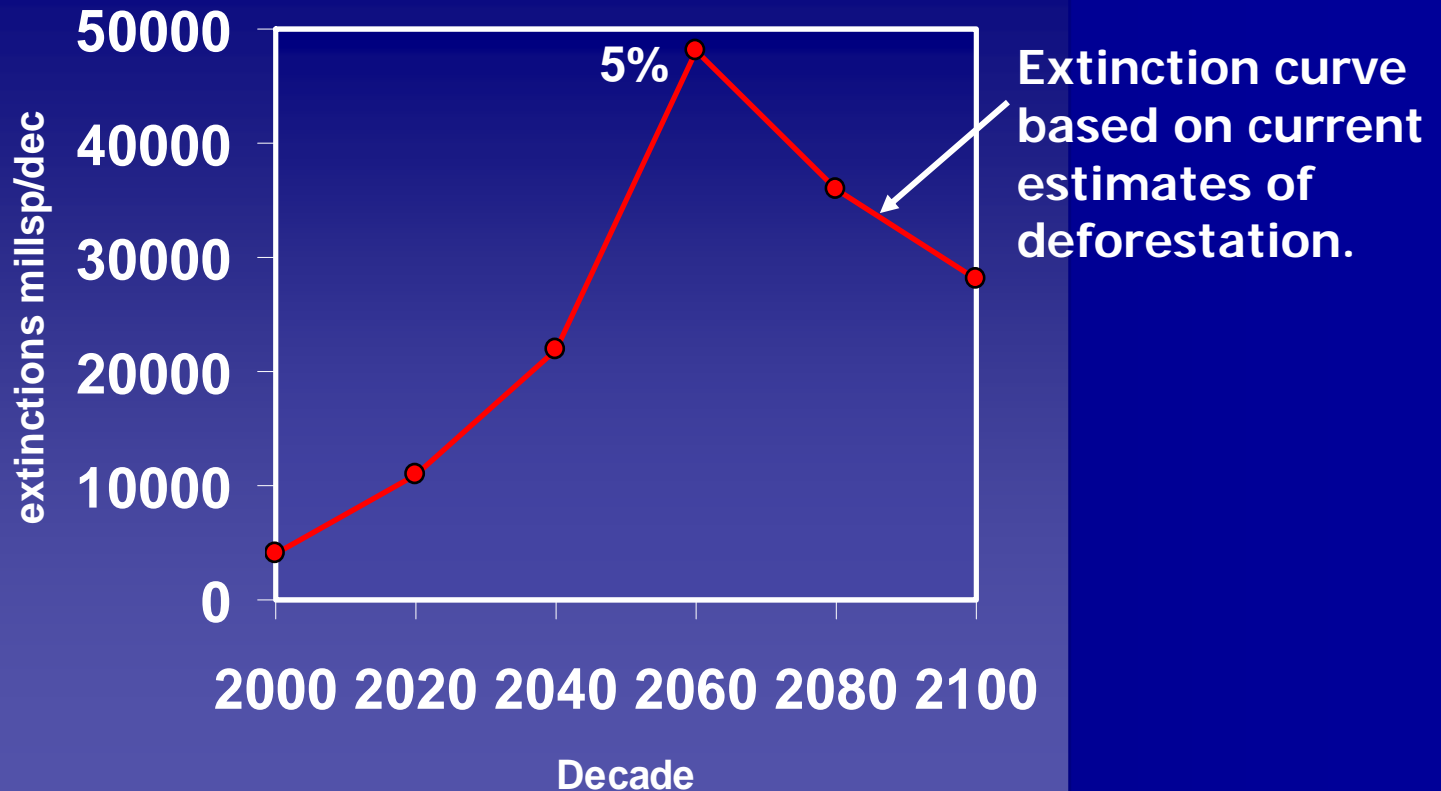
16% of tropical forest species (endemics) have been committed to extinction so far.

# Extinction: initially gradual but then abrupt



# Future Extinction Rates

The peak is 1000-10 000x the background rate!



Redrawn from Pimm and Raven *Nature* 2000

**What are the solutions?**

# Solutions

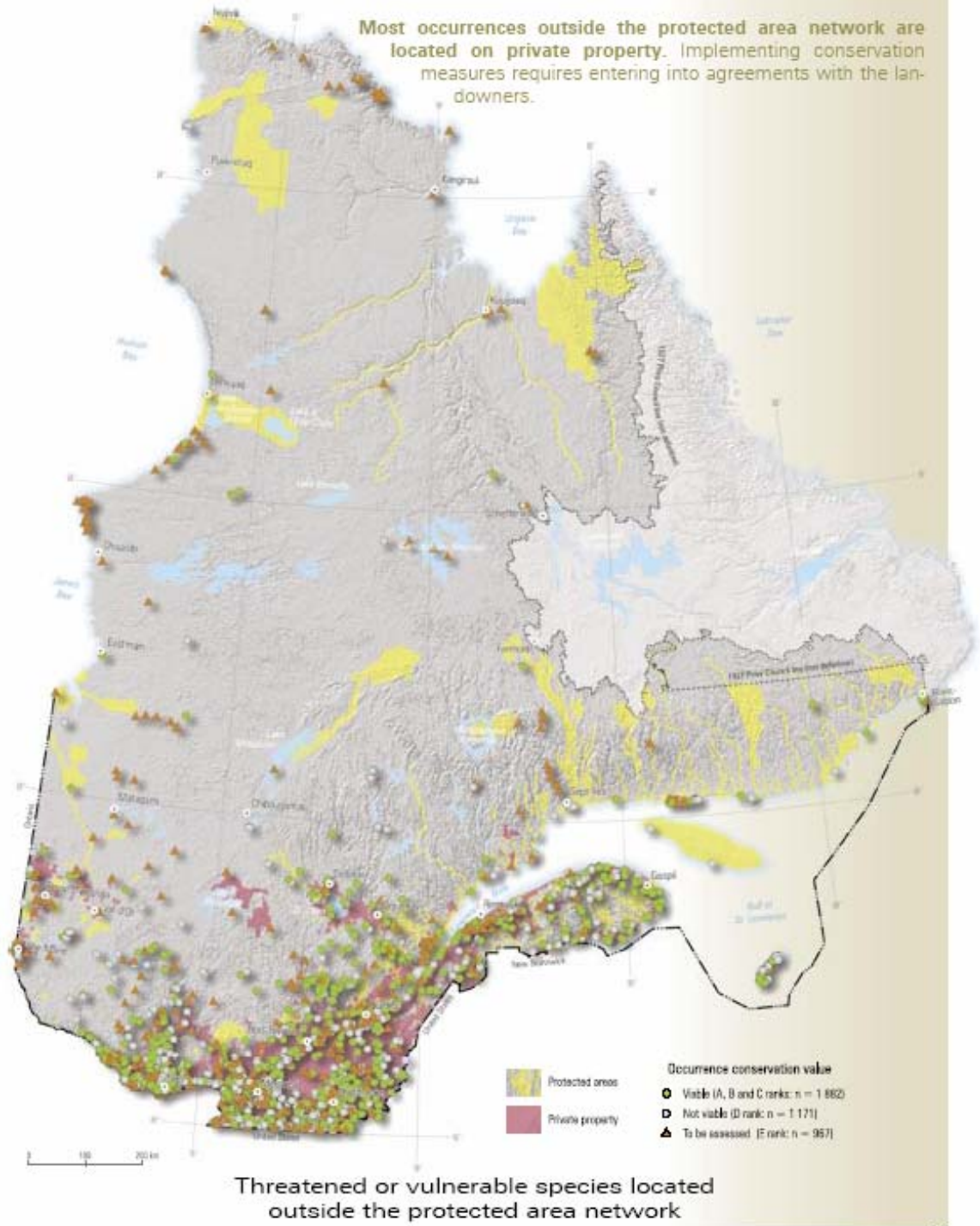
- Consolidate global protected area network (currently 11.5%), that includes viable (large) populations of as many species as possible.
- Prevent the protected areas from becoming too fragmented.
- Habitat corridors can reconnect fragmented landscapes.



# Global Protected Area Network for Hotspots



In 17 tropical forest areas designated as hotspots, only 12% of the original primary vegetation remains.



# Québec's Protected Area Network (~3% of land)

- Protected areas
- Private Property

Threatened species found outside the PAN are found on private property

# Habitat Corridors as a Conservation Strategy

**Corridors increase the effective area of a fragmented landscape:**

**1-Facilitate movement between feeding and breeding habitats**

**2-Facilitate dispersal and genetic exchange between populations**





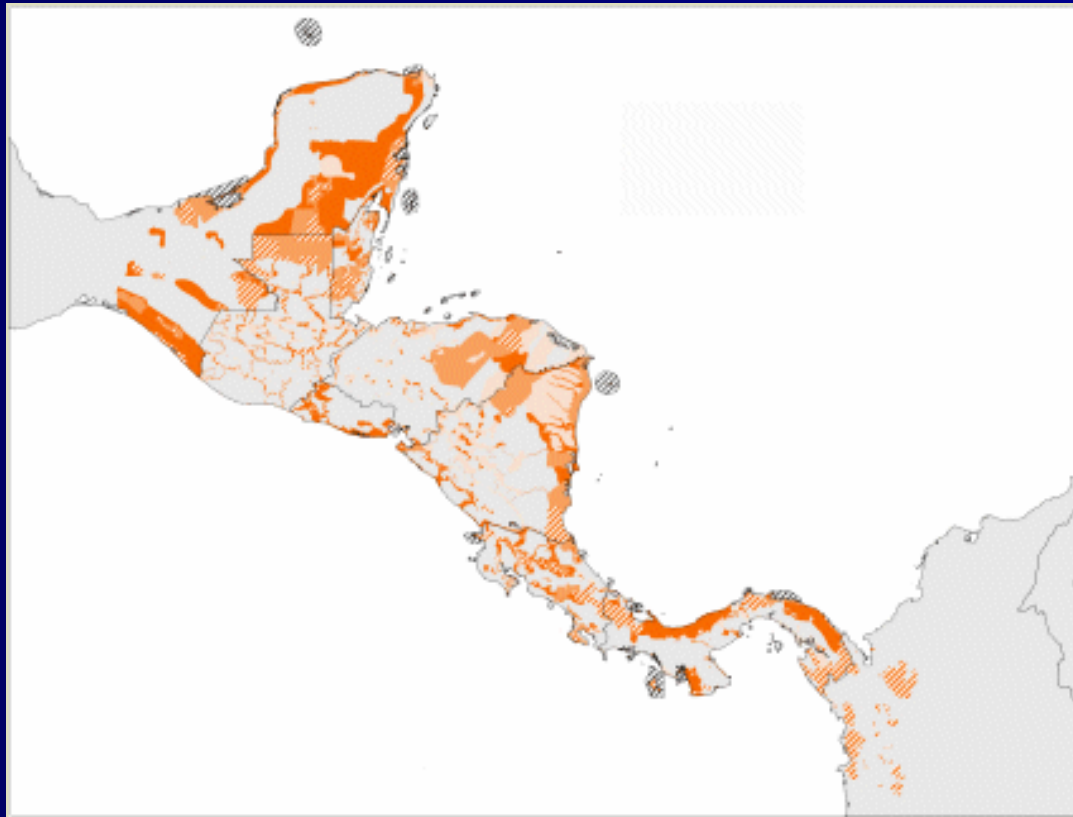
# Habitat Corridors near Sorel-Tracy, Quebec



- Forest corridors segments
- Anthropic habitat
- Farmland habitat
- Aquatic habitat
- Natural habitat
- ② Segment number
- Optimal route of the forest corridor

70 0 70 Kilometres

# Mesoamerican Corridor Project



The corridor, represented by the colour red in the map, contains 5% of known global biodiversity

# Some Conclusions

1) Local and global extinction is occurring at an unprecedented rate (100-1000x) due to the economic activities of human societies.

2) Data show that biodiversity loss is delayed, and coming decades will see a significant extinction debt paid. These changes are irreversible from a human perspective.

3) Mitigation of biodiversity loss requires both local and global conservation initiatives.