

Our endangered cousins the great apes

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Dept. Human Genetics

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Thanks!



Marcelo Nobrega

Aaron Turkewitz



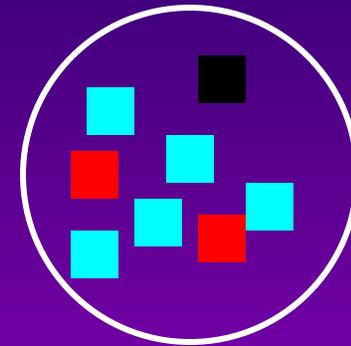
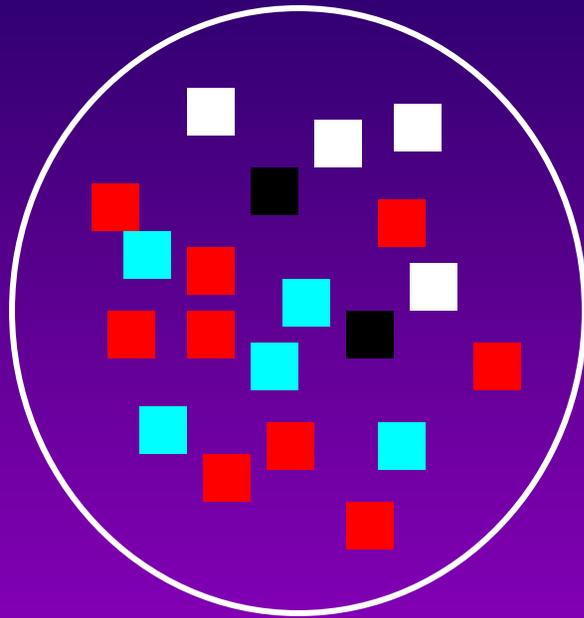
Outline

- Review on conservation genetics
- Introduction to our endangered cousins
 - ◆ Notion of species, subspecies/population
 - ◆ Investigating the genetics structure of common chimpanzee
- How bad is it?

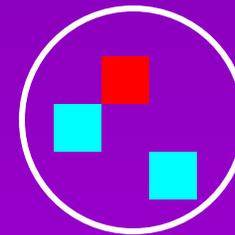
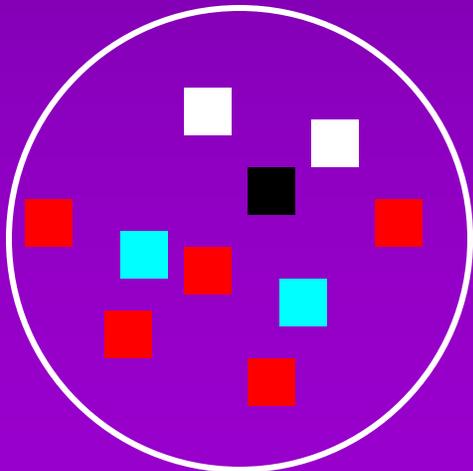
Conservation Genetics

- Conservation biology studies populations affected by habitat loss, exploitation, and/or environmental change.
 - ◆ Used to be address from a mathematical, evolutionary, or taxonomic point of view
 - ◆ Maximizes the number of individuals in the population AND ensures that they have the capacity for continued adaptation to a changing environment.
 - ◆ This capacity is brought about by genetic diversity and it is essential that this is maintained.
 - “effective” population size is positively correlated with the genetic diversity possessed by the population as a whole.

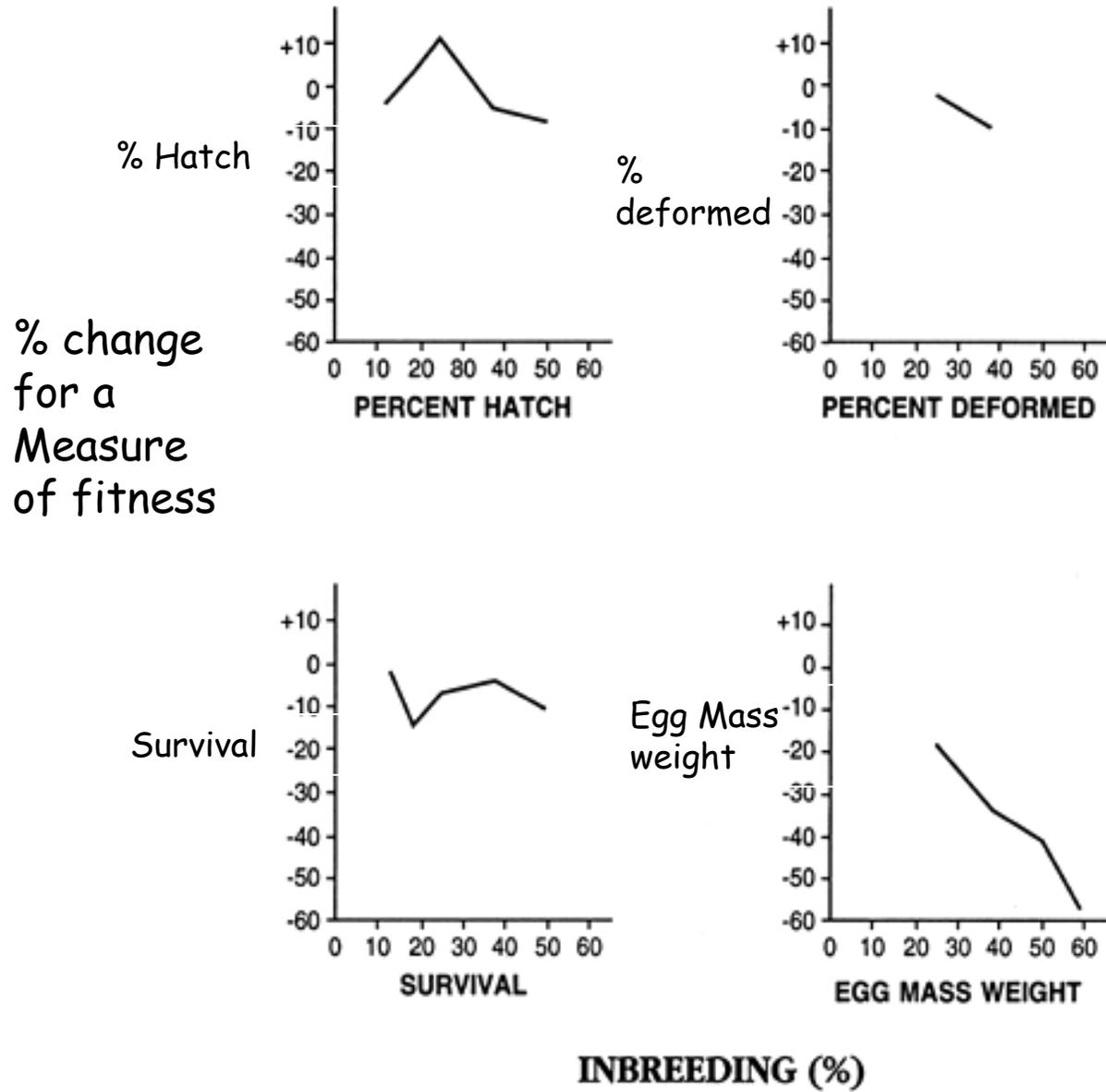
The loss of genetic variation decreases a species' ability to evolve to deal with change in the environment



Event kill 80% non-blue



Inbreeding reduces population fitness



Random genetic drift becomes the main evolutionary process, instead of natural selection

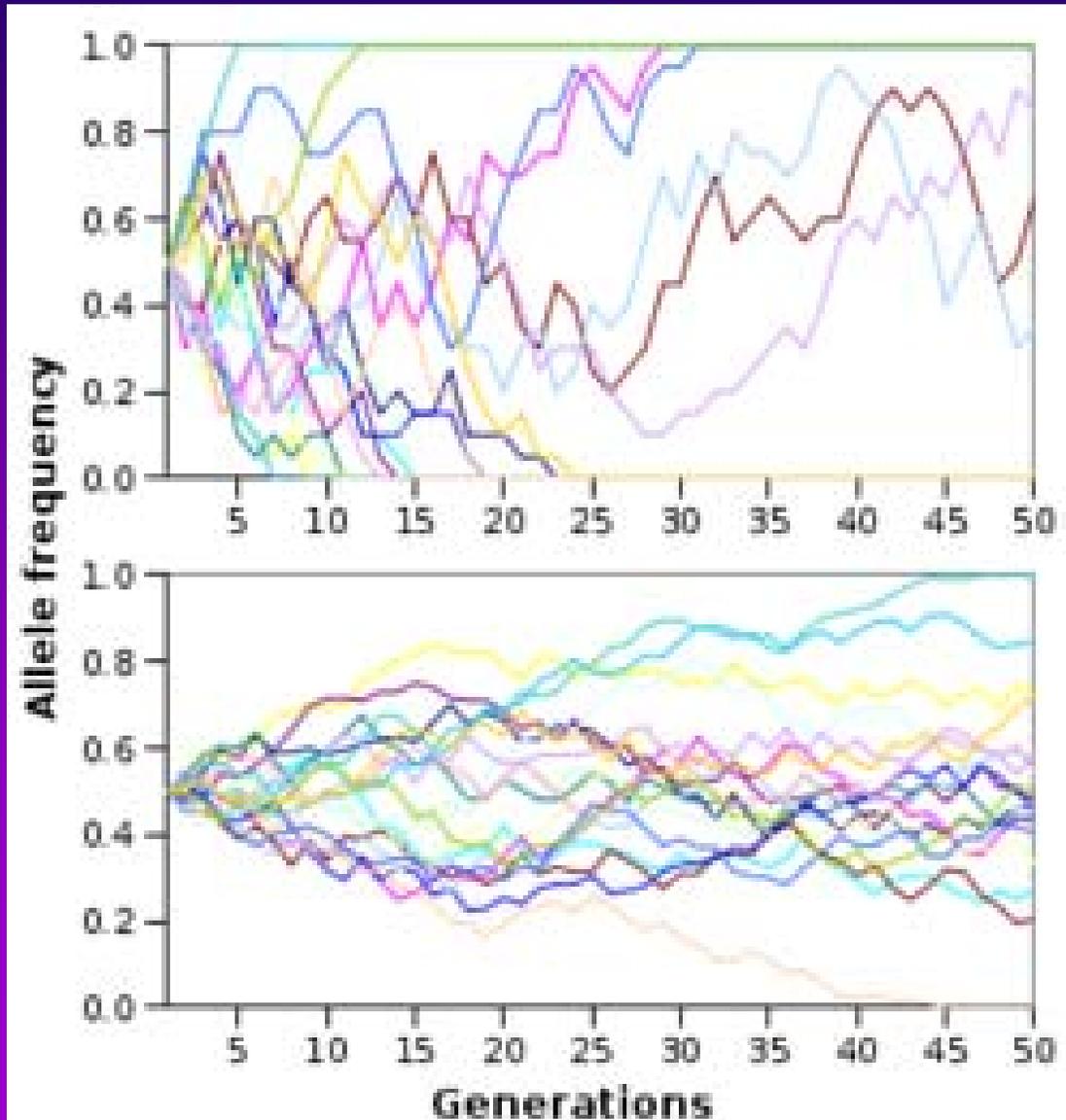
N=10

Simulations of genetic drift for 20 alleles with initial frequency 0.5.

In general, alleles drift to fixation (frequency of 0 or 1) significantly faster in smaller populations.

Thus even harmful mutations can accumulate

N= 100



Conservation Genetics

- Genetics studies the inheritance and investigates the genes responsible for inherited traits.
 - ◆ Provides new insights into the extent of diversity among the individuals in a population
 - ◆ Without using genetics, we could focus our efforts on the wrong population or waste valuable resources on a population that isn't as endangered...

The great apes



- Our closest living relatives.
- 95-99% of DNA shared between human and chimpanzees.
- Living models to understand the evolution of biology and culture of humans.
- Endangered environments and species.



Notion of species and subspecies or population

- A species is a group of organisms capable of interbreeding and producing fertile offspring

Notion of species and subspecies or population



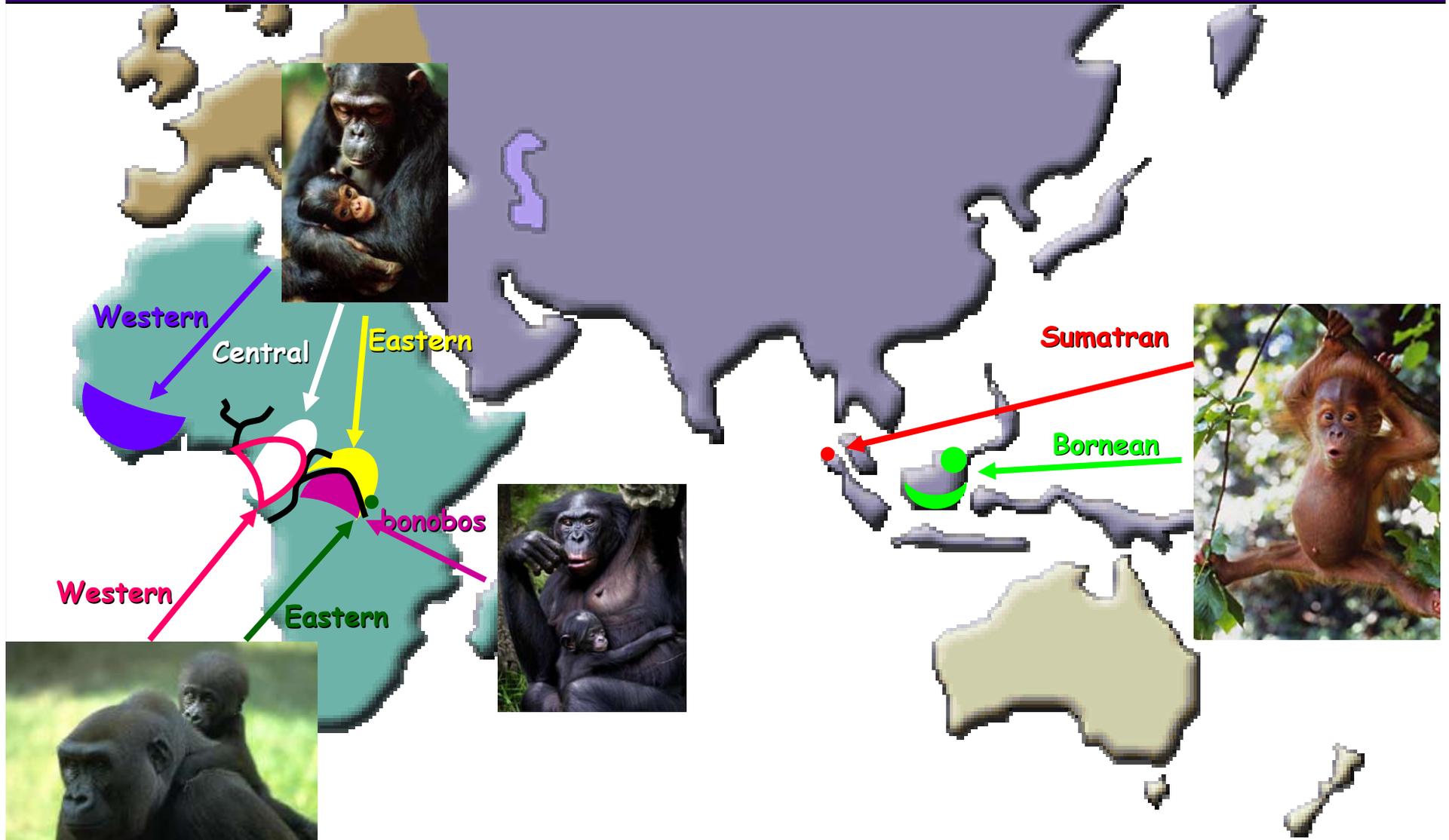
Notion of species and subspecies or population

- A species is a group of organisms capable of interbreeding and producing fertile offspring
 - ◆ Gorilla, orangutans and chimpanzee are clearly different species.
 - ◆ What about bonobo and chimpanzees? Some hybrids reported, but none in the wild (don't overlap in their current ranges).

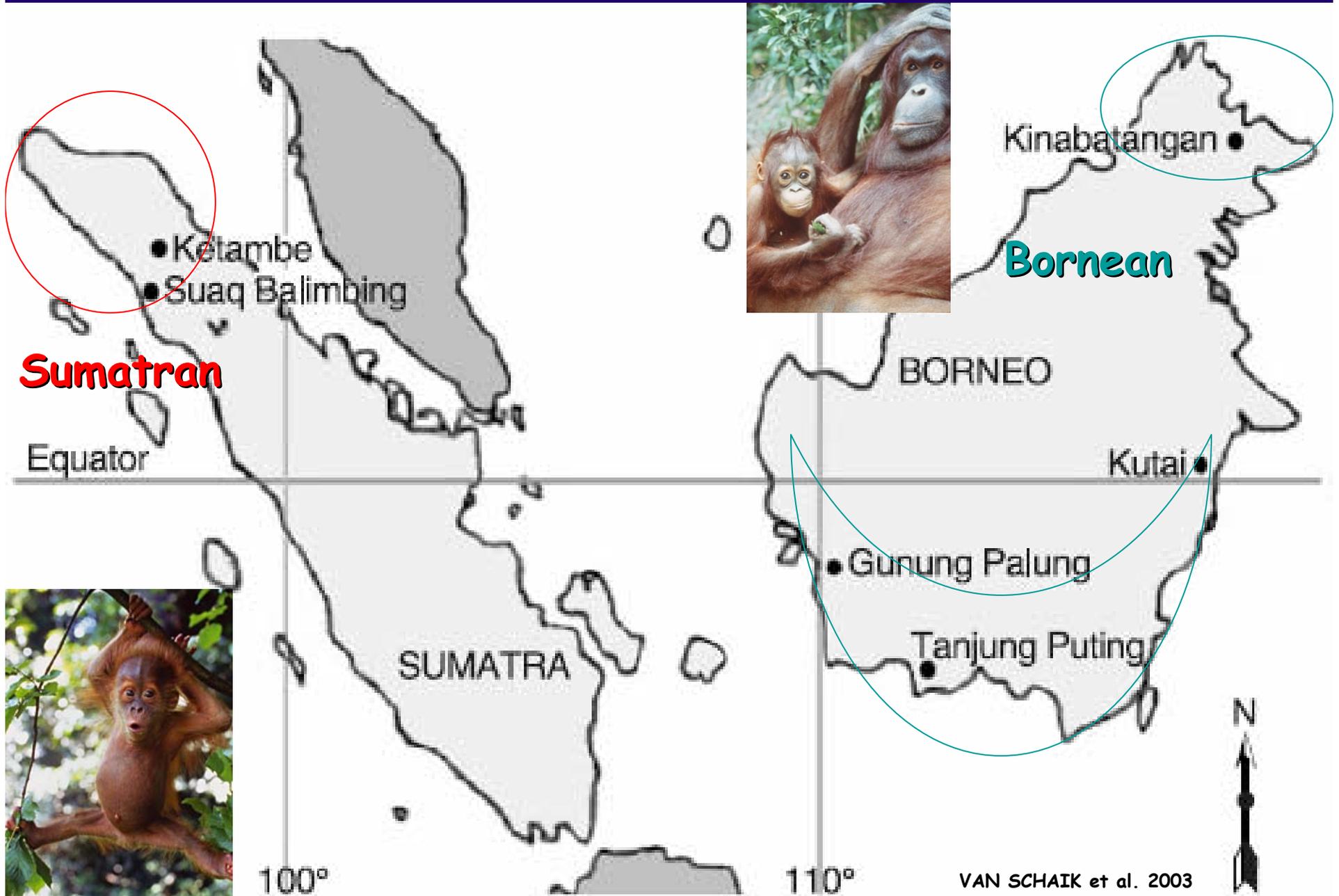
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- What is a subspecies?

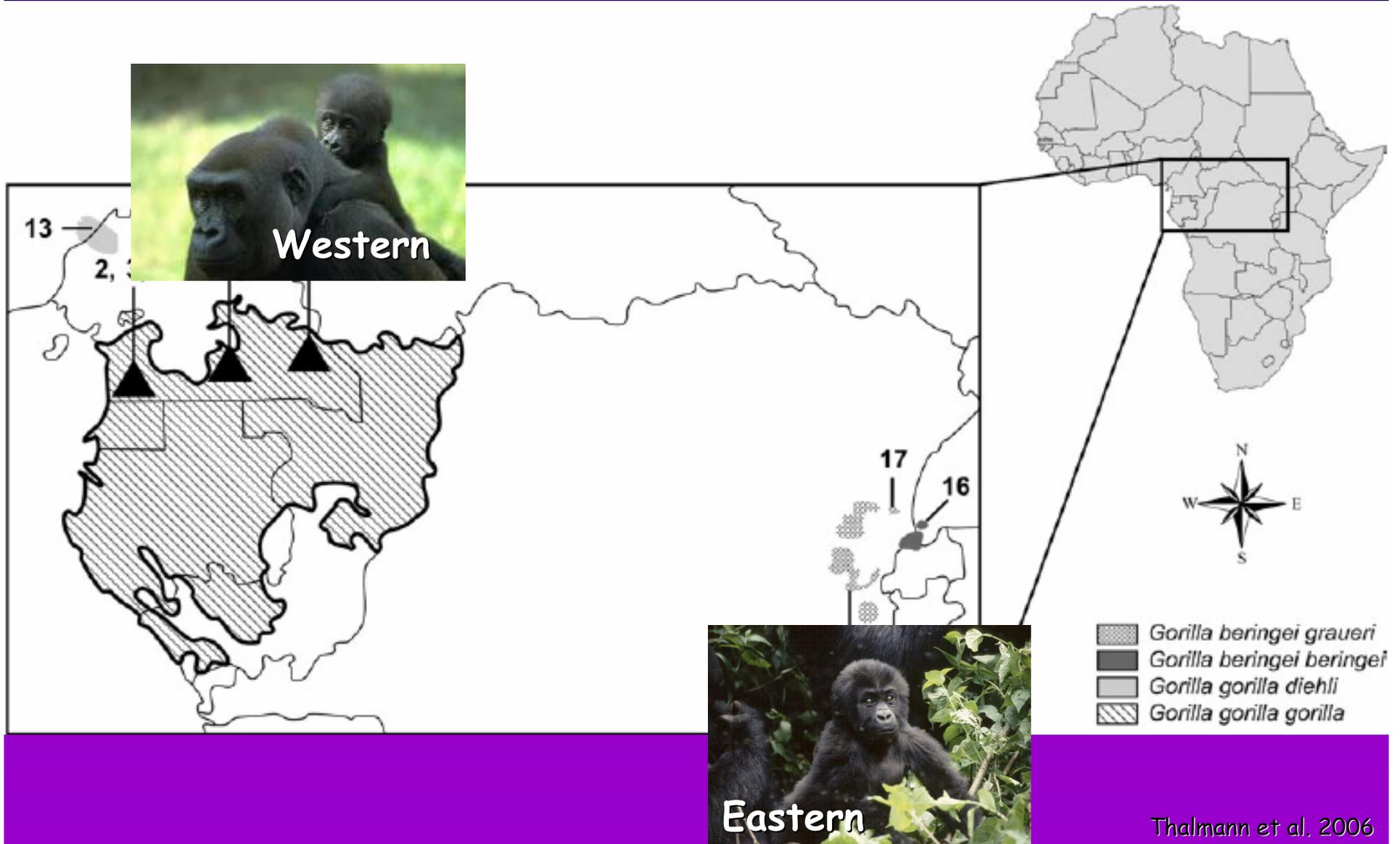
Geographical ranges of the great ape populations and species



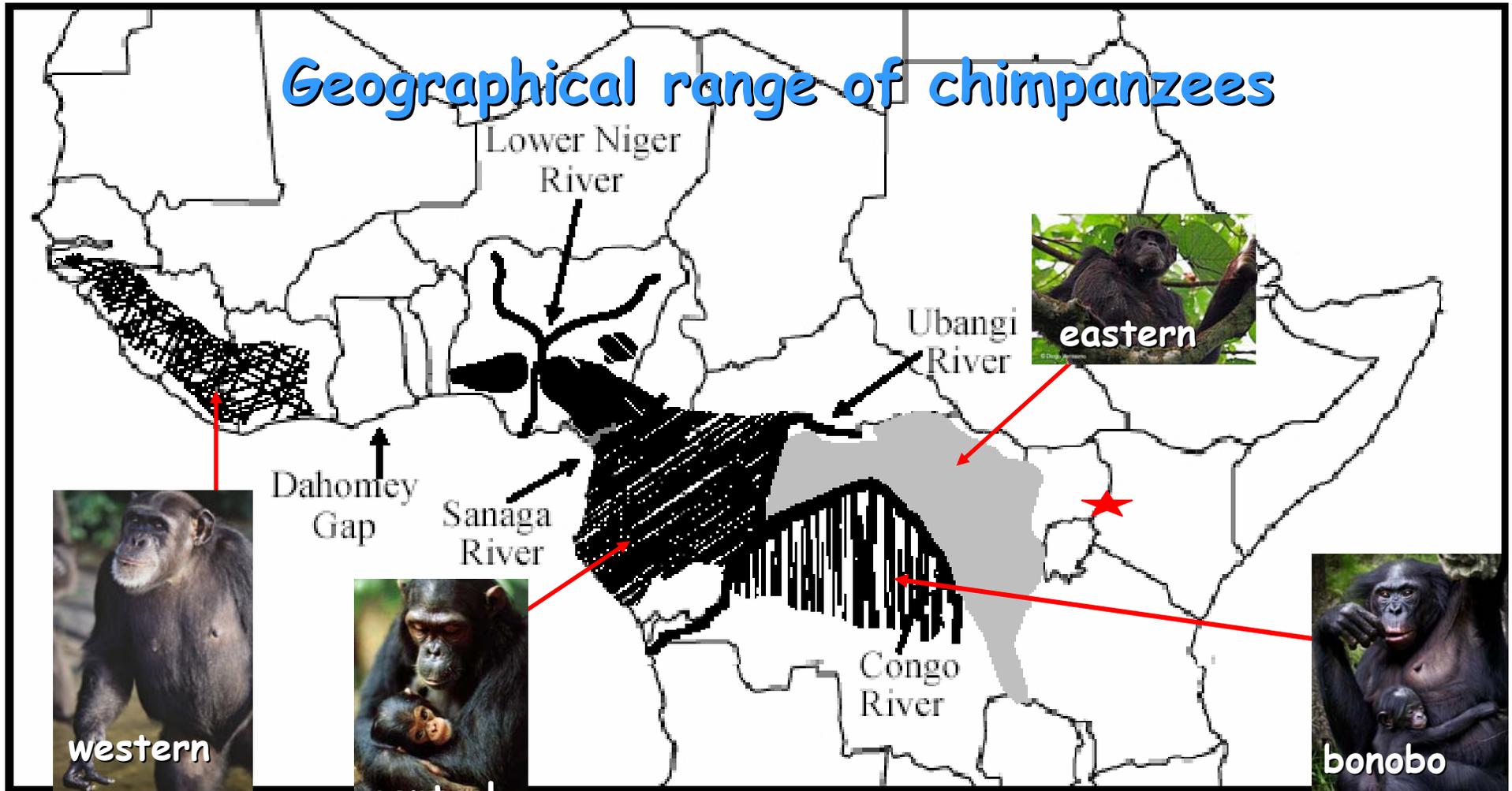
Geographical range of Orangutans



Geographical range of Gorillas



Geographical range of chimpanzees



West African chimpanzees (*P. troglodytes verus*)



Phylogenetically unclear at present (*P. troglodytes*)



E Nigeria / W Cameroon chimpanzees (*P. troglodytes vellerosus*)



Central African chimpanzees (*P. troglodytes troglodytes*)



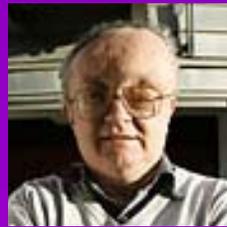
East African chimpanzees (*P. troglodytes schweinfurthii*)



Bonobos (*P. paniscus*)

Genetic Structure of Chimpanzee Populations

Celine Becquet, Nick Patterson, Anne Stone, Molly Przeworski
and David Reich 2007, PLoS Genetics 3:e66.



Genetic Structure of Chimpanzee Populations

■ Goals of the study

- ◆ Do the subspecies labels correspond to well-defined genetic populations?
- ◆ Is there evidence of migration between them?
- ◆ How many genetic markers do we need to assign individuals?
- ◆ What about the individuals of unknown origins?

Data - Samples

- 6 labels - 84 individuals

- ◆ 16 Central

- ◆ 7 Eastern

- ◆ 41 Western (1 w/ "Nigerian mtDNA")

- ◆ 11 Unknown chimpanzee subspecies (1 w/ "Nigerian mtDNA")

- ◆ 3 Hybrid (1 w/ "Nigerian mtDNA")

- ◆ 6 Bonobos

Data - 51 Wild Samples

■ 6 labels - 84 individuals

◆ 16 Central (12 wild)

- Gabon / province of Gabon

◆ 7 Eastern (6 wild)

- Country of origin

◆ 41 Western (33 wild - 1 w/ "Nigerian mtDNA")

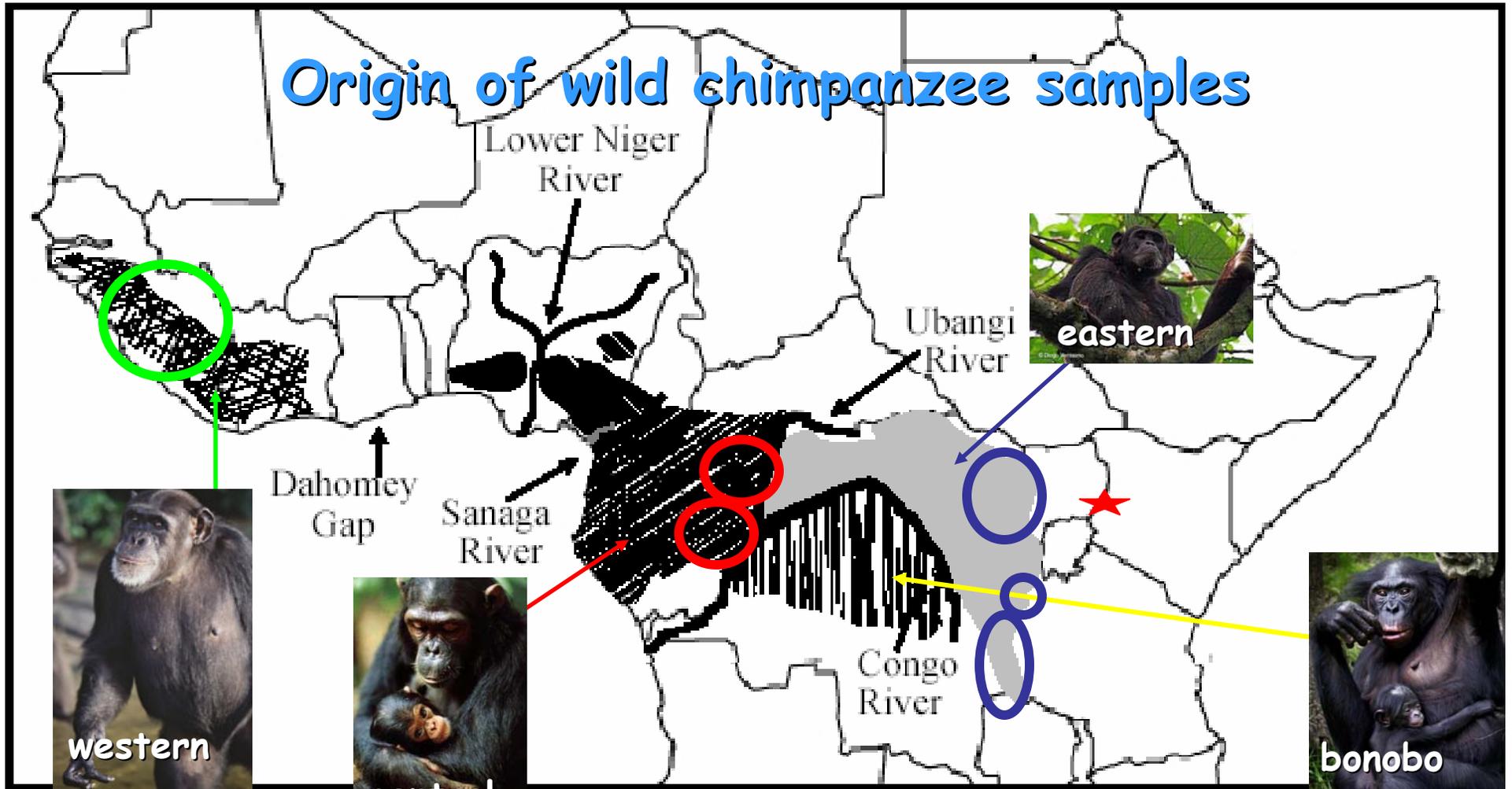
- Sierra-Leone or unknown origin

◆ 11 Unknown chimpanzee subspecies (1 w/ "Nigerian mtDNA")

◆ 3 Hybrid (1 w/ "Nigerian mtDNA")

◆ 6 Bonobos

Origin of wild chimpanzee samples



West African chimpanzees (*P. troglodytes verus*)



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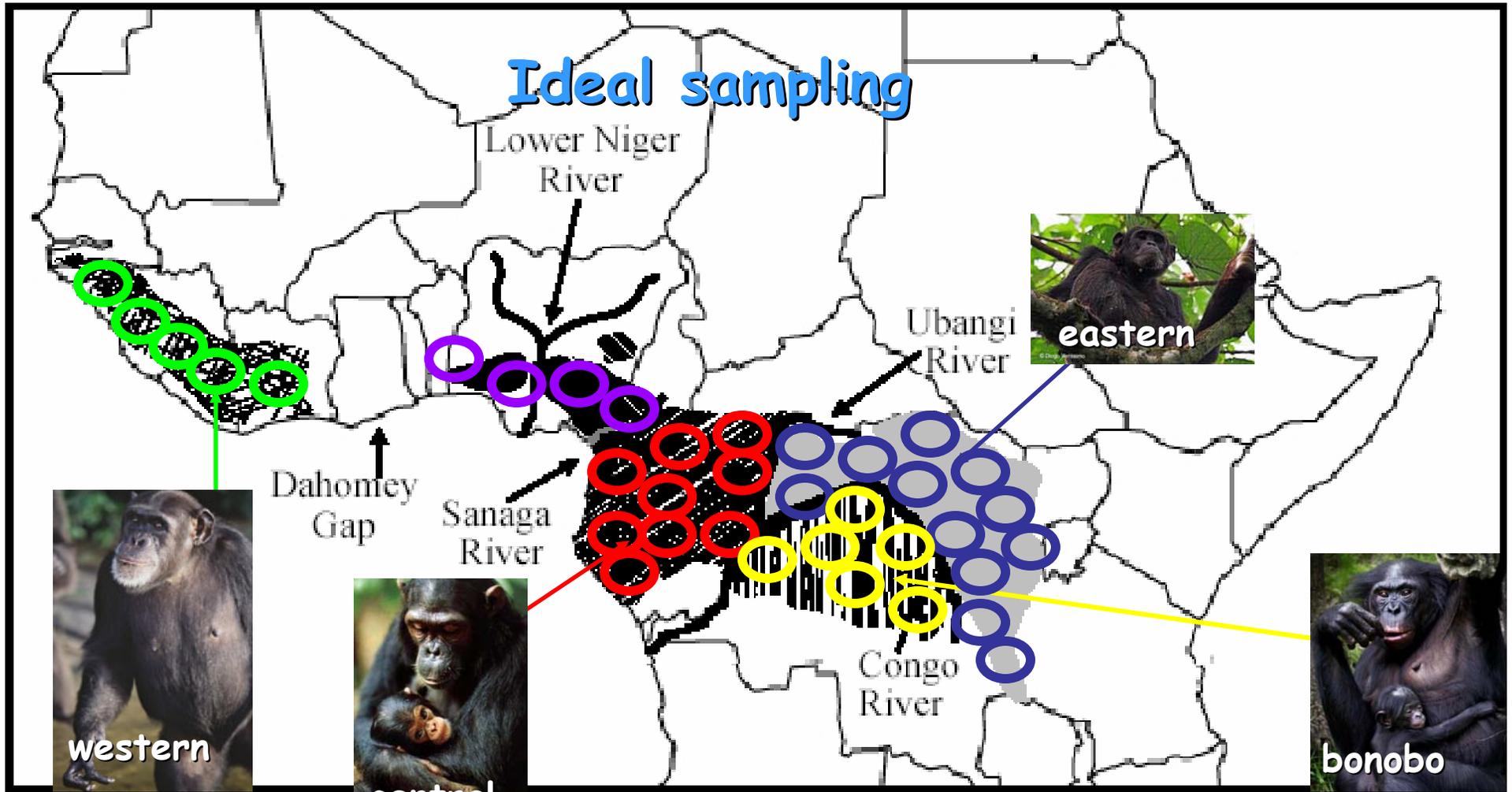
Central African chimpanzees (*P. troglodytes troglodytes*)



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Bonobos (*P. paniscus*)



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Bonobos (*P. paniscus*)

Chimp nest



Chimp nest



Chimp nest



Bonobo nest



Orangutan nest



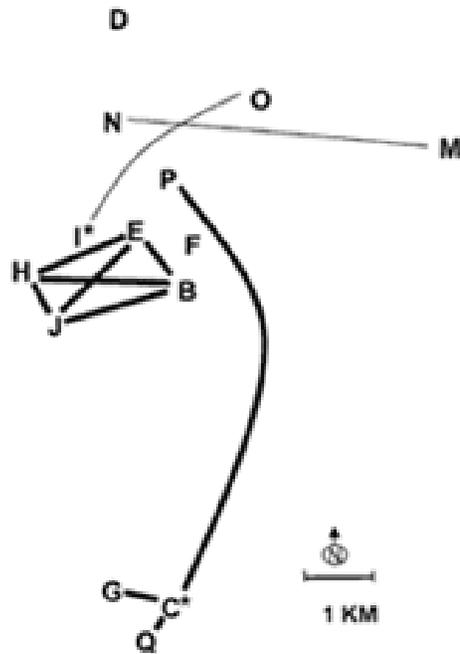
Orangutan nest



Orangutan nest



Sampling in the field Gorilla nest



Relative locations of gorilla nest sites, from Bradley et al. 2004. *Current Biology* 14:510.



Data - Genetic Markers

■ 310 Microsatellites

- ◆ Good quality (estimated based on duplicates: average of two erroneous genotype calls per individual)
- ◆ 295 autosomal markers
- ◆ 221 tetra-, 62 tri-, 11 di-nucleotides

Why microsatellites?

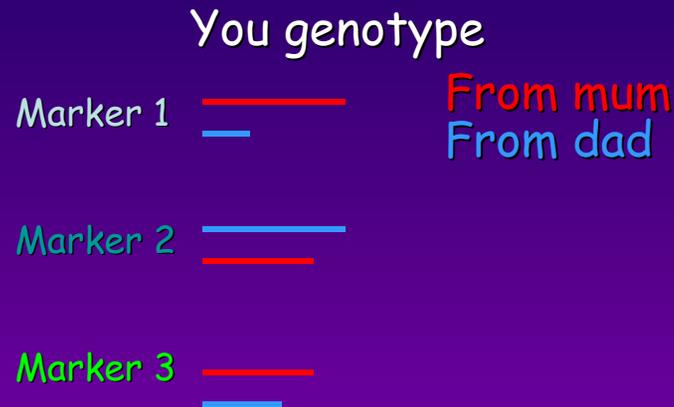
You genotype

Marker 1  From mum
From dad

Marker 2 

Marker 3 

Why microsatellites?



■ Useful because

- ◆ Highly variable (usually two different alleles within an individual)
- ◆ Fingerprints are used in forensic and paternity/parentage tests

Program STRUCTURE

1. There are 4 populations each of which is characterized by a set of allele frequencies at each marker.

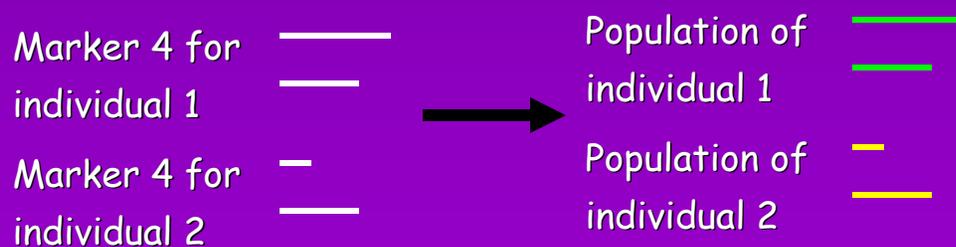
	Pop1	Pop2	Pop3	Pop4
Marker 4	—— 50% —— 25% —— 25%	—— 75% —— 25%	—— 1% —— 75% — 24%	—— 50% — 50%

Program STRUCTURE

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	Pop1	Pop2	Pop3	Pop4
Marker 4	 50% 25% 25%	 75% 25%	 1% 75% 24%	 50% 50%

2. Individuals in the sample are assigned to populations, or jointly to two or more populations if their genotypes indicate that they are admixed.

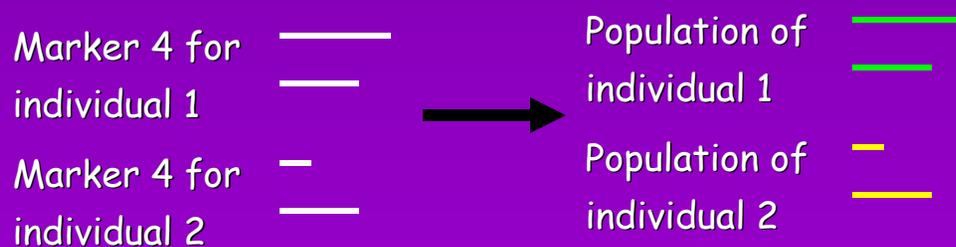


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3. Loop on 1 and 2 until it fits the data

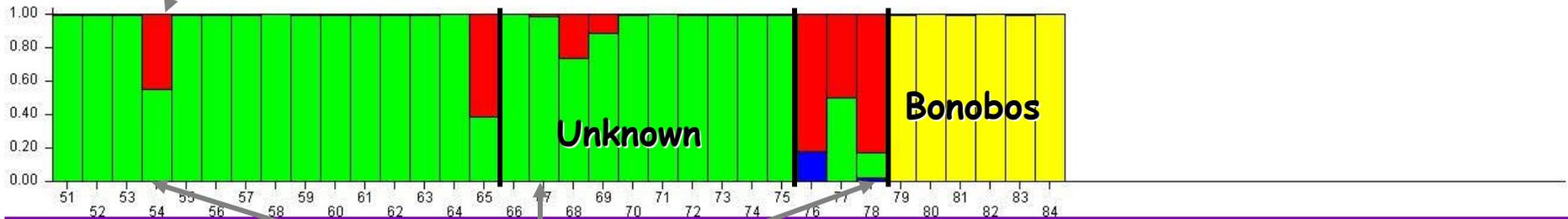
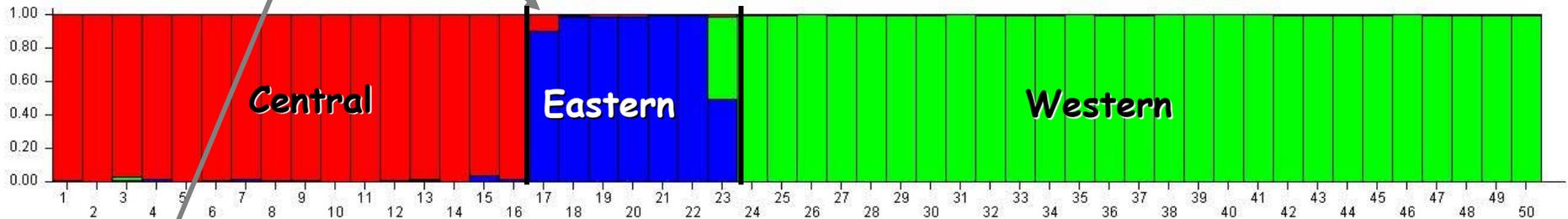
Output of the Program STRUCTURE

The 2 alleles at
the 310 markers
for this individuals



STRUCTURE with four clusters

Wild-caught
hybrids



Nigerian mtDNA

Hybrids

Concept of Informativeness

Different alleles

Marker 1		60%		100%
		40%		

Marker 2		50%		10%
		50%		50%
				40%

Marker 3		100%		5%
				95%

Marker 4		10%		50%
		90%		50%

Pop1

Pop2

Concept of Informativeness

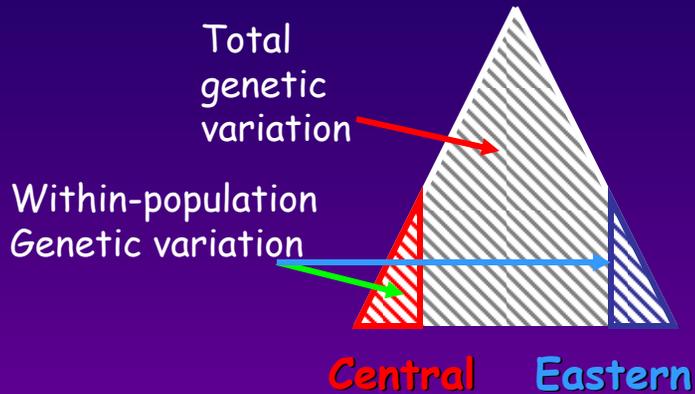
Different alleles

	Pop1	Pop2
Marker 1	60% 40%	100%
Marker 2	50% 50%	10% 50% 40%
Marker 3	100%	5% 95%
Marker 4	10% 90%	50% 50%

Concept of Informativeness

- Calculated the informativeness of the markers (Rosenberg *et al.* 2002)
- Run STRUCTURE for different set of most informative markers
- Found:
 - ◆ **30 most informative markers** = minimum set to find four clusters.
 - ◆ 71/75 samples assigned to same cluster.
 - ◆ Identified 6/9 hybrids.

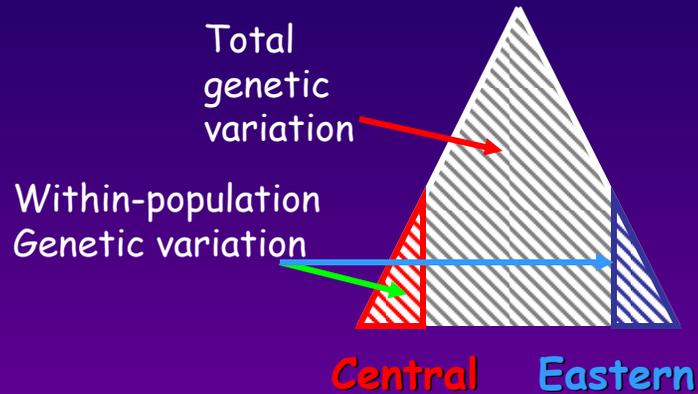
Population differentiation: F_{ST}



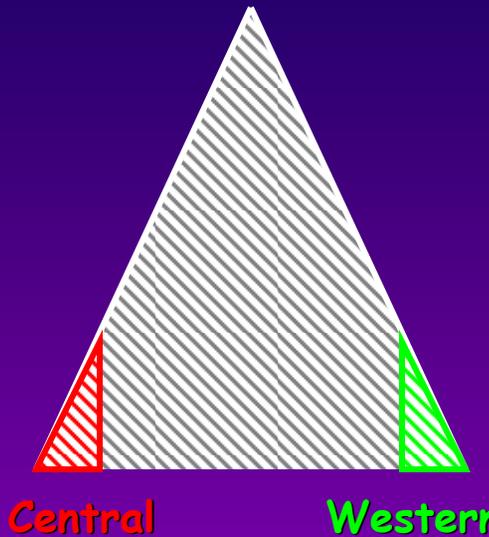
$$F_{ST_{C,E}} = 0.05$$

$$F_{ST} = \frac{Tot_{var} - Within_{var}}{Tot_{var}}$$

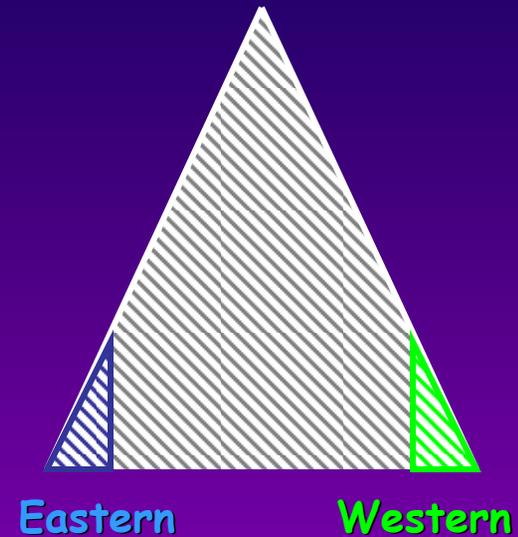
Population differentiation: F_{ST}



$$F_{ST_{C,E}} = 0.05$$



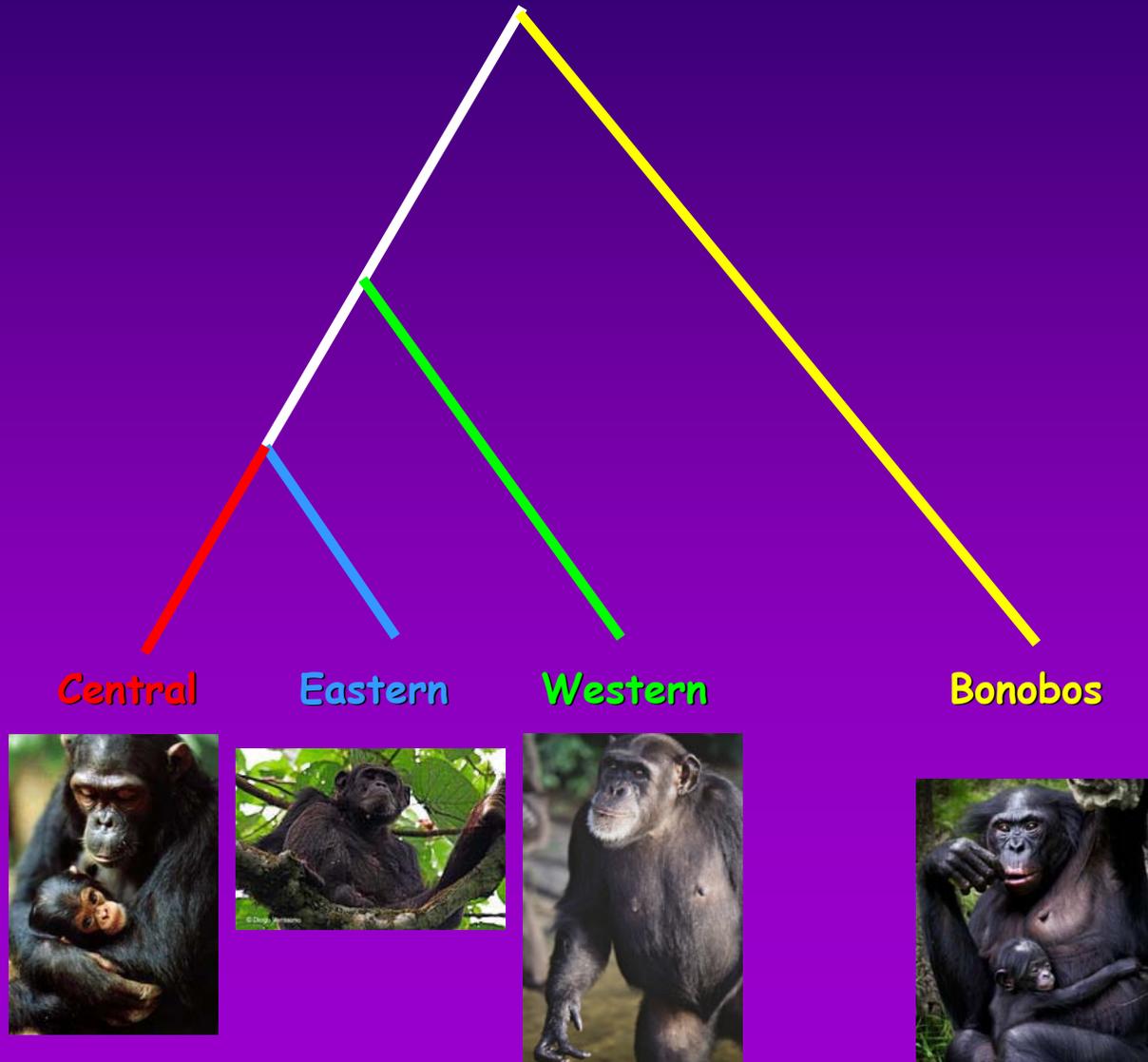
$$F_{ST_{C,W}} = 0.25$$



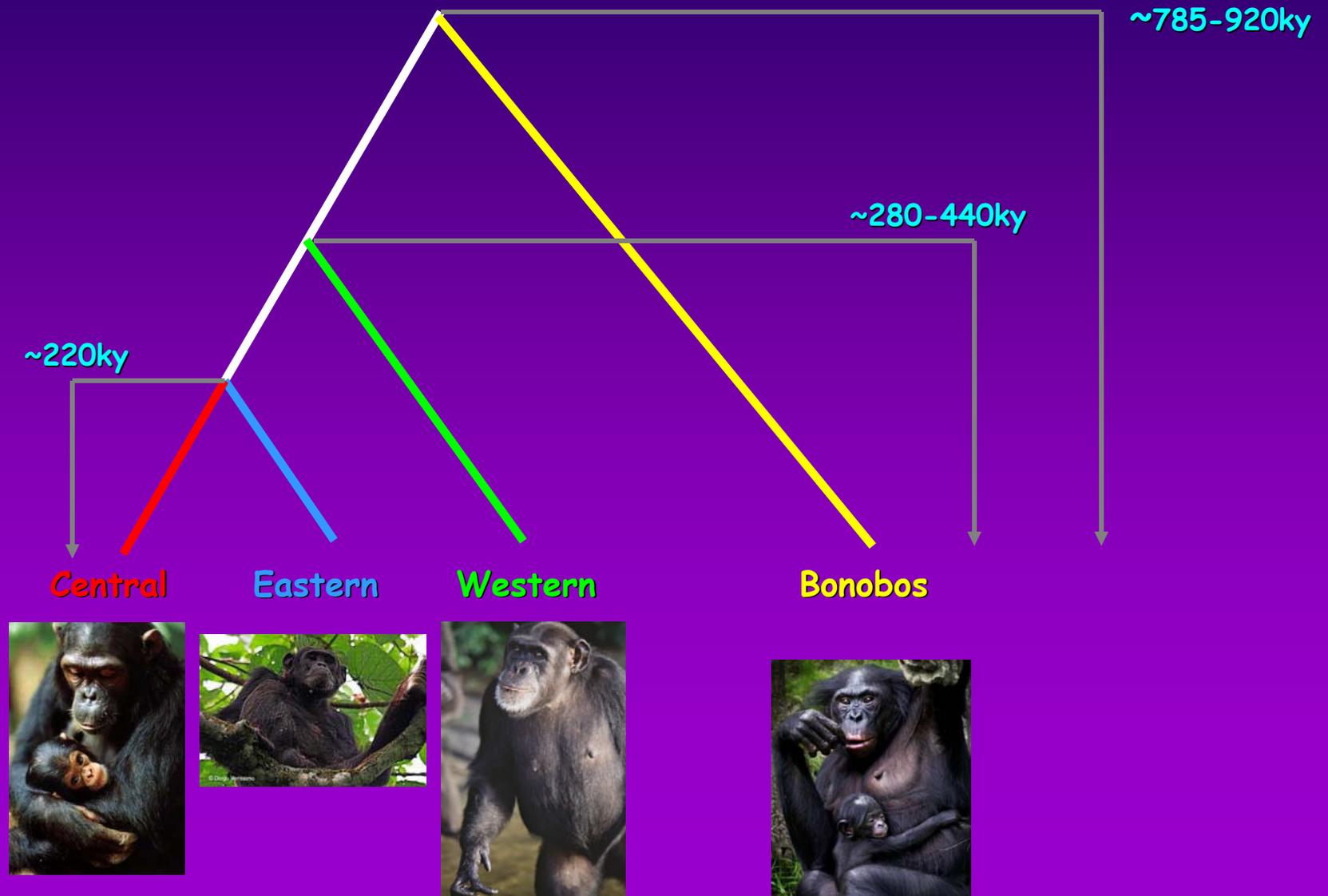
$$F_{ST_{E,W}} = 0.31$$

$$F_{ST_{Bonobo-chimpanzee}} = 0.51 - 0.68$$

Tells us about the history of these populations and species



Divergence time estimates from another study



Conclusions of the study

- The subspecies labels correspond to genetically defined populations.
- Little evidence of migration in the wild (at least with these samples).
- Central and Eastern chimpanzee are more closely related than they are to Western chimpanzee.
- Propose 30 markers which provide excellent power for classification

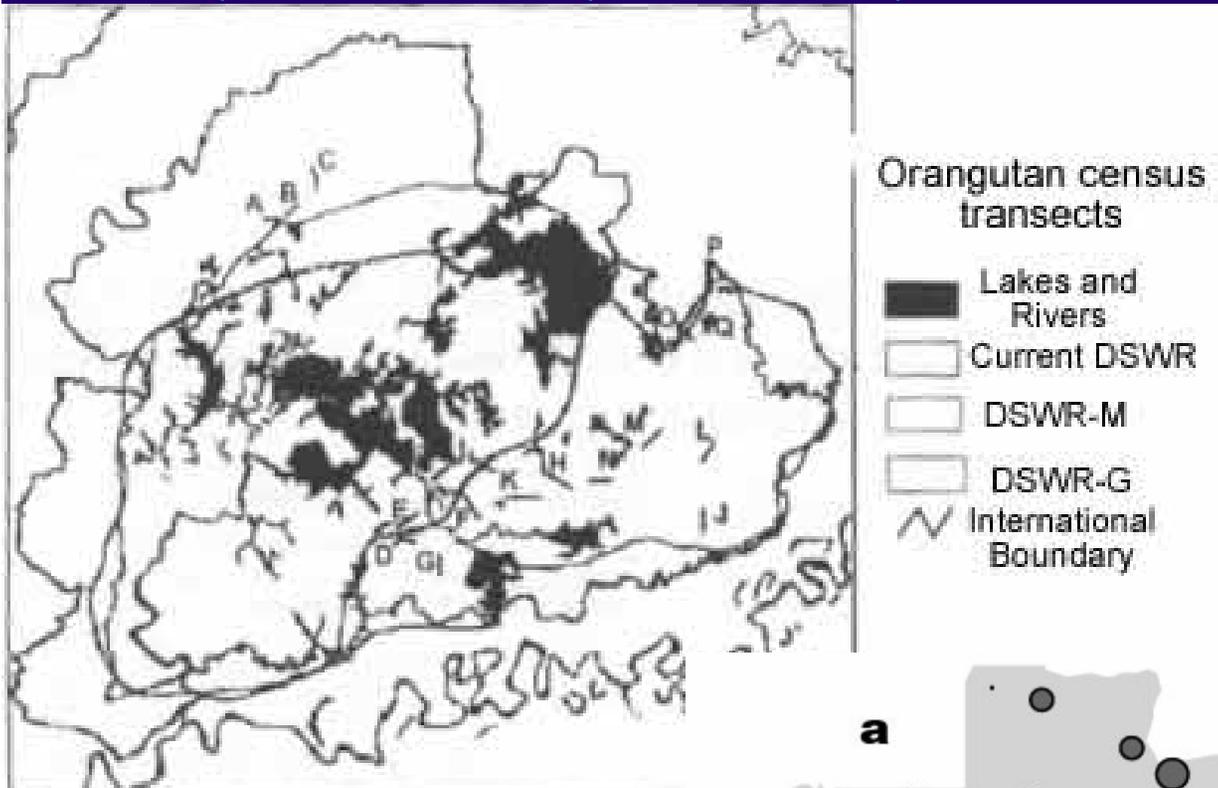
How bad is it?

The chimpanzee, gorilla, bonobo and orangutan are listed as endangered species

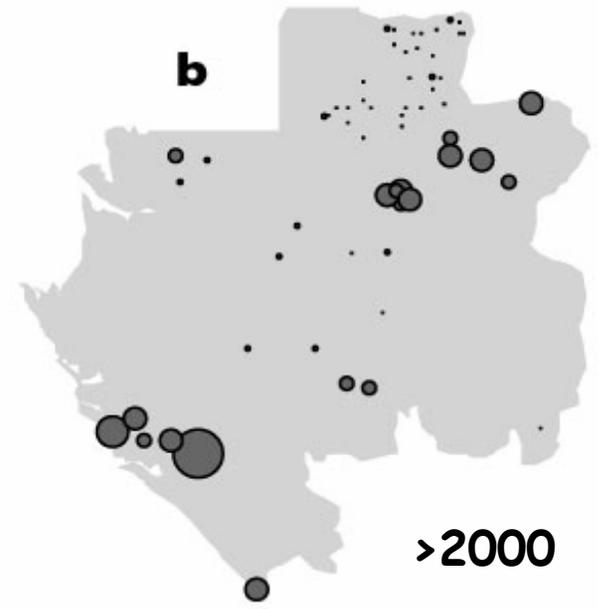
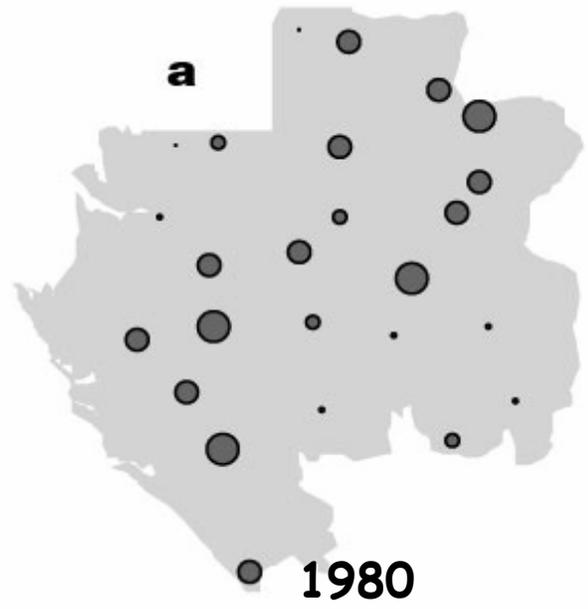
All the great ape populations and species have declined to the point that the long-term survival of the species in the wild is in serious jeopardy



Great apes by their nature are extremely vulnerable
They occur at very low density



Encounter rates of ape nest groups per km in Gabon



Great apes by their nature are extremely vulnerable

They grow relatively slowly, are long-lived, have low reproductive rates

Orangutan mothers often go eight years or longer between offspring



Great apes by they nature are extremely vulnerable

They grow relatively slowly, are long-lived, have low reproductive rates

Females will typically produce only 3 to 6 offspring during her lifetime.



Great apes by their nature are extremely vulnerable

They grow relatively slowly, are long-lived, have low reproductive rates

There is an average of 5 to 6 year intervals between surviving births



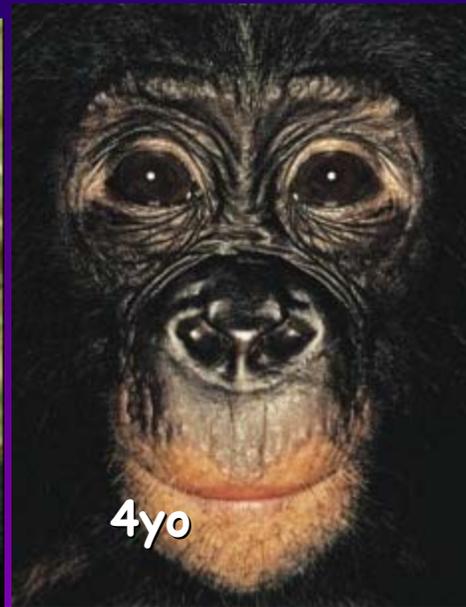
Great apes by their nature are extremely vulnerable

They grow relatively slowly, are long-lived, have low reproductive rates

Births about every 5 years. Females have between five and six offspring in a lifetime.



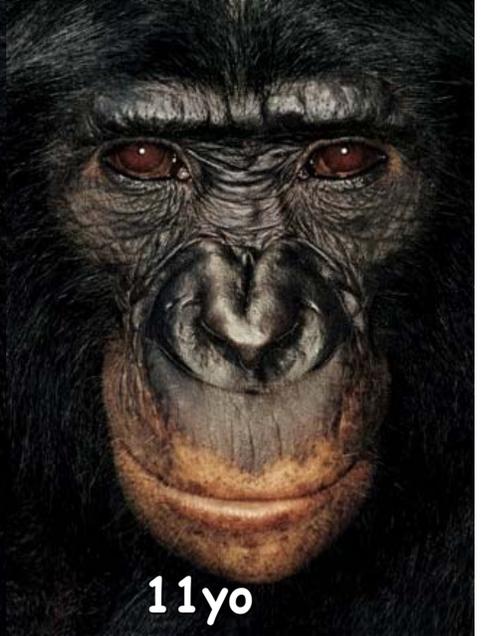
Baby



4yo



7yo



11yo



2yo



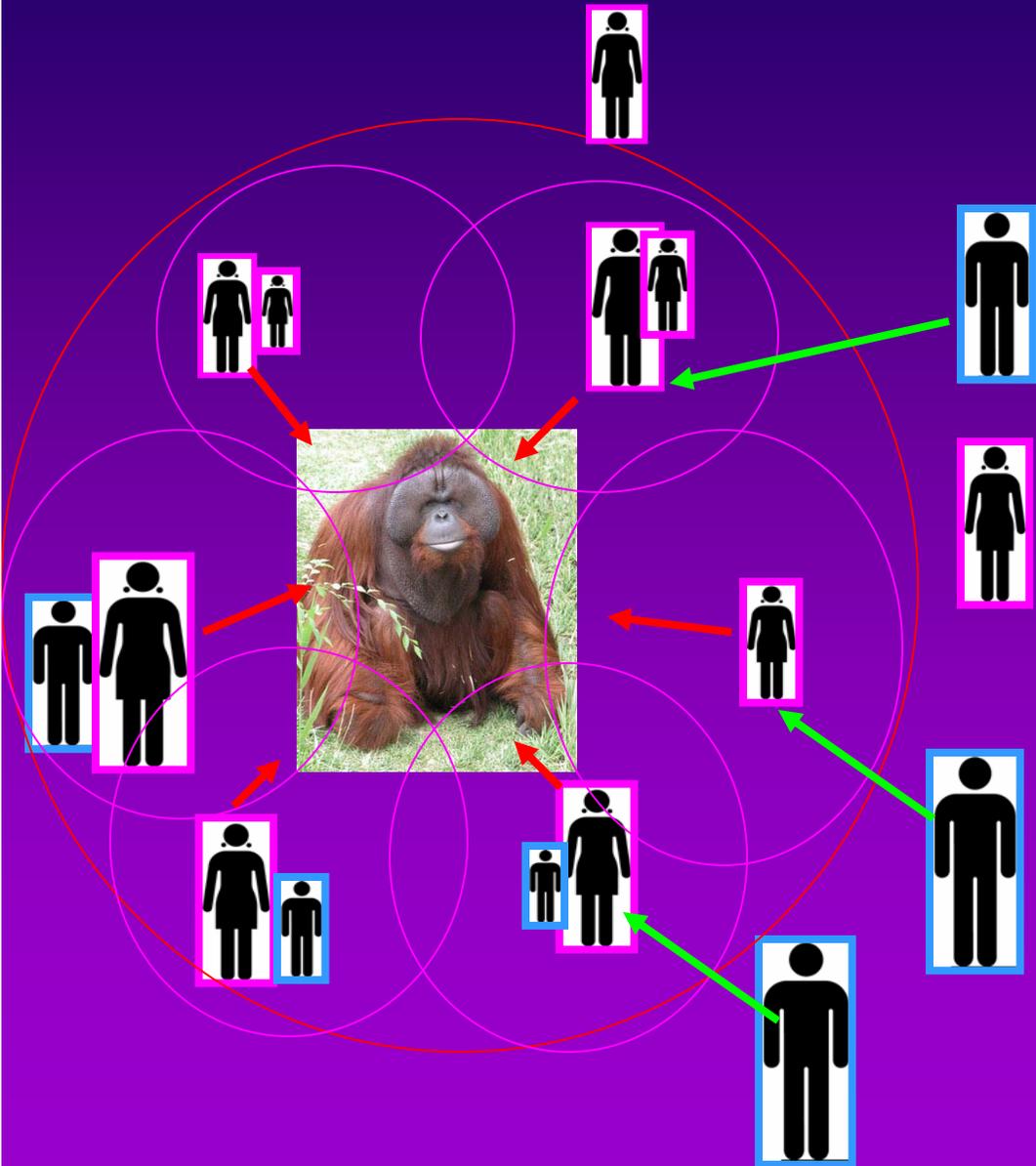
27yo

Great apes by their nature are extremely vulnerable
They have complex social relationships



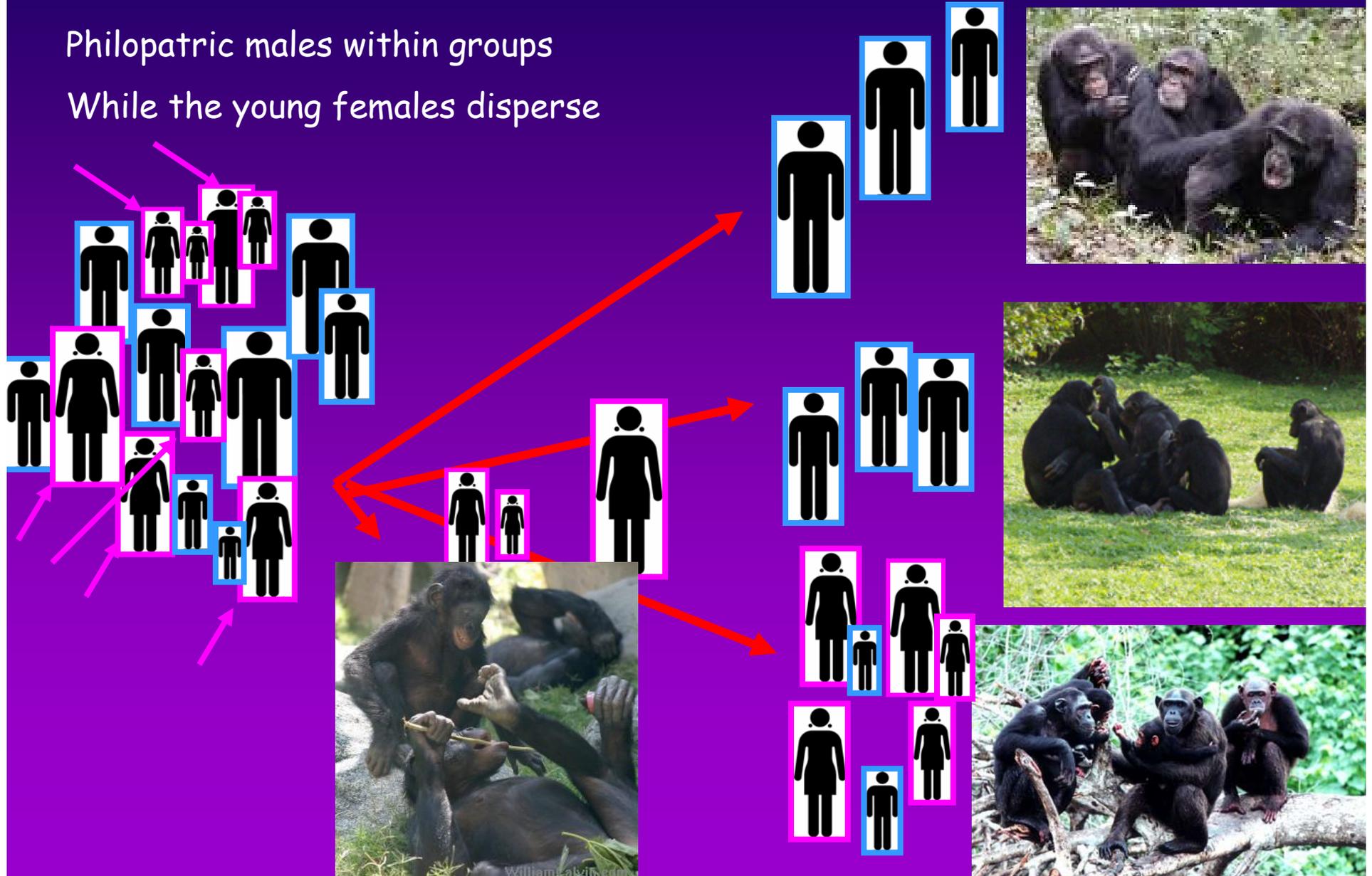
Orangutan

Adolescents of both sexes range alone while adult females range with their dependent offspring

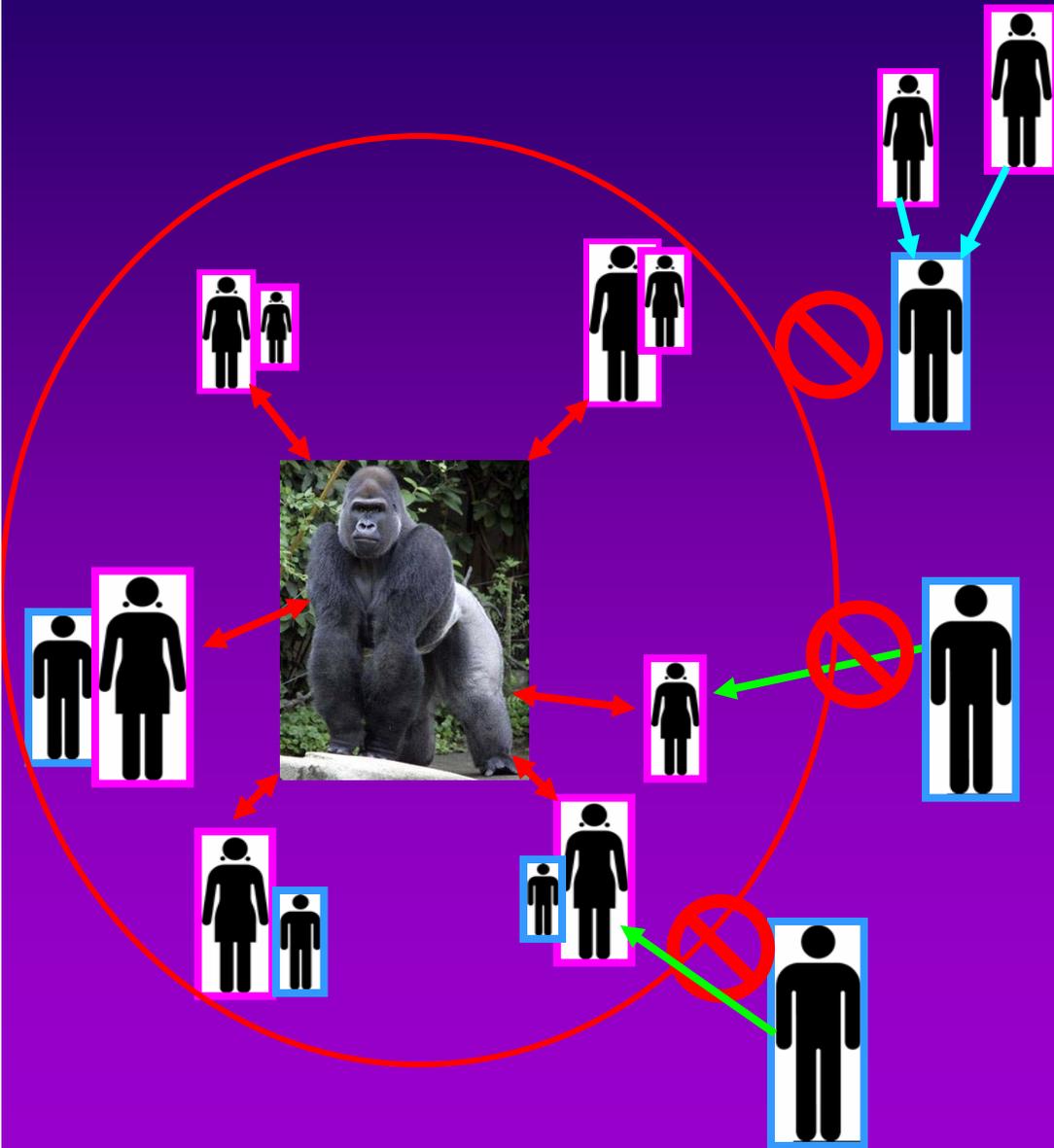


Chimp and bonobo: fission-fusion societies

Philopatric males within groups
While the young females disperse



Gorilla: Harem like societies



Differences between Chimp and bonobo

- Diet

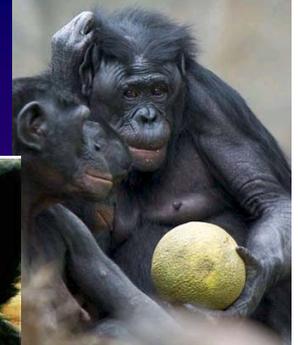
- Locomotion

- Social group

- Mum/son relationships

- Tool use

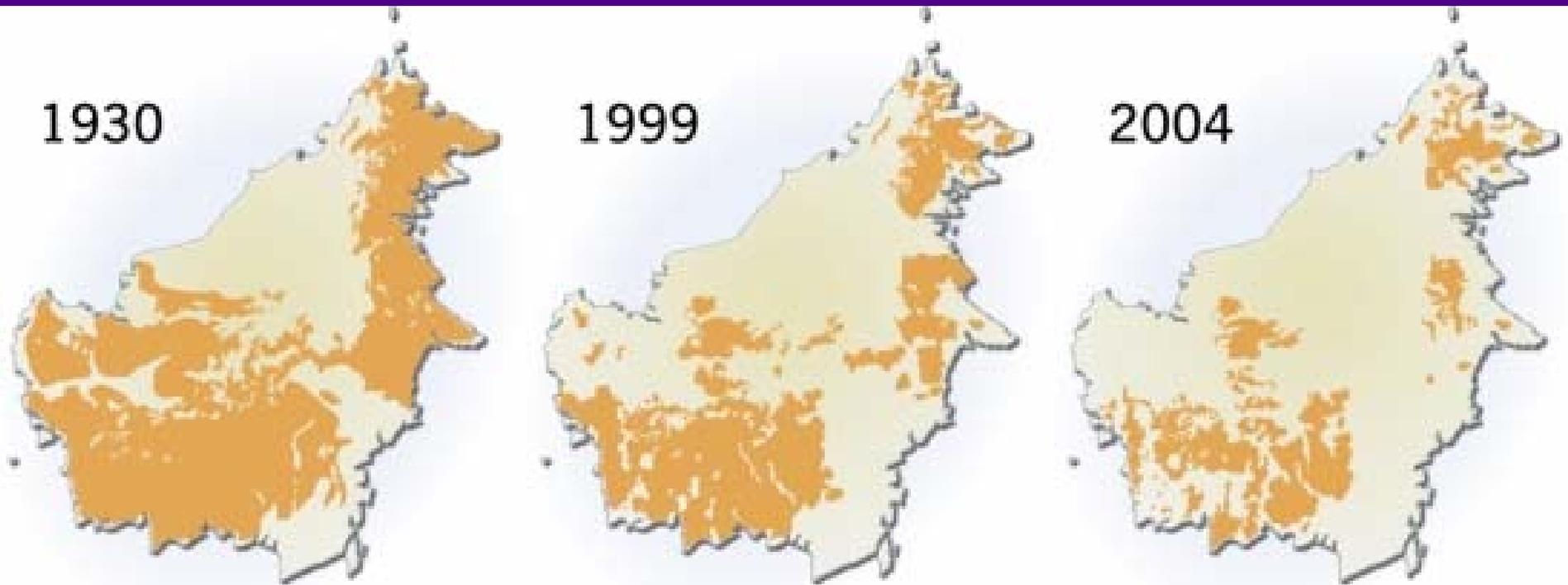
- Behavior



Threat of competition for habitat (i.e., Logging)

- Directly reduces habitat

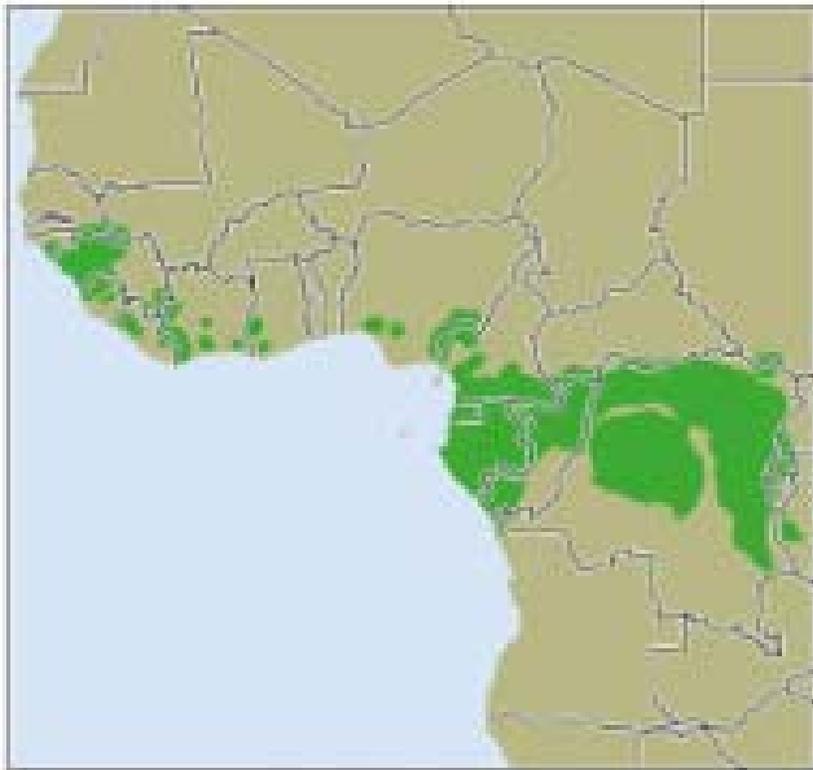
Decreasing habitat of Orangutans on Borneo



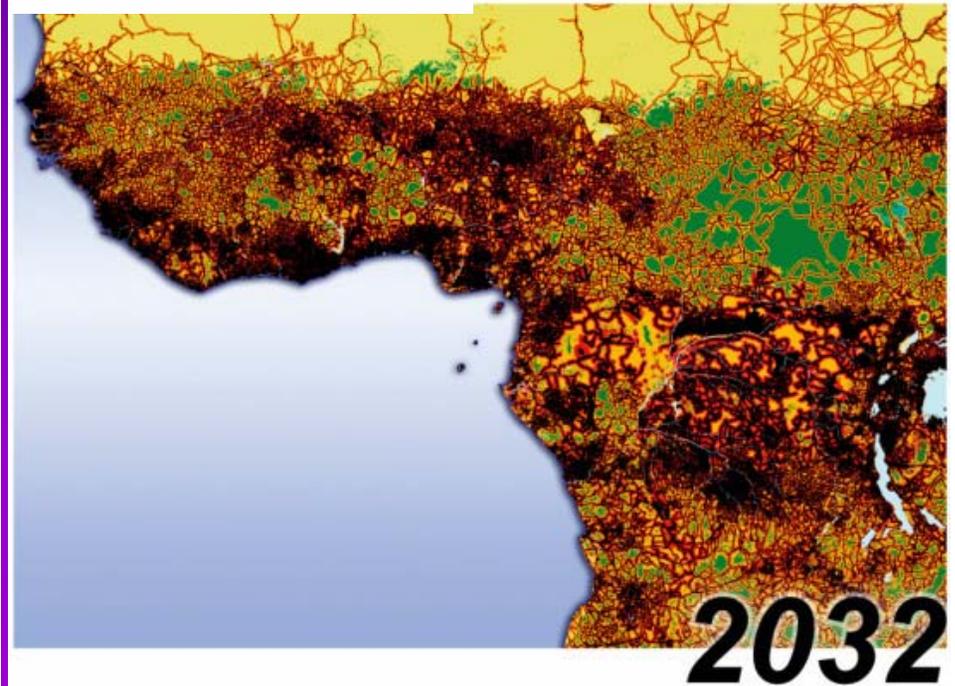
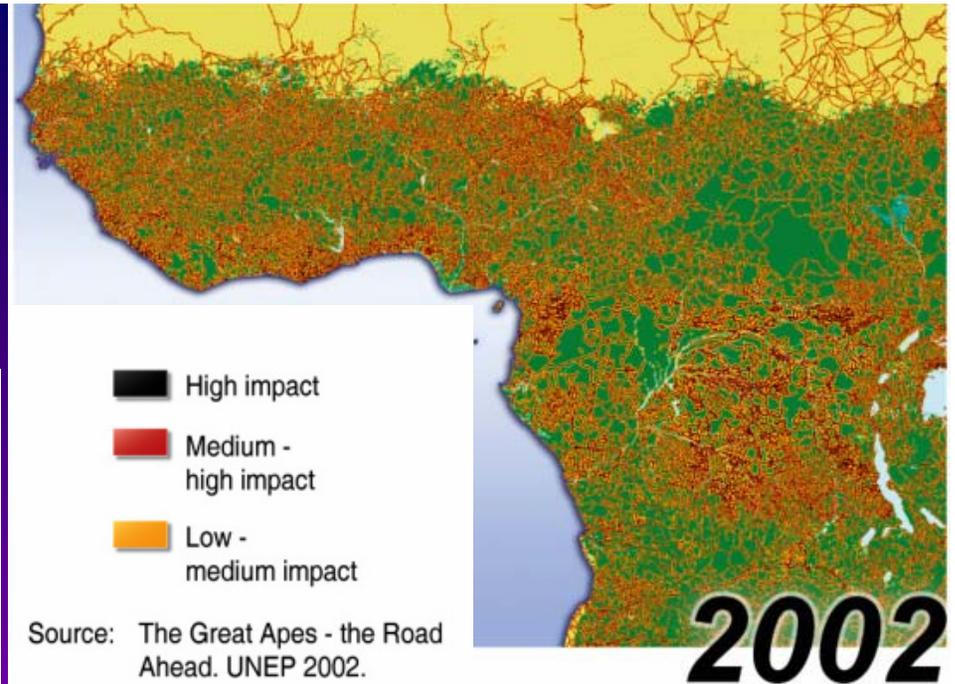
Radday, M. 2007. 'Borneo Maps'. January 24, 2007,

Current and future human impacts on Great Ape habitat in Africa (Chimpanzee, Bonobo and Gorilla).

GLOBIO2 model (prepared for GEO-3) using DCW (ESRI), Landsat 2000 (ORNL), ArcAtlas (ESRI and Data+) and GLCCv2 (USGS)



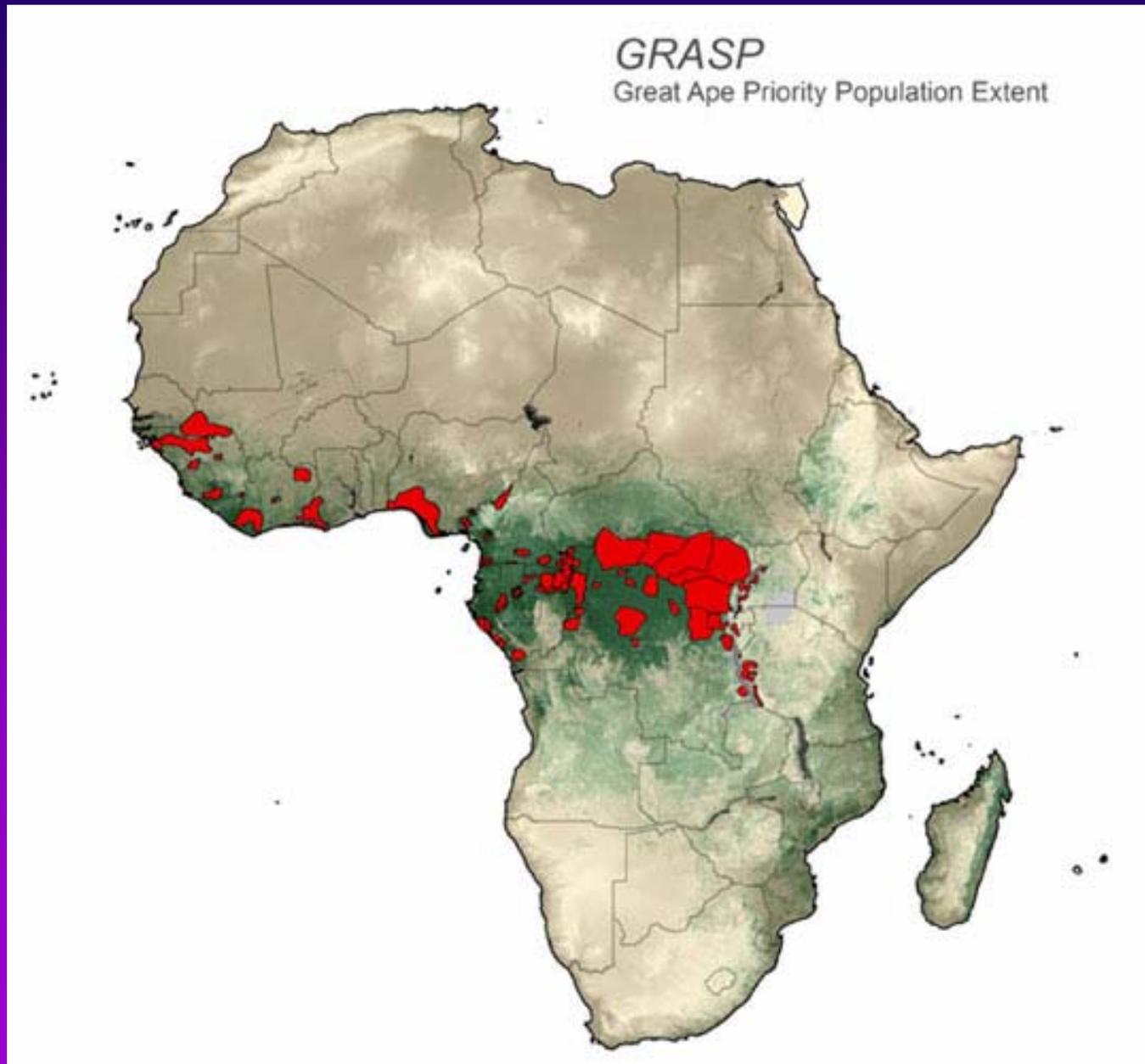
Current distribution of African great apes (Chimpanzee, Bonobo and Gorilla).



Threat of competition for habitat (i.e., Logging)

- Directly reduces habitat
- Roads it creates mean :
 - ◆ Habitat is highly fragmented!

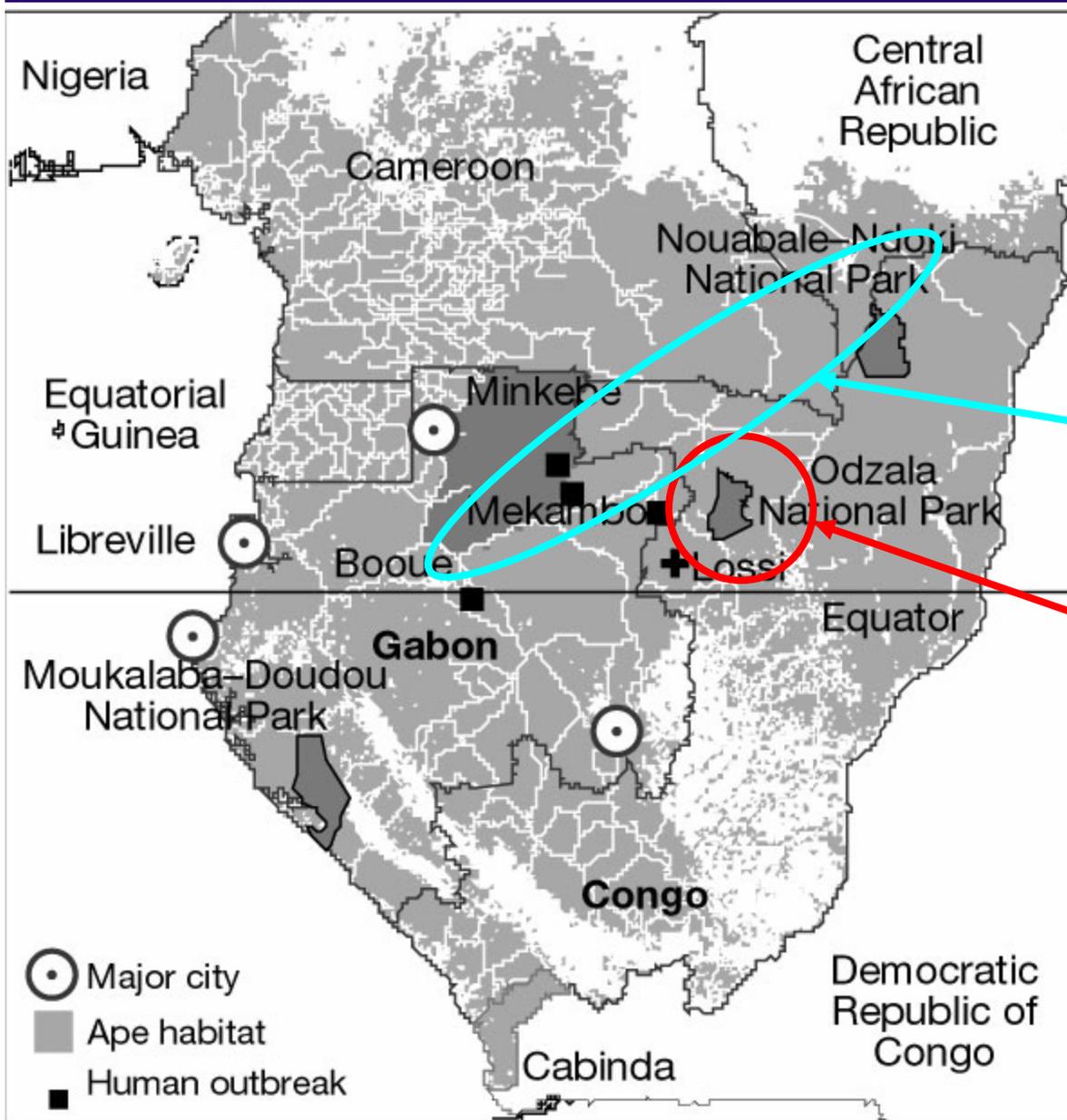
Habitat is highly fragmented (map 2006)



Threat of competition for habitat (i.e., Logging)

- Directly reduces habitat
- Roads it creates mean :
 - ◆ Habitat is highly fragmented!
 - ◆ Easier access into deep jungle and the animals that live there
 - Makes hunting for bushmeat easier
 - Live capture
 - Exposure to emerging or introduced diseases (i.e., Ebola)

Easier access into deep jungle and the animals that live there



major roads in white

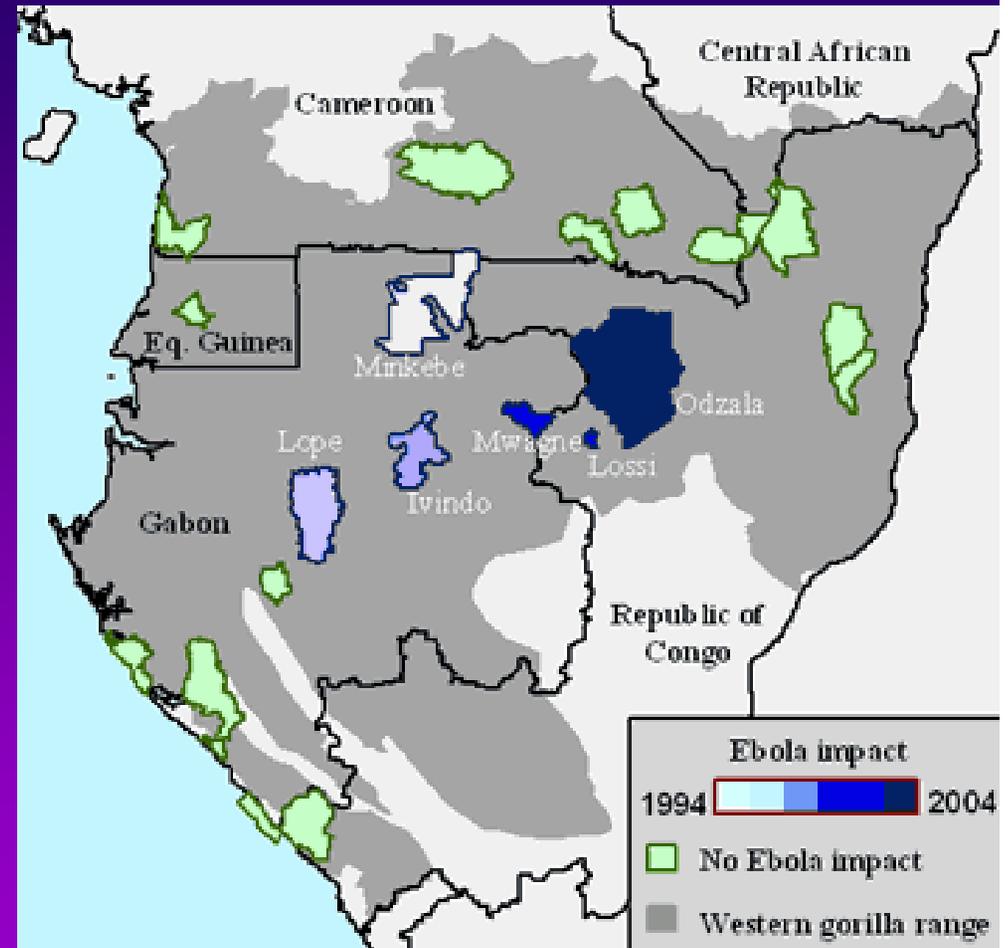
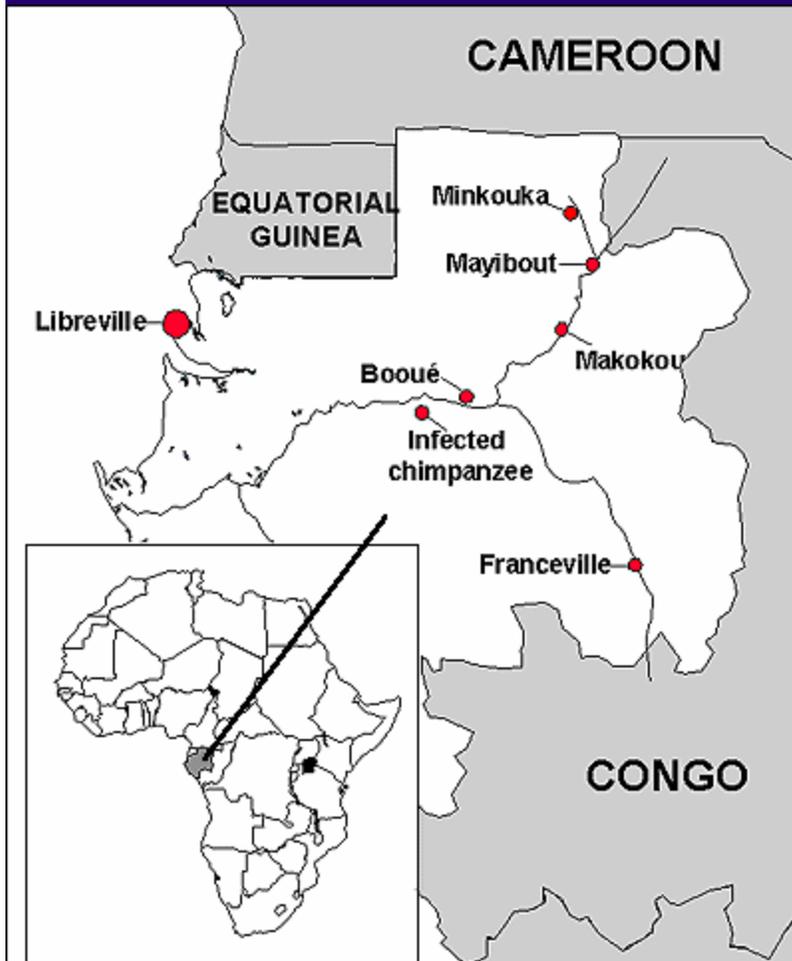
Hunting Carcasses

Ebola epidemic

Makes hunting for bushmeat easier



Exposure to emerging or introduced diseases (i.e., Ebola)



Geographic distribution of the three Ebola virus hemorrhagic fever epidemics and site of the infected chimpanzee in Gabon. (1997)

Ebola killed at least 5000 gorilla

PONGO PYMAEUS ¹	BORNEAN ORANGUTAN	53,000-54,500 Est.
<i>Pongo p. pygmaeus</i>		3,000 - 4,500 Est.
<i>Pongo p. wurmbii</i>		35,000 Est.
<i>Pongo p. morio</i>		15,000 Est.
PONGO ABELLI ^{2,3}	SUMATRAN ORANGUTAN	6,700 Est.
GORILLA GORILLA	WESTERN GORILLA	94,700 Est.
<i>Gorilla g. gorilla</i>	Western Lowland gorilla	94,500 Est.
<i>Gorilla g. diehli</i>	Cross River gorilla	200 Est.
GORILLA BERINGEI	EASTERN GORILLA	5,380 Est.
<i>Gorilla b. beringei</i> ⁴	Mountain gorilla	380 Est.
<i>Gorilla b. graueri</i>	Eastern Lowland gorilla	5,000
PAN TROGLODYTES ⁵	CHIMPANZEE	203,000 Est.
<i>Pan t. schweinfurthii</i>	Eastern chimpanzee	76,400-119,600 Est.
<i>Pan t. verus</i>	Western chimpanzee	21,300-55,600 Est.
<i>Pan t. troglodytes</i>	Central chimpanzee	70,000-116,500 Est.
<i>Pan t. vellerosus</i>	Nigeria chimpanzee	5,000-8,000 Est.
PAN PANISCUS	BONOBO	20,000 - 50,000 Est.
HOMO SAPIENS	HUMAN	6 Billion + Est.

Action to conserve ape species

- Protect habitat: create reservations and sanctuaries
- Increase value of living apes and intact habitat to the local populations
 - ◆ Involve locals to preservation
 - ◆ Create local patrols to help reduce bushmeat hunting
 - ◆ Provide substitute to logging (gas bottle)
 - ◆ Use local help in the study of colonies in the wild
 - ◆ Ecotourism

But conserve the whole species? Or each populations/subspecies?

- Reduce fragmentation

- ◆ Within homogeneous populations
- ◆ Avoid contact between populations

- Limit inbreeding

- ◆ But avoid extreme outbreeding, since it lowers the fitness as well

- Requires knowledge on the genetic diversity of the great apes!

So what? - Example of the common chimpanzee populations

- How to conserve the common chimpanzees in their natural habitat?
 - ◆ Which subspecies to conserve in priority?
 - ◆ Should we bother with all of them?
- How to control the breeding in captivity to preserve the genetic integrity of the common chimpanzees?
 - ◆ Would you bother using these 30 markers?
 - ◆ Should we avoid mixtures to reproduce?

Thanks!

