Our endangered cousins
the great apes

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Marcelo Nobrega

Aaron Turkewitz

Thanks!
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 kills 80% non-blue
Inbreeding reduces population fitness

% change for a Measure of fitness

% Hatch

% deformed

Survival

Egg Mass weight

INBREEDING (%)
Random genetic drift becomes the main evolutionary process, instead of natural selection.

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.
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.

~15 My

~8 My

~6-7 My

~.8 My
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 chimpanzees are clearly different species.
  - What about bonobo and chimpanzees? Some hybrids reported, but none in the wild (don’t overlap in their current ranges).
A species is a group of organisms capable of interbreeding and producing fertile offspring.

- Gorilla, orangutans and chimpanzees are clearly different species.
- What about bonobo and chimpanzees? Some hybrids reported, but none in the wild. (don't overlap in their current ranges).

What is a subspecies?
Geographical ranges of the great ape populations and species
Geographical range of Orangutans

Sumatran

Bornean

Van Schaik et al. 2003
Geographical range of Gorillas

Thalmann et al. 2006
**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
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Won & Hey 2005
Ideal sampling

West African chimpanzees (*P. troglodytes verus*)
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Bonobos (*P. paniscus*)

Won & Hey 2005
Chimp nest
Chimp nest
Bonobo nest
Orangutan nest
Orangutan nest
Orangutan nest
Sampling in the field Gorilla nest

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?
### Why microsatellites?

**You genotype**

<table>
<thead>
<tr>
<th>Marker 1</th>
<th></th>
<th><strong>From mum</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>From dad</strong></td>
</tr>
</tbody>
</table>

| Marker 2 |  |  |

| Marker 3 |  |  |
Why microsatellites?

You genotype

Marker 1  ___  From mum
            ___  From dad

Marker 2  ___

Marker 3  ___

- Useful because
  - Highly variable (usually two different alleles within an individual)
  - Fingerprints are used in forensic and paternity/parentage tests
1. There are 4 populations each of which is characterized by a set of allele frequencies at each marker.

<table>
<thead>
<tr>
<th>Marker 4</th>
<th>Pop1</th>
<th>Pop2</th>
<th>Pop3</th>
<th>Pop4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>75%</td>
<td>1%</td>
<td>50%</td>
</tr>
<tr>
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<td>25%</td>
<td>25%</td>
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<td>24%</td>
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</tbody>
</table>
There are 4 populations each of which is characterized by a set of allele frequencies at each marker.

<table>
<thead>
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<th>Population</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Marker 4</td>
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<td></td>
<td>24%</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Population of individual 1</th>
<th>Population of individual 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker 4 for individual 1</td>
<td>Marker 4 for individual 2</td>
</tr>
</tbody>
</table>

Pritchard et al. 2000
1. There are 4 populations each of which is characterized by a set of allele frequencies at each marker.

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<tr>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Marker 4 for individual 1</th>
<th>Population of individual 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>25%</td>
<td>25%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marker 4 for individual 2</th>
<th>Population of individual 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24%</td>
</tr>
</tbody>
</table>

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

Program STRUCTURE

Pritchard et al. 2000
Output of the Program STRUCTURE

The 2 alleles at the 310 markers for this individuals

Pritchard et al. 2000
STRUCTURE with four clusters

Central

Eastern

Western

Unknown

Bonobos

Hybrids

Wild-caught hybrids

Nigerian mtDNA

Pritchard et al. 2000
## Concept of Informativeness

### Different alleles

<table>
<thead>
<tr>
<th>Marker</th>
<th>Pop1</th>
<th>Pop2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marker 1</td>
<td>60%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td></td>
</tr>
<tr>
<td>Marker 2</td>
<td>50%</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40%</td>
</tr>
<tr>
<td>Marker 3</td>
<td>100%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95%</td>
</tr>
<tr>
<td>Marker 4</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>50%</td>
</tr>
</tbody>
</table>

**Pop1**  **Pop2**
# Concept of Informativeness

## Different alleles

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<th>10%</th>
</tr>
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<tr>
<td>50%</td>
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<td></td>
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<tr>
<td>40%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Marker 3</th>
<th>100%</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>95%</td>
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</tbody>
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<th>50%</th>
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<tbody>
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<td>90%</td>
<td>50%</td>
<td></td>
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<tr>
<td>50%</td>
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</tr>
</tbody>
</table>

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**Pop1** | **Pop2**
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: \( F_{ST} \)

\[
F_{ST} = \frac{\text{Tot}_{\text{var}} - \text{Within}_{\text{var}}}{\text{Tot}_{\text{var}}}
\]

\( F_{ST_{C,E}} = 0.05 \)
Population differentiation: $F_{ST}$

- **Within-population Genetic variation**
  - Eastern: $F_{ST_{C,E}} = 0.05$
  - Central: $F_{ST_{C,W}} = 0.25$
  - Western: $F_{ST_{E,W}} = 0.31$

- **Total genetic variation**
  - Central:
  - Eastern:
  - Western:

- **Bonobo–chimpanzee**
  - $F_{ST_{Bonobo–chimpanzee}} = 0.51 – 0.68$
Tells us about the history of these populations and species

Central

Eastern

Western

Bonobos
Divergence time estimates from another study

- Central: ~220ky
- Eastern: ~220ky
- Western: ~280-440ky
- Bonobos: ~785-920ky
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:

- 1980
- >2000
Great apes by 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 their 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.
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), Landscan 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.

Walsh et al. 2003
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
<table>
<thead>
<tr>
<th>Species Code</th>
<th>Common Name</th>
<th>Population Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pongo p. pygmaeus</td>
<td>Bornean Orangutan</td>
<td>3,000 - 4,500 Est.</td>
</tr>
<tr>
<td>Pongo p. wurmbii</td>
<td></td>
<td>35,000 Est.</td>
</tr>
<tr>
<td>Pongo p. morio</td>
<td></td>
<td>15,000 Est.</td>
</tr>
<tr>
<td>Pongo abelli</td>
<td>Sumatran Orangutan</td>
<td>6,700 Est.</td>
</tr>
<tr>
<td>Gorilla g. gorilla</td>
<td>Western Lowland gorilla</td>
<td>94,500 Est.</td>
</tr>
<tr>
<td>Gorilla g. diehli</td>
<td>Cross River gorilla</td>
<td>200 Est.</td>
</tr>
<tr>
<td>Gorilla b. beringei</td>
<td>Mountain gorilla</td>
<td>380 Est.</td>
</tr>
<tr>
<td>Gorilla b. graueri</td>
<td>Eastern Lowland gorilla</td>
<td>5,000</td>
</tr>
<tr>
<td>Pan t. schweinfurthii</td>
<td>Eastern chimpanzee</td>
<td>76,400-119,600 Est.</td>
</tr>
<tr>
<td>Pan t. verus</td>
<td>Western chimpanzee</td>
<td>21,300-55,600 Est.</td>
</tr>
<tr>
<td>Pan t. troglodytes</td>
<td>Central chimpanzee</td>
<td>70,000-116,500 Est.</td>
</tr>
<tr>
<td>Pan t. vellerosus</td>
<td>Nigeria chimpanzee</td>
<td>5,000-8,000 Est.</td>
</tr>
<tr>
<td>Pan paniscus</td>
<td>Bonobo</td>
<td>20,000 - 50,000 Est.</td>
</tr>
<tr>
<td>Homo sapiens</td>
<td>Human</td>
<td>6 Billion + Est.</td>
</tr>
</tbody>
</table>
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!