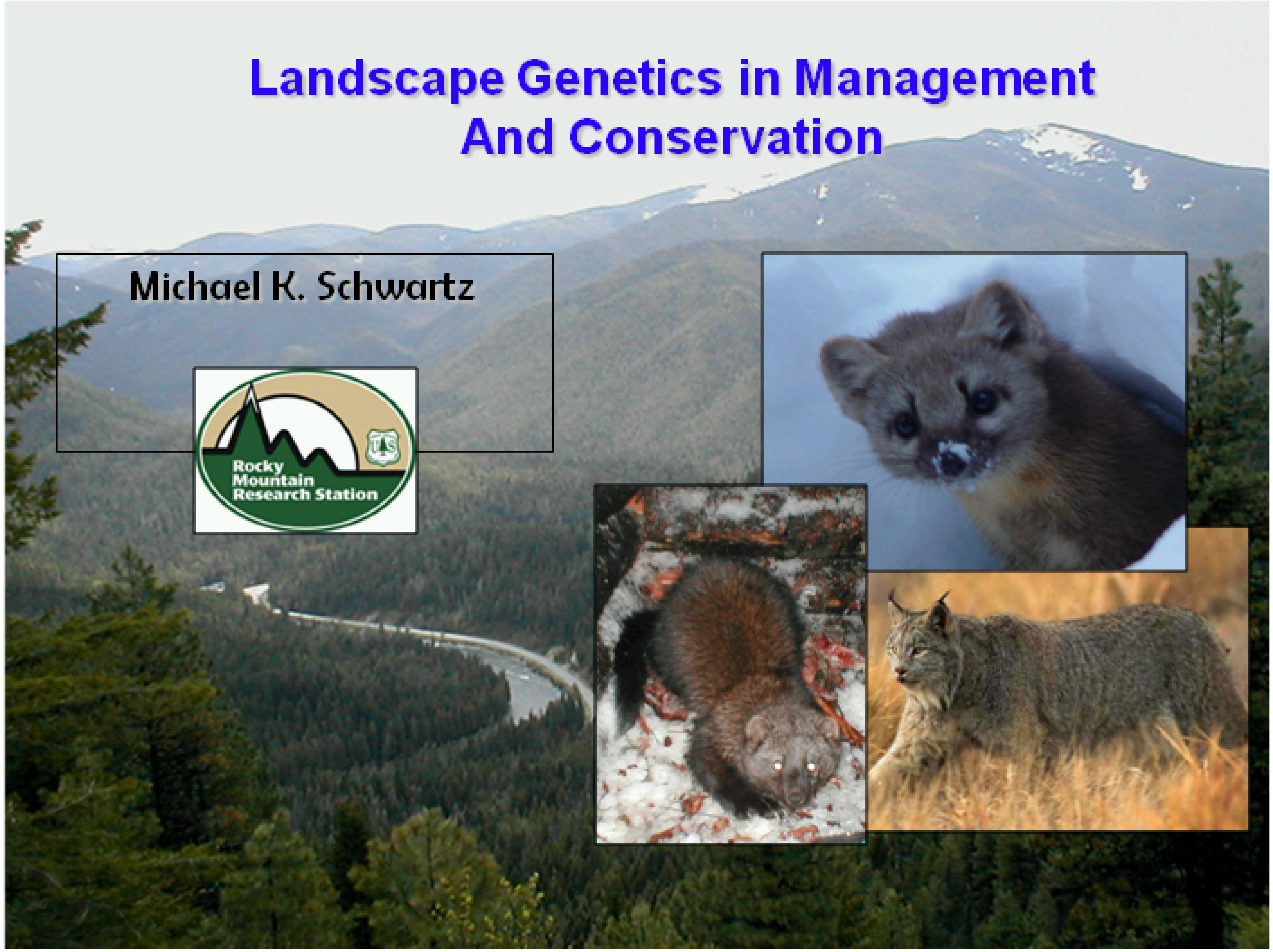

Landscape Genetics in Management
And Conservation
Michael K. Schwartz
Rocky Mountain Research Station

Slide 1

Why Do We Care About Gene Flow And Movement of Animals?

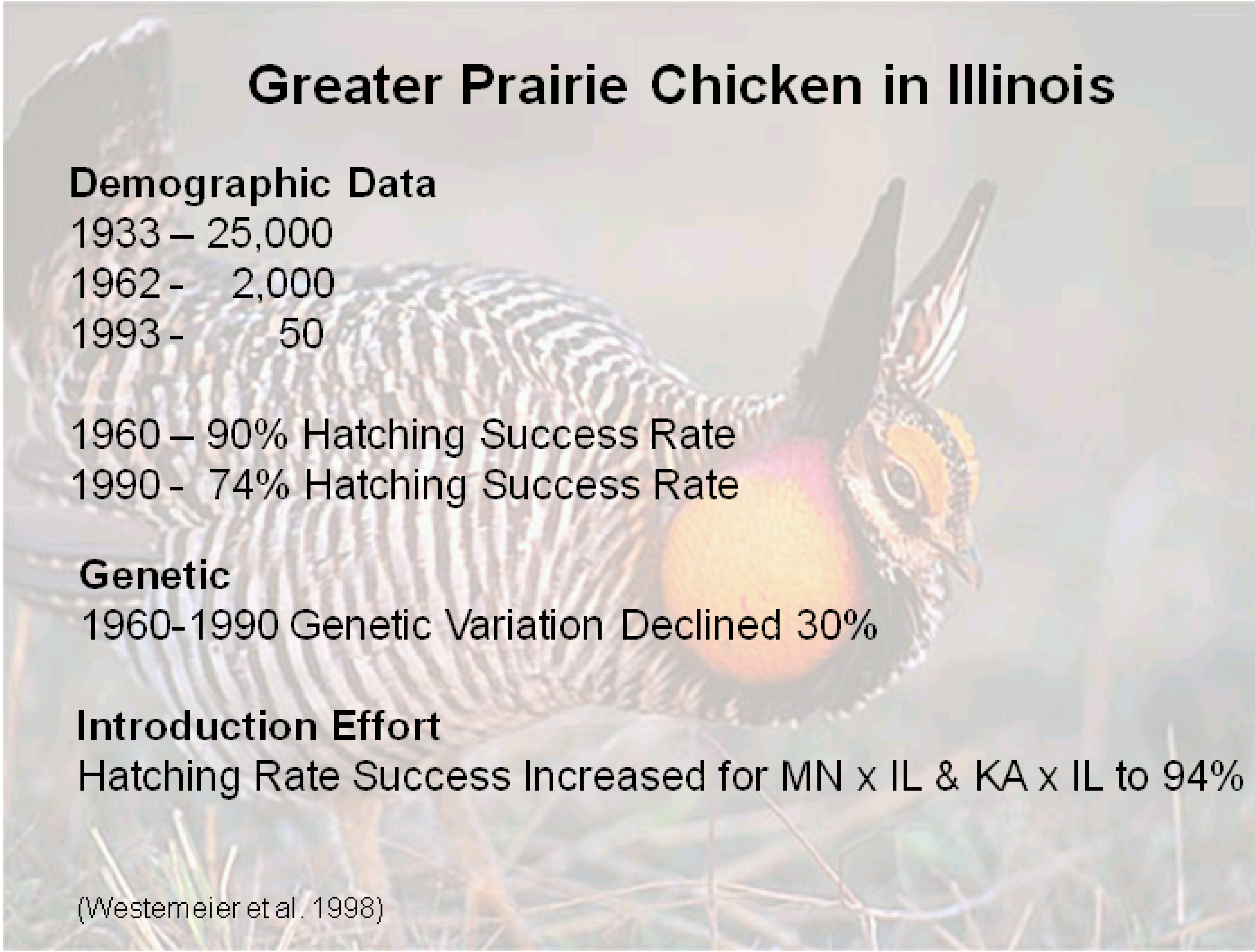
Slide 2

Without Movement and Gene Flow

- Inbreeding of Populations
- Depression of Population Fitness
- Suite of Demographic Problems Arise
  (As a consequence of inbreeding or alone; i.e., allee)
- Increase in Extinction Risk

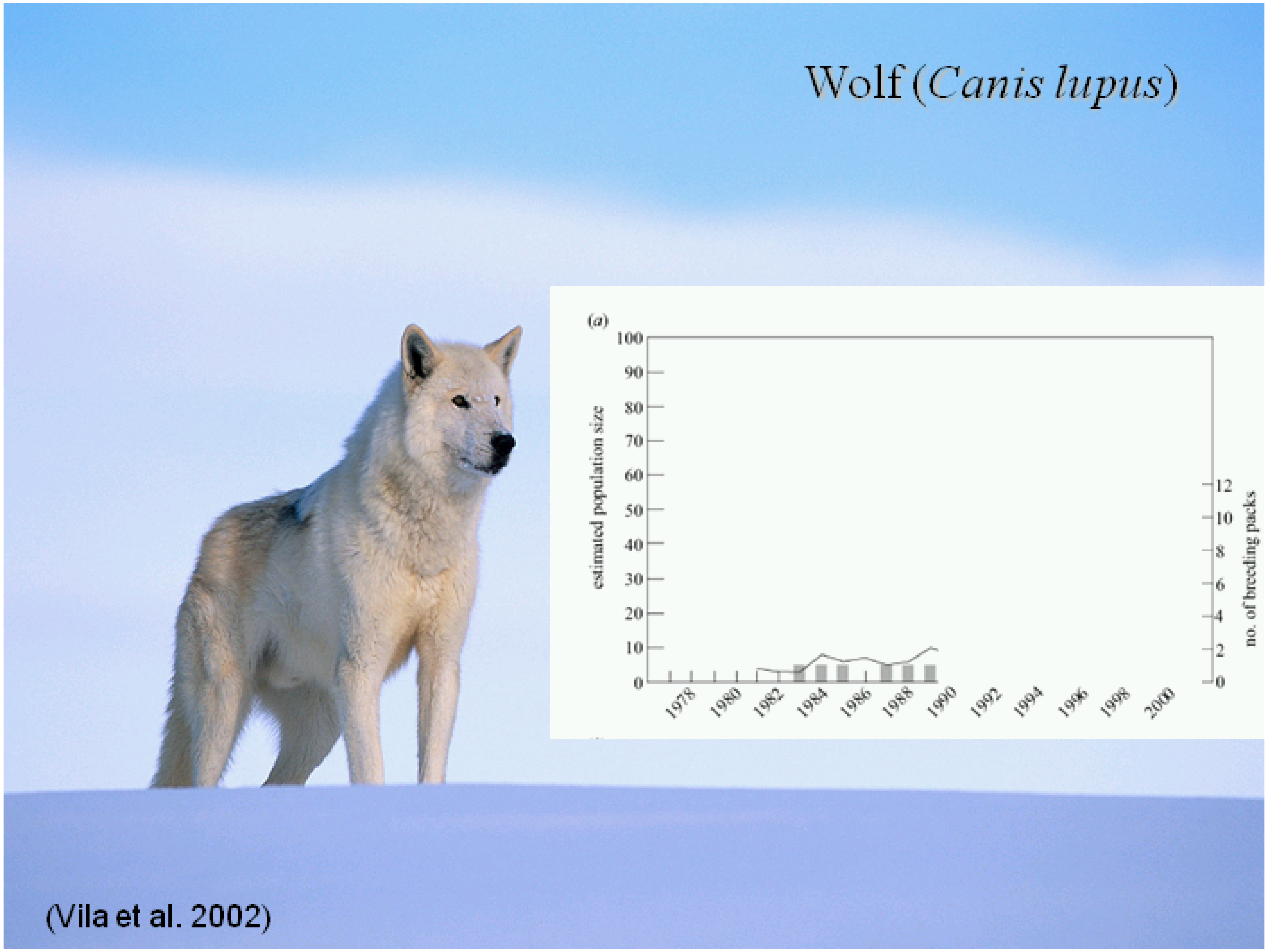
Slide 3

Slide 4

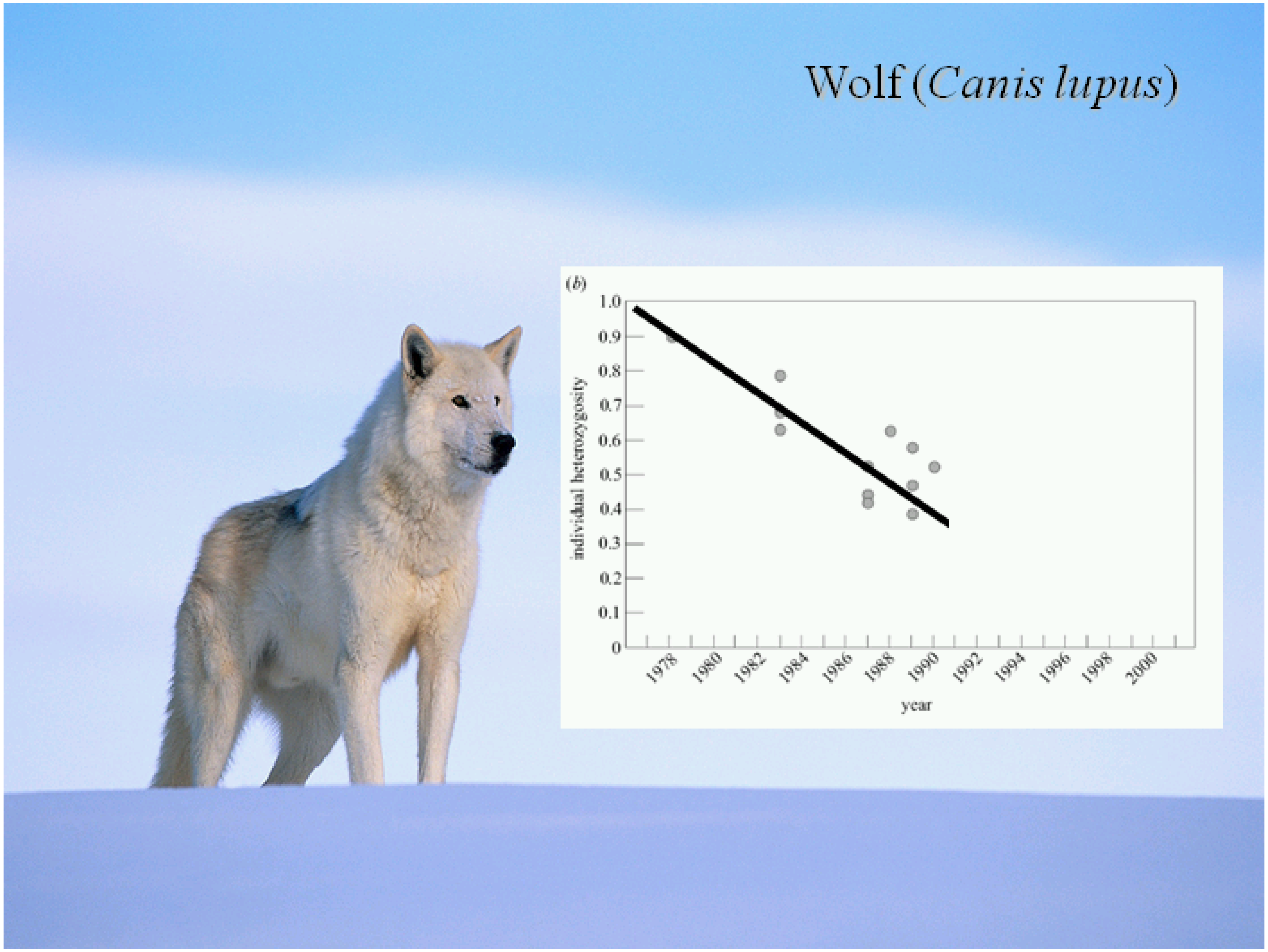

Greater Prairie Chicken in Illinois
Demographic Data
1933 – 25,000
1962 - 2,000
1993 - 50
1960 – 90% Hatching Success Rate
1990 - 74% Hatching Success Rate
Genetic
1960-1990 Genetic Variation Declined 30%
Introduction Effort
Hatching Rate Success Increased for MN x IL & KA x IL to 94%
(Westemeier et al. 1998)

Slide 5

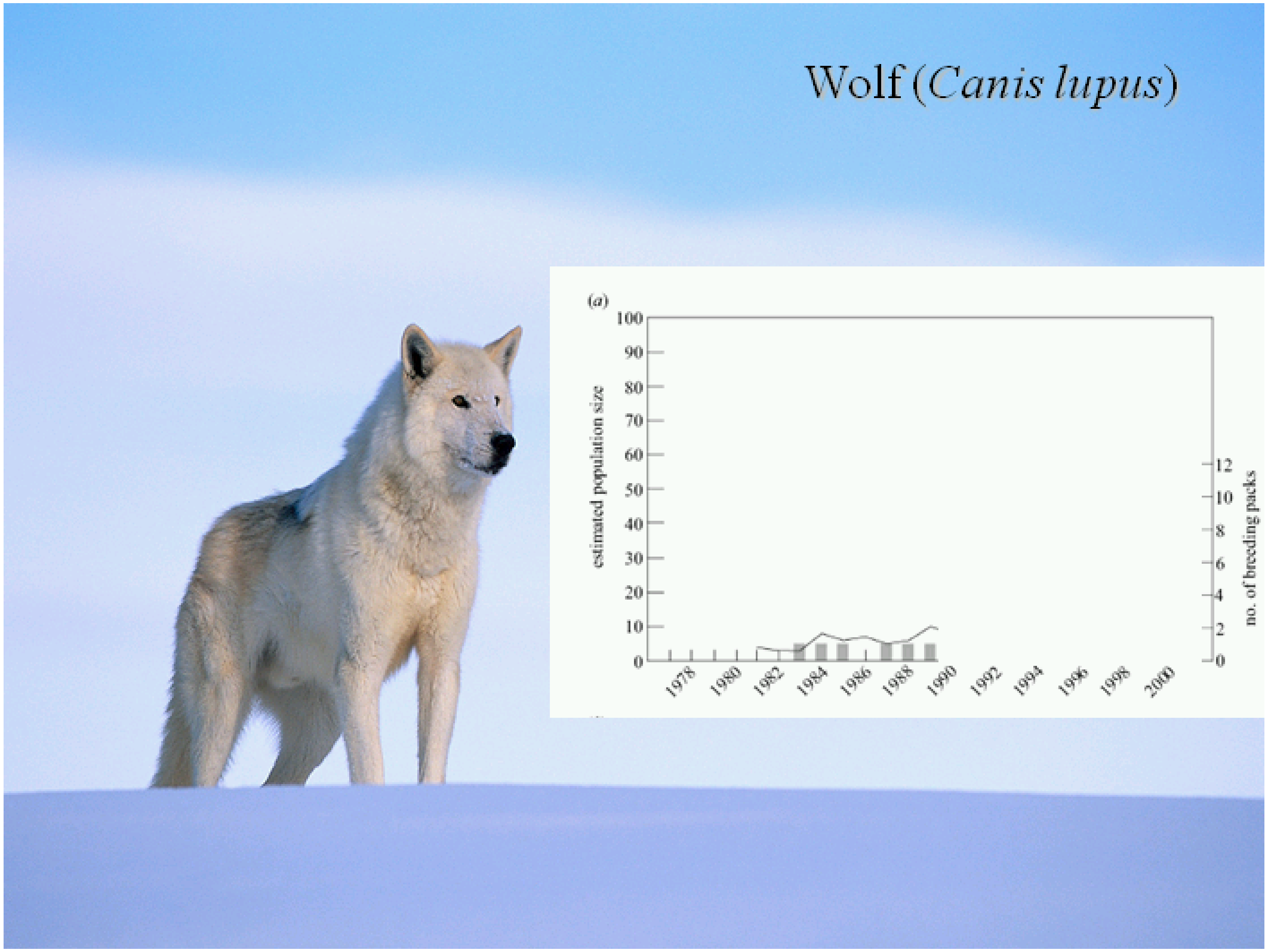
Slide 6


Wolf (*Canis lupus*)
(a)
estimated population size
100
90
80
70
60
50
40
30
20
10
0
no. of breeding packs
12
10
8
6
4
2
0
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
(Vila et al. 2002)

Slide 7


Wolf (*Canis lupus*)
(b)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
individual heterozygosity
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
year

Slide 8


Wolf (*Canis lupus*)
(*a*)
estimated population size
no. of breeding packs
100
90
80
70
60
50
40
30
20
10
0
12
10
8
6
4
2
0
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Slide 9

Review
TRENDS in Ecology and Evolution Vol.19 No.9 September 2004
Full text provided by www.sciencedirect.com

The alluring simplicity and complex reality of genetic rescue

David A. Tallmon[1], Gordon Luikart[1] and Robin S. Waples[2]

[a]Laboratoire d'Ecologie Alpine, Génomique des Populations et Biodiversité, CNRS UMR 5553, Université Joseph Fourier, BP 53, 38041 Grenoble, Cedex 09, France
[b]National Marine Fisheries Service, Northwest Fisheries Science Center, 2725 Montlake Boulevard East, Seattle, WA 98112, USA

Slide 10

Gene Flow

Slide 11

Gene Flow is the incorporation of genes into the gene pool of one population from other populations

Slide 12

Types of Movement

Dispersal - permanent movement away from site where organism was born

Migration - number of individuals that move and breed in a population other than birth site

Slide 13

Dispersal ≠ Gene Flow

Migration = Gene Flow

Slide 14

How Much Gene Flow Is Enough?

Slide 15

The One-Migrant-per-Generation Rule in Conservation and Management

L. SCOTT MILLS* AND FRED W. ALLENDORF†

*Wildlife Biology Program, School of Forestry, University of Montana, Missoula, MT 59812, U.S.A., email smills@selway.umt.edu

†Division of Biological Sciences, University of Montana, Missoula, MT 59812, U.S.A.

Abstract: *In the face of continuing habitat fragmentation and isolation, the optimal level of connectivity between populations has become a central issue in conservation biology. A common rule of thumb holds that one migrant per generation into a subpopulation is sufficient to minimize the loss of polymorphism and heterozygosity within subpopulations while allowing for divergence in allele frequencies among subpopulations. The one-migrant-per-generation rule is based on numerous simplifying assumptions that may not hold in natural populations. We examine the conceptual and theoretical basis of the rule and consider both genetic and nongenetic factors that influence the desired level of connectivity among subpopulations. We conclude that one migrant per generation is a desirable minimum, but it may be inadequate for many natural populations. We suggest that a minimum of 1 and a maximum of 10 migrants per generation would be an appropriate general rule of thumb for genetic purposes, bearing in mind that factors other than genetics may further influence the ideal level of connectivity.*

Slide 16

Animal Conservation (2000) 3, 261–266

Is one migrant per generation sufficient for the genetic management of fluctuating populations?

John A. Vucetich[1] and Thomas A. Waite[2]

[1]School of Forestry, Michigan Technological University, Houghton, MI 49931, USA
[2]Department of Evolution, Ecology, and Organismal Biology and Department of Anthropology, Ohio State University, C
43210, USA

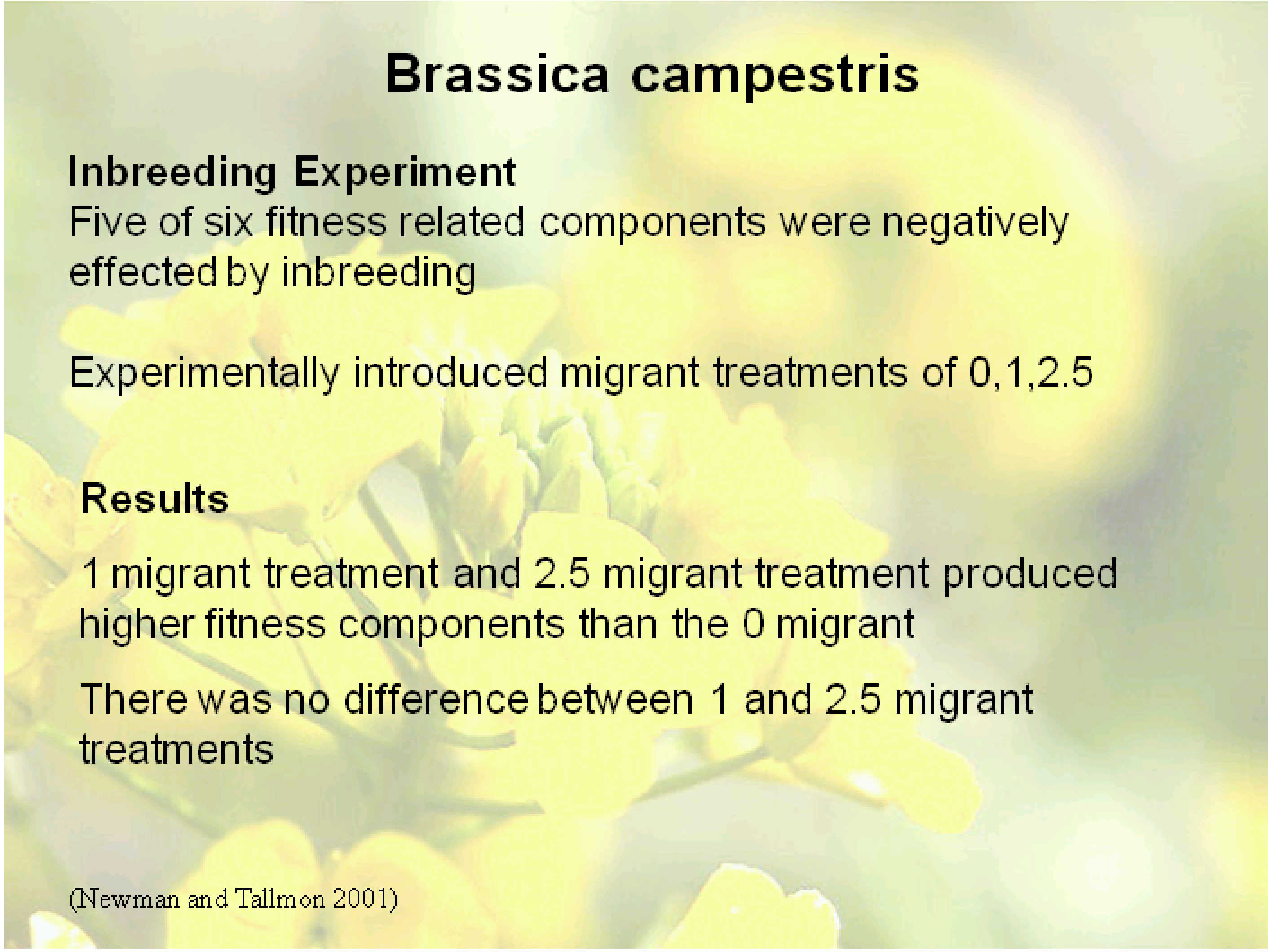
(Received 7 January 1999; accepted 13 March 2000)

Abstract

Small isolated populations may face an increasing risk of extinction due to the loss of genetic diversity. This increasing risk, though, may be offset by gene flow, provided the population receives an adequate number of migrants per generation. We show that as temporal fluctuation in population size (FPS) increases, so too does the required number of immigrants. This increase in the requisite number of immigrants arises because the ratio of census size to effective population size decreases with increasing FPS. Because all populations fluctuate, our work extends a recent challenge to the widely adopted one migrant per generation rule, which refers to the supposedly requisite number of immigrants. In a sample of 44 animal populations, ~60% of the populations fluctuated enough to require >10 immigrants per generation to avoid a substantial loss of genetic diversity, and ~25% fluctuated enough to require >20 immigrants per generation. We thus recommend that estimation of the requisite number of immigrants take into account fluctuation in population size.

Slide 17

Slide 18

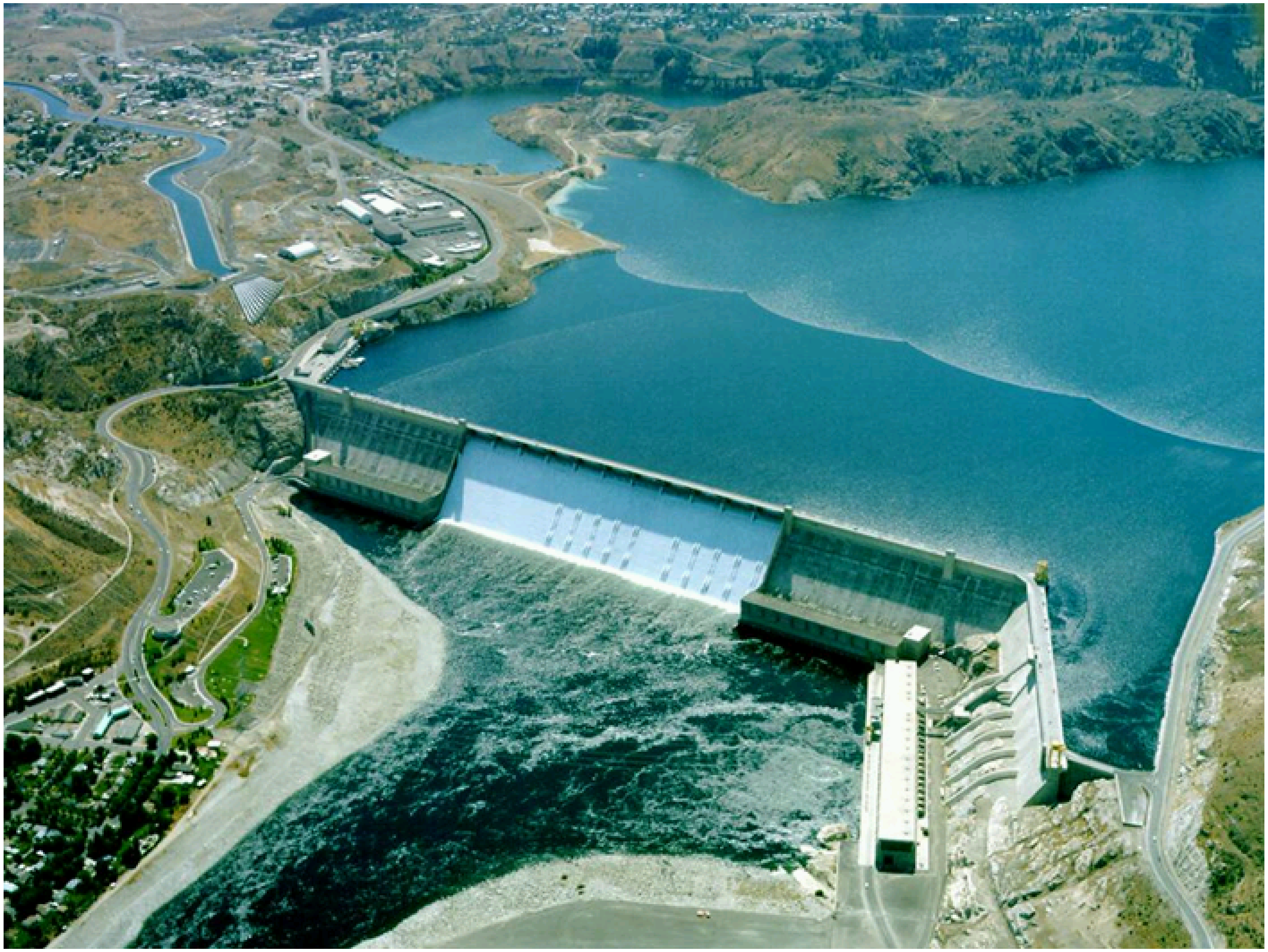

Brassica campestris
Inbreeding Experiment
Five of six fitness related components were negatively effected by inbreeding
Experimentally introduced migrant treatments of 0,1,2.5
Results
1 migrant treatment and 2.5 migrant treatment produced higher fitness components than the 0 migrant
There was no difference between 1 and 2.5 migrant treatments
(Newman and Tallmon 2001)

Slide 19

Are Animals Moving From One Area to Another?

Slide 20

Slide 21



Slide 22

Slide 23

Slide 24

Slide 25

Slide 26

Slide 27

Slide 28

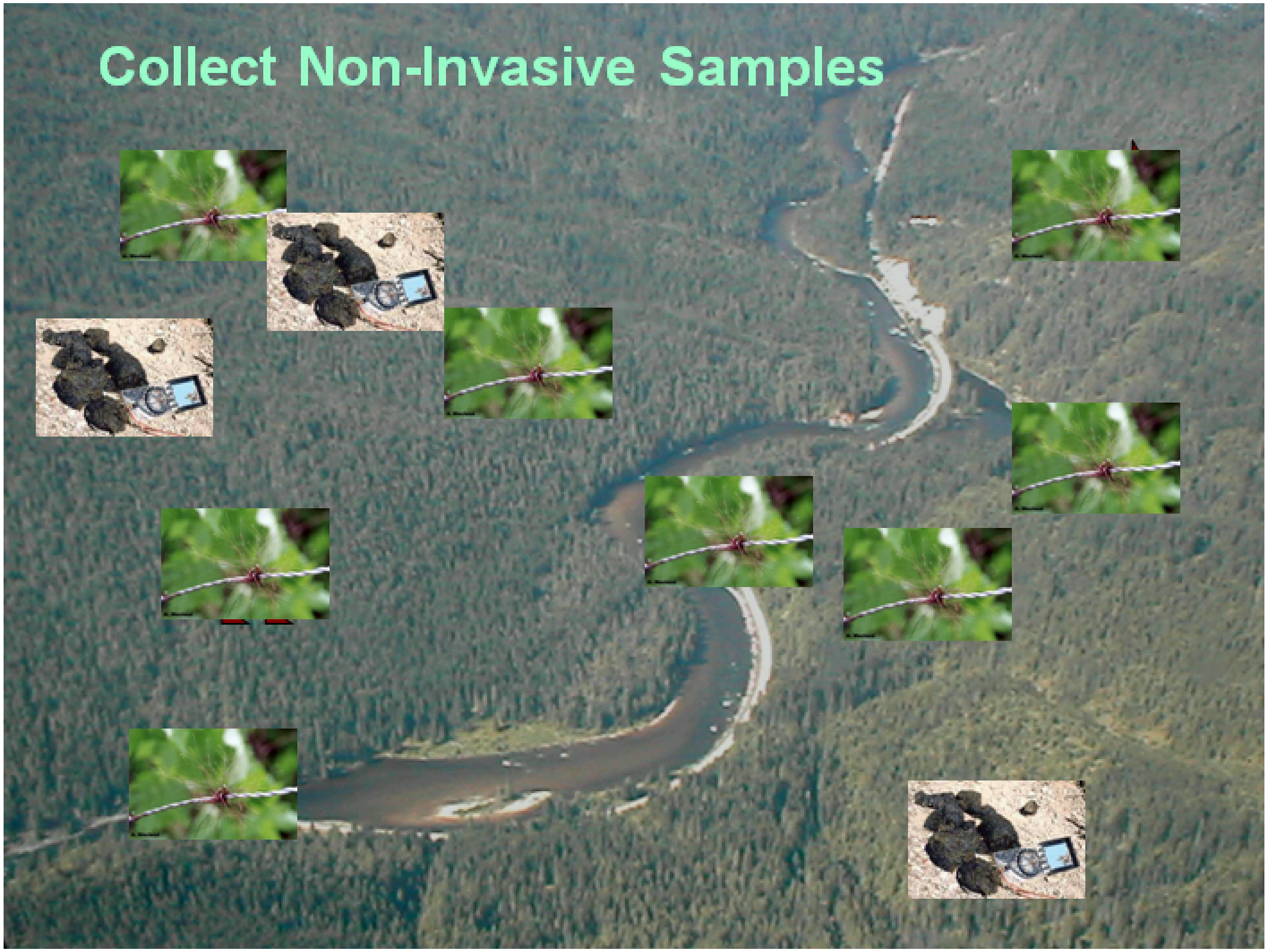
Ways to Empirically Evaluate Wildlife Connectivity

- Radio-telemetry
- Satellite Telemetry
- Genetics / Geneflow
- Others?

Slide 29

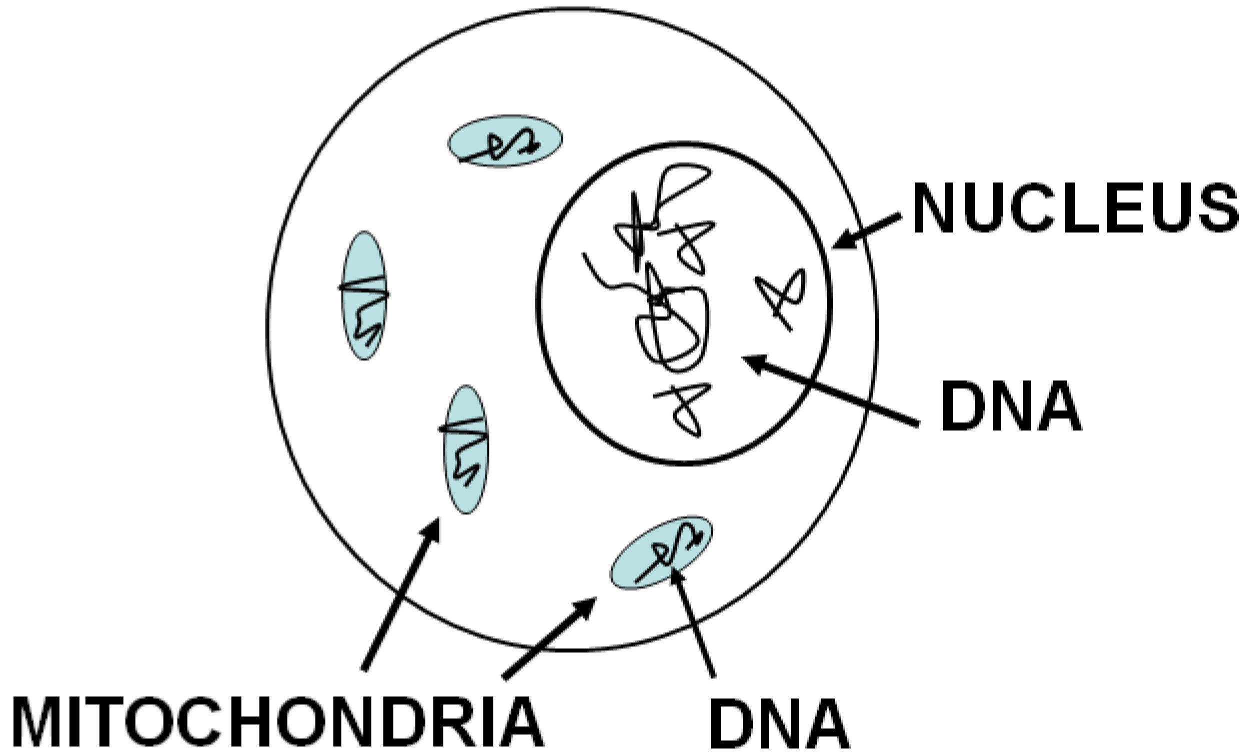

Is this river (landscape feature)
A barrier to movement / gene flow?

Slide 30



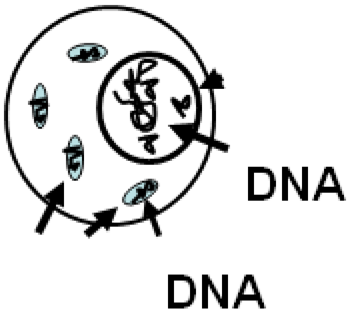
Slide 31

Quick Genetics Primer



Slide 32

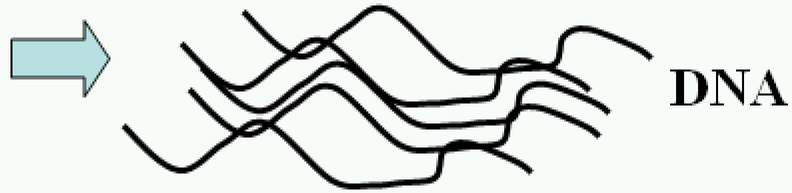
Two Types of DNA



- **Mitochondrial DNA (mtDNA)**
  - 1000's of copy per cell (20x more)
  - Maternally Inherited
  - Highly conserved

- **Nuclear DNA**
  - Two copies per cell
  - Inherited from both parents
  - Highly variable regions (microsatellite DNA) for distinguishing individuals

Two Types of DNA

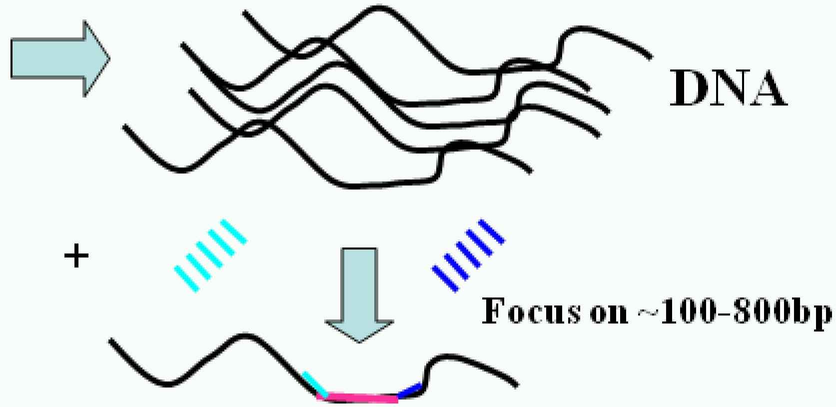


Step 1

Separate DNA from other cellular material

All of the DNA (nuclear and mitochondrial) together

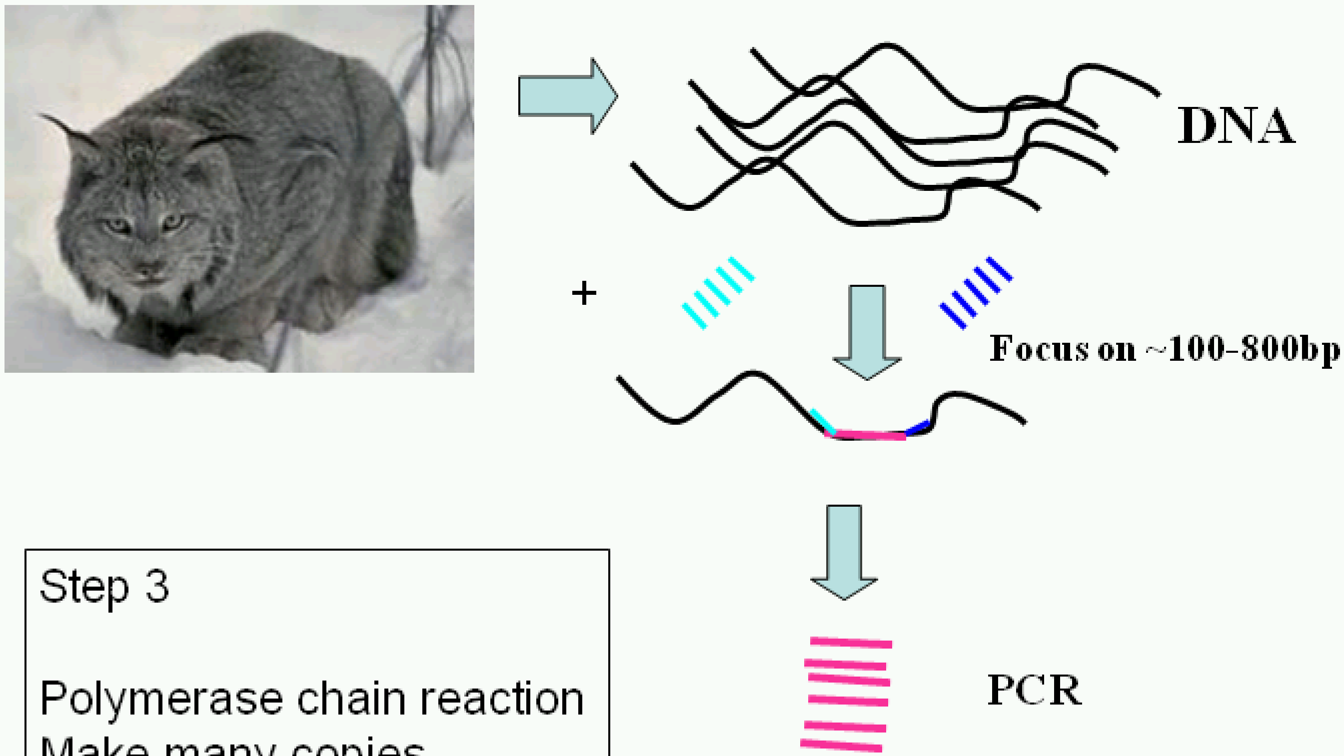
Slide 34



Step 2

Add a **primer** pair (2 short pieces of DNA ~ 20 bp)
Latch on on either side of an area of interest

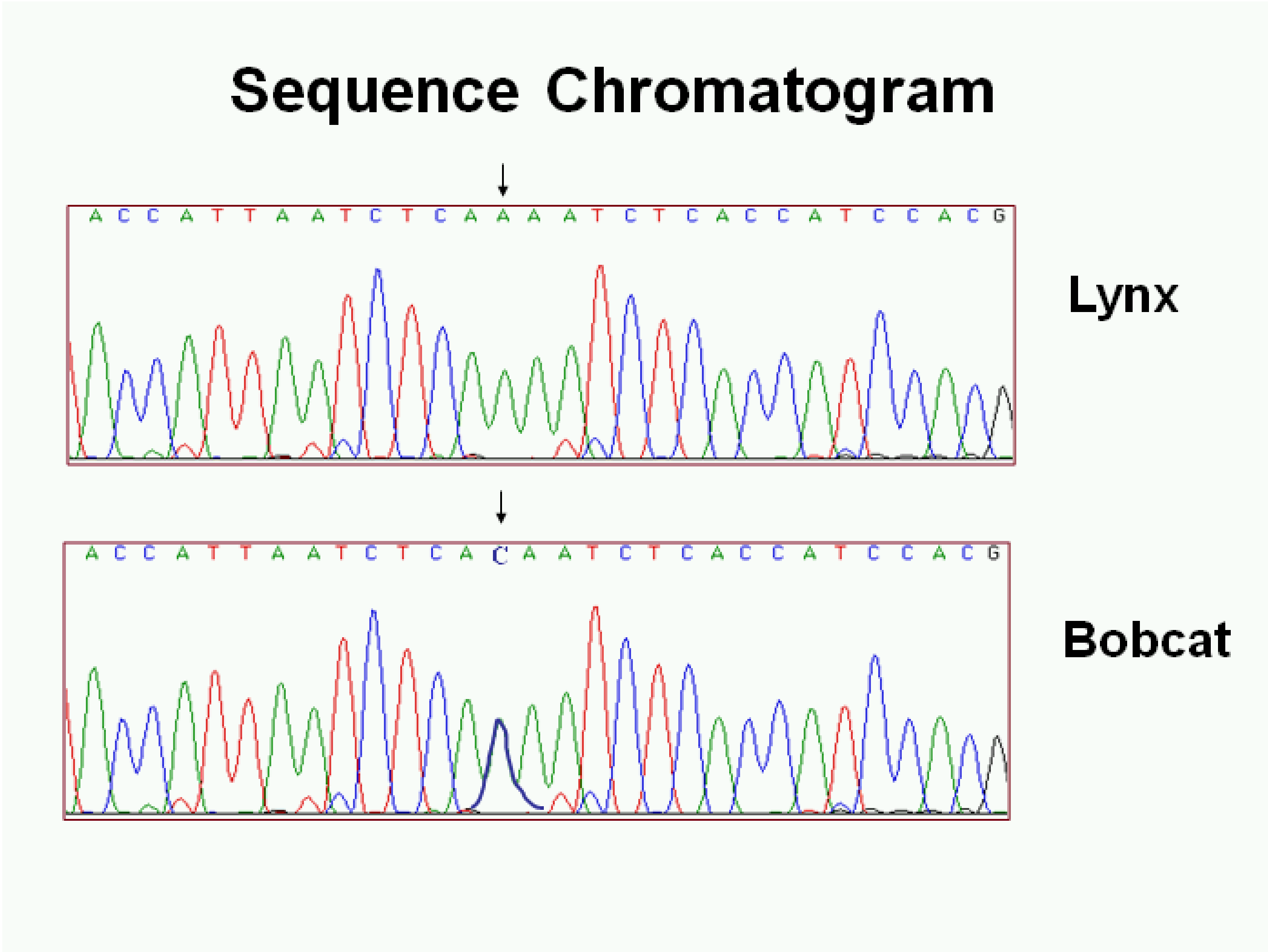
Slide 35



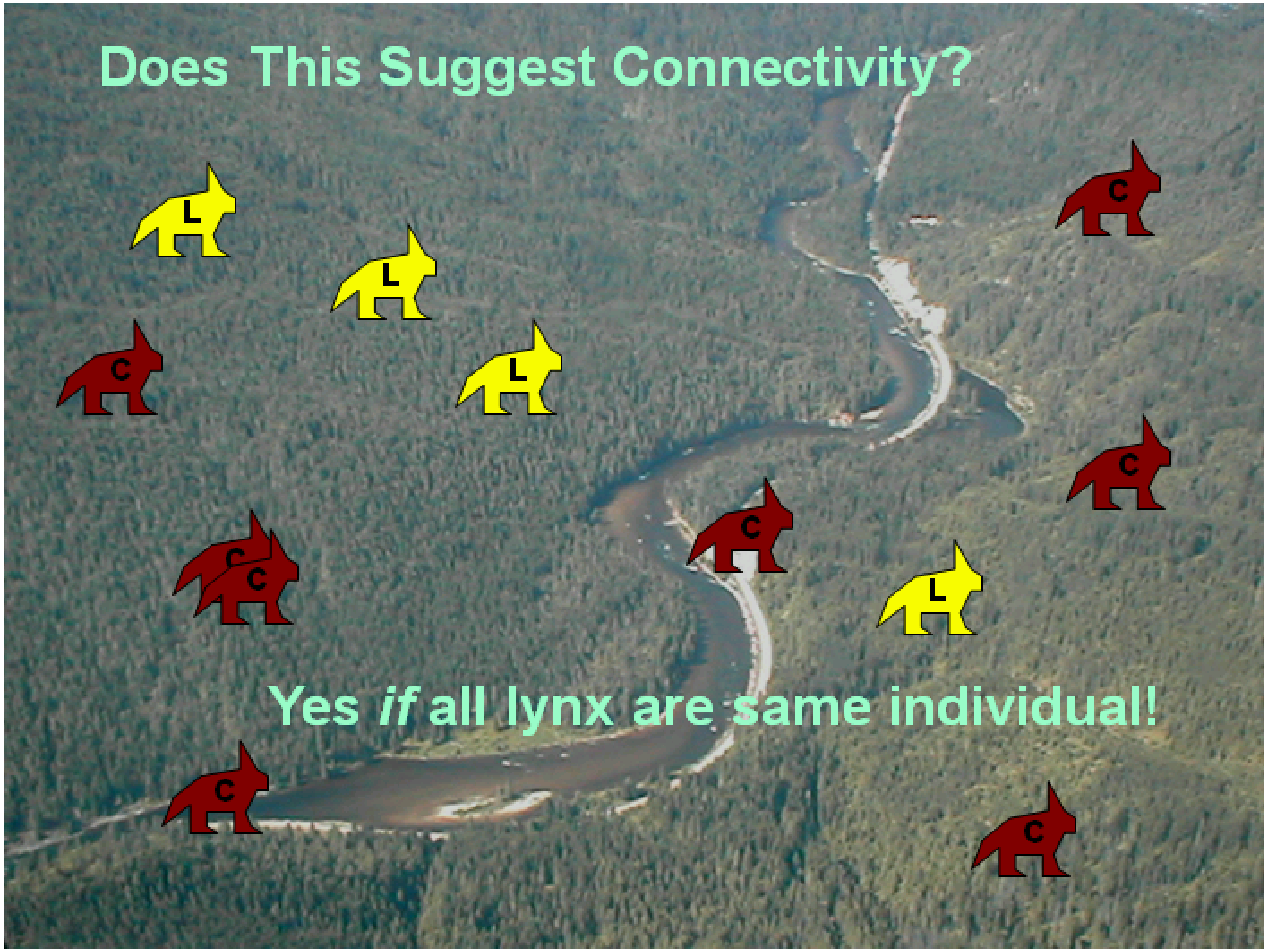
Step 3

Polymerase chain reaction
Make <u>many</u> copies

Slide 36


Sequence Chromatogram
A C C A T T A A T C T C A A A A T C T C A C C A T C C A C G
Lynx
A C C A T T A A T C T C A C A A T C T C A C C A T C C A C G
Bobcat

Slide 37


Does This Suggest Connectivity?
L
L
L
L
C
C
C
C
C
C
C
C
Yes *if* all lynx are same individual!

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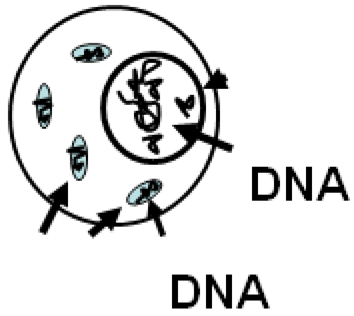
Two Types of DNA



- **Mitochondrial DNA (mtDNA)**
  - 1000's of copy per cell (20x more)
  - Maternally Inherited
  - Highly conserved (good for species ID)

- **Nuclear DNA**
  - Two copies per cell
  - Inherited from both parents
  - Highly variable regions (microsatellite DNA for distinguishing individuals)

Two Types of DNA

Microsatellite DNA

- Highly Variable DNA Region

A stretch of DNA with mono-, di-, tri- or tetranucleotide units repeated

Examples:

AAAAAAAAAAAAAAAAA....
GTGTGTGTGTGTGTGTGT.....
CATCATCATCATCATCAT.....
ACGGACGGACGGACGGA....

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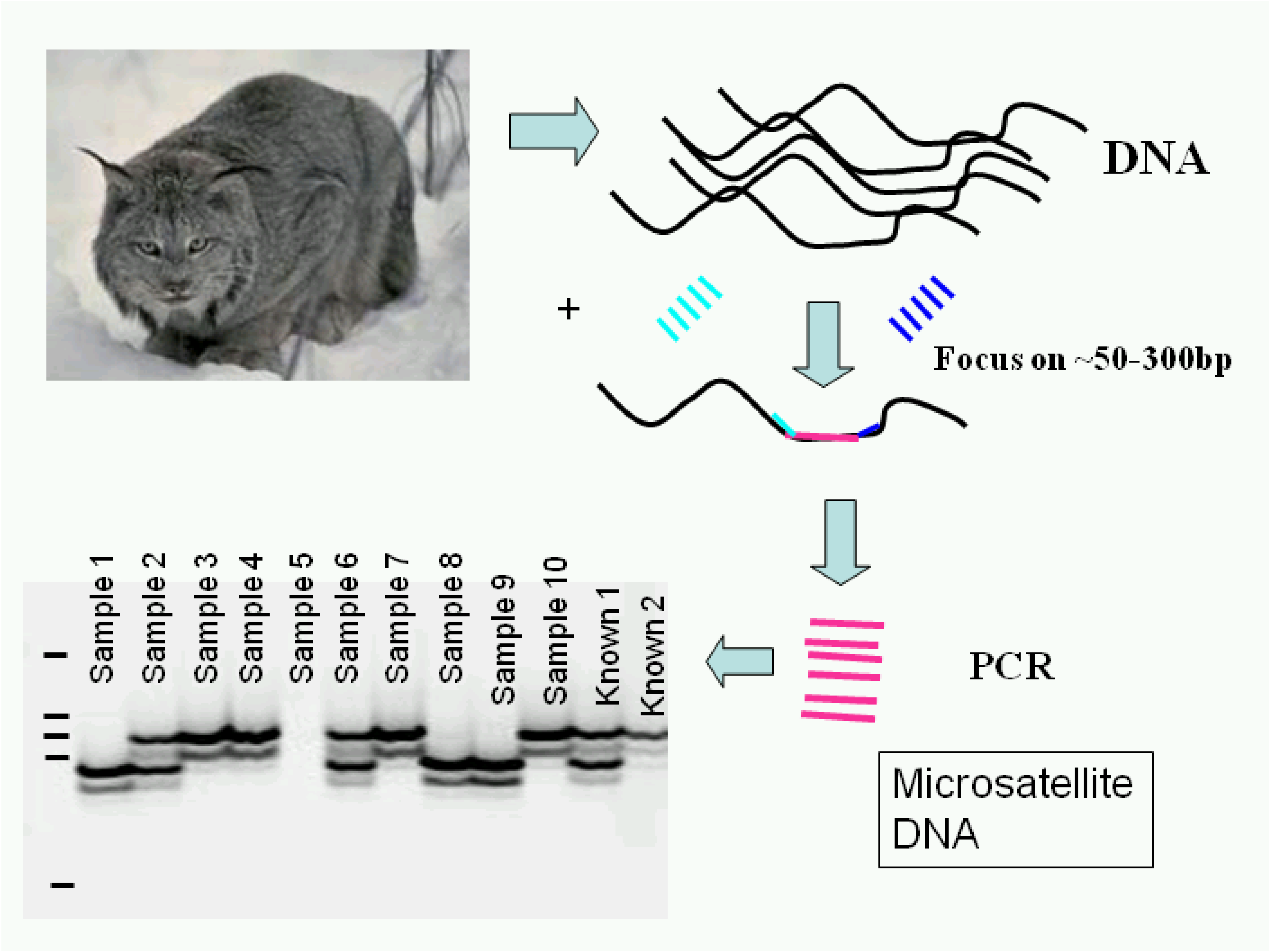
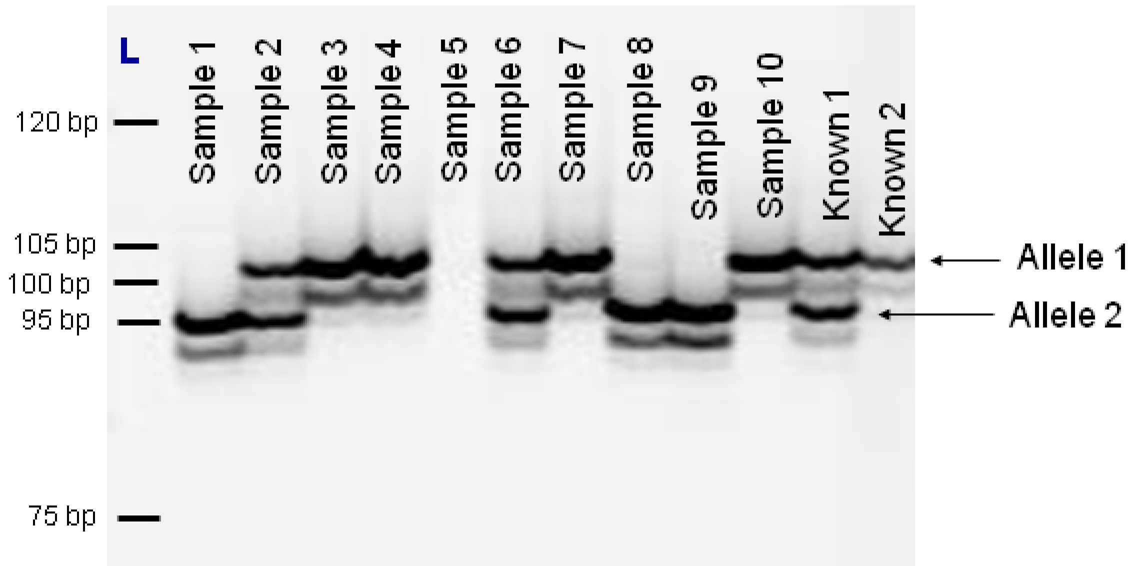
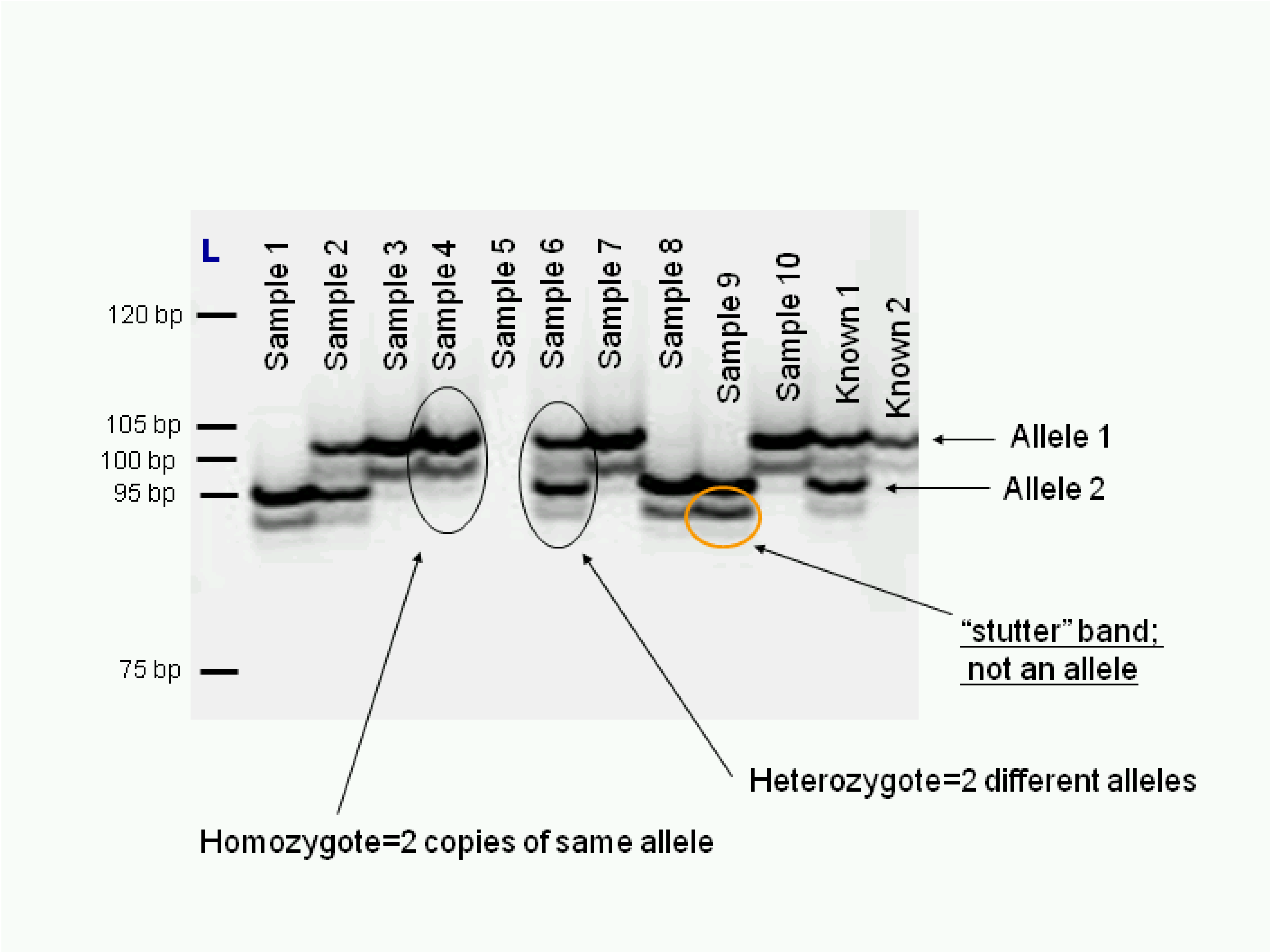


DNA
+
Focus on ~50-300bp
PCR
Microsatellite DNA
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Known 1
Known 2

Slide 41

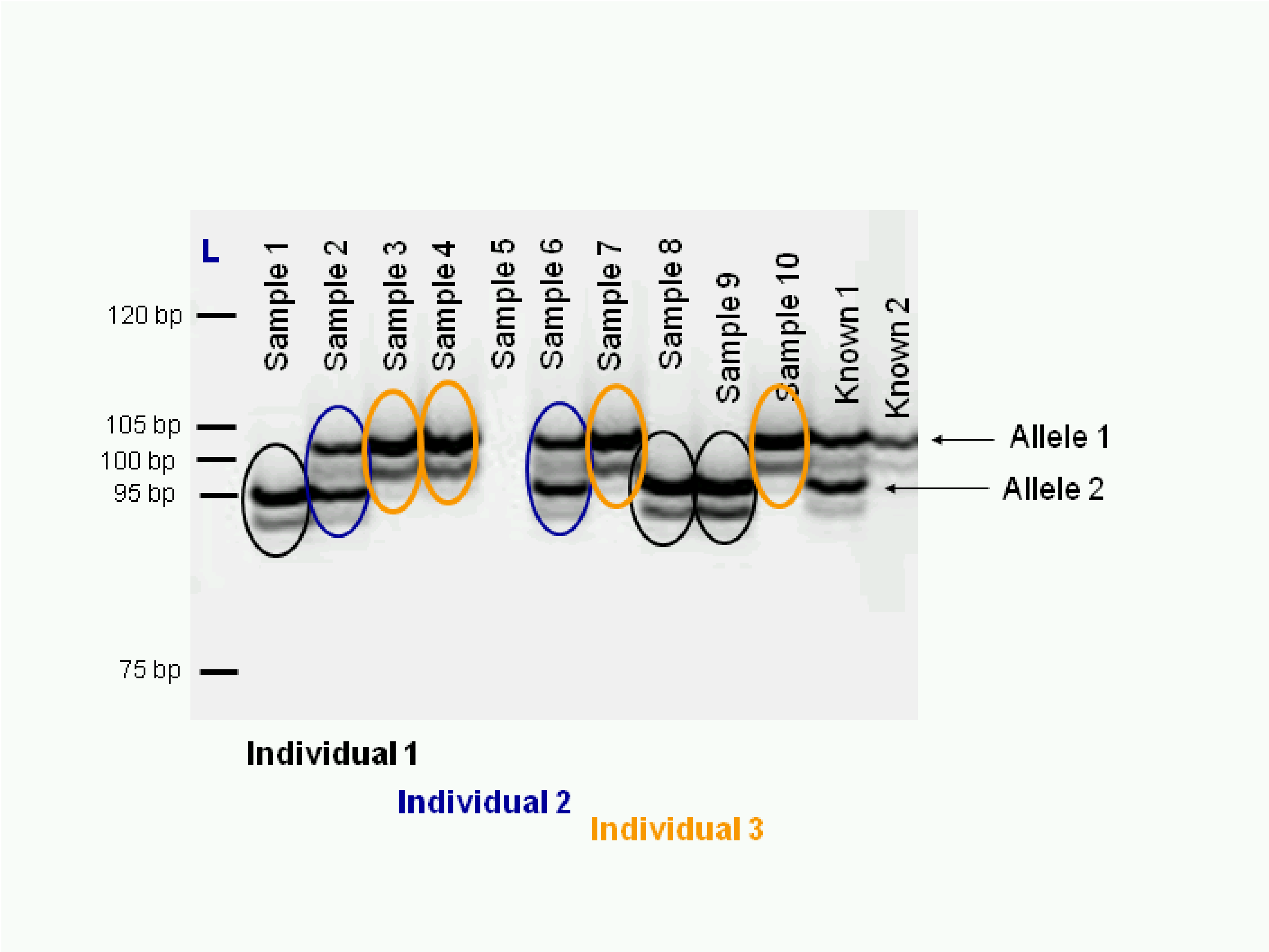

L
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Known 1
Known 2
120 bp
105 bp
100 bp
95 bp
75 bp
Allele 1
Allele 2

Slide 42

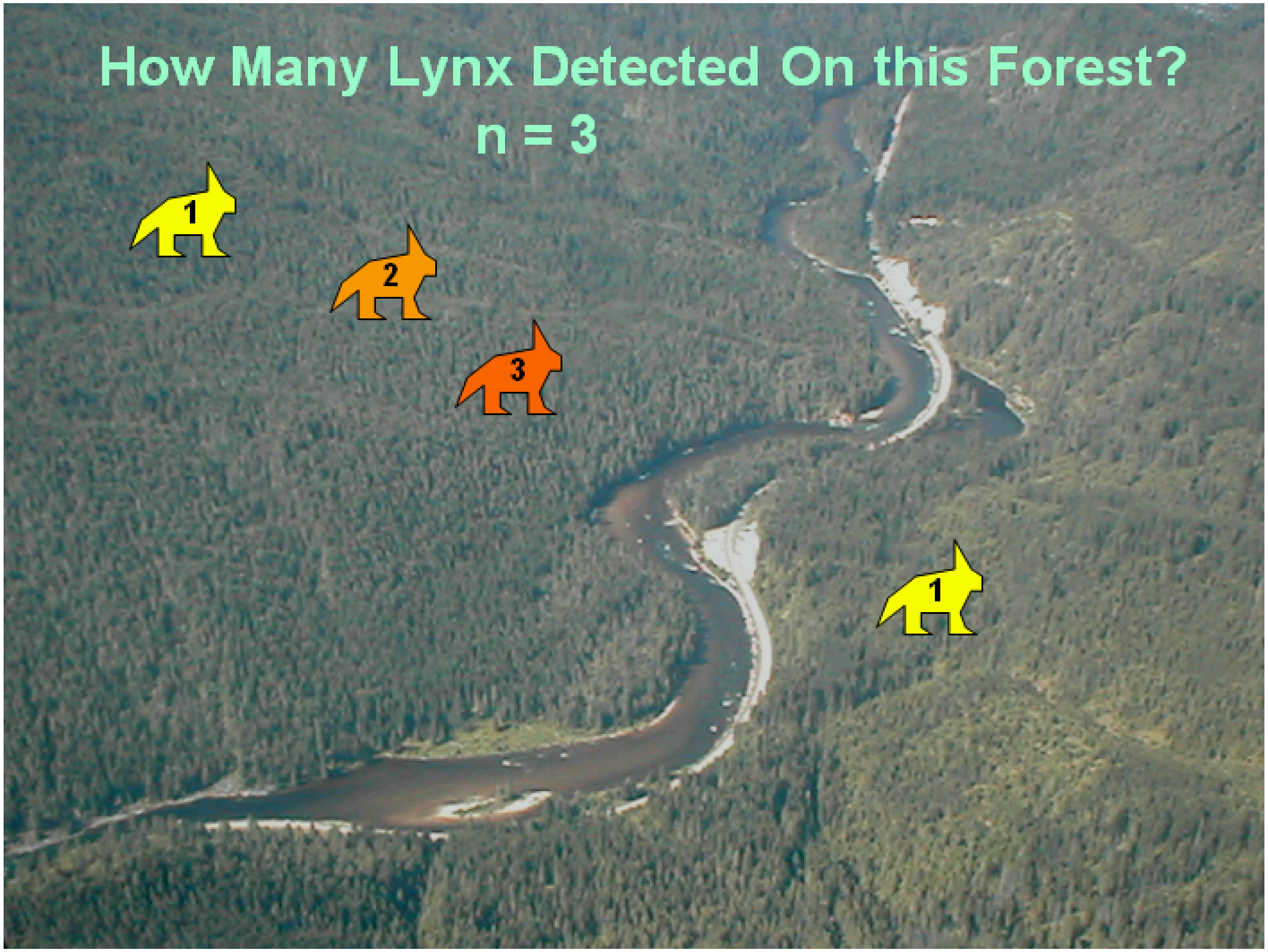


L
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Known 1
Known 2
120 bp
105 bp
100 bp
95 bp
75 bp
Allele 1
Allele 2
"stutter" band; not an allele
Heterozygote=2 different alleles
Homozygote=2 copies of same allele

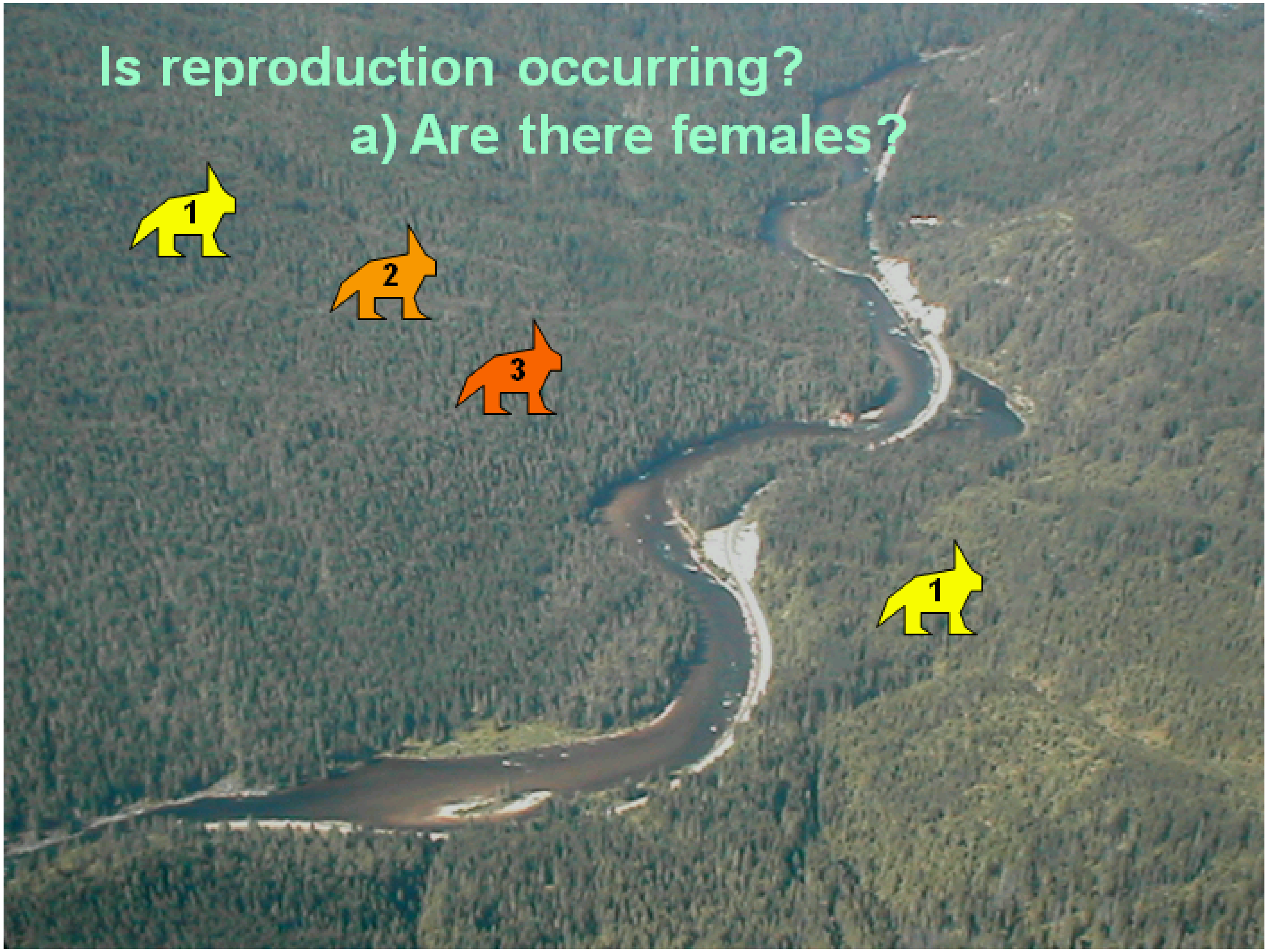
Slide 43


L
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Known 1
Known 2
120 bp
105 bp
100 bp
95 bp
75 bp
Allele 1
Allele 2
Individual 1
Individual 2
Individual 3

Slide 44



Slide 45



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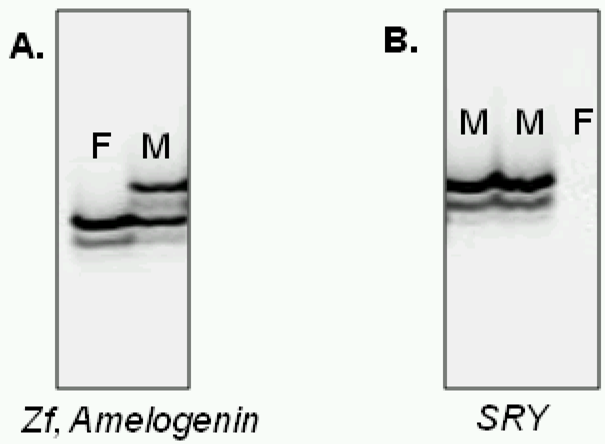
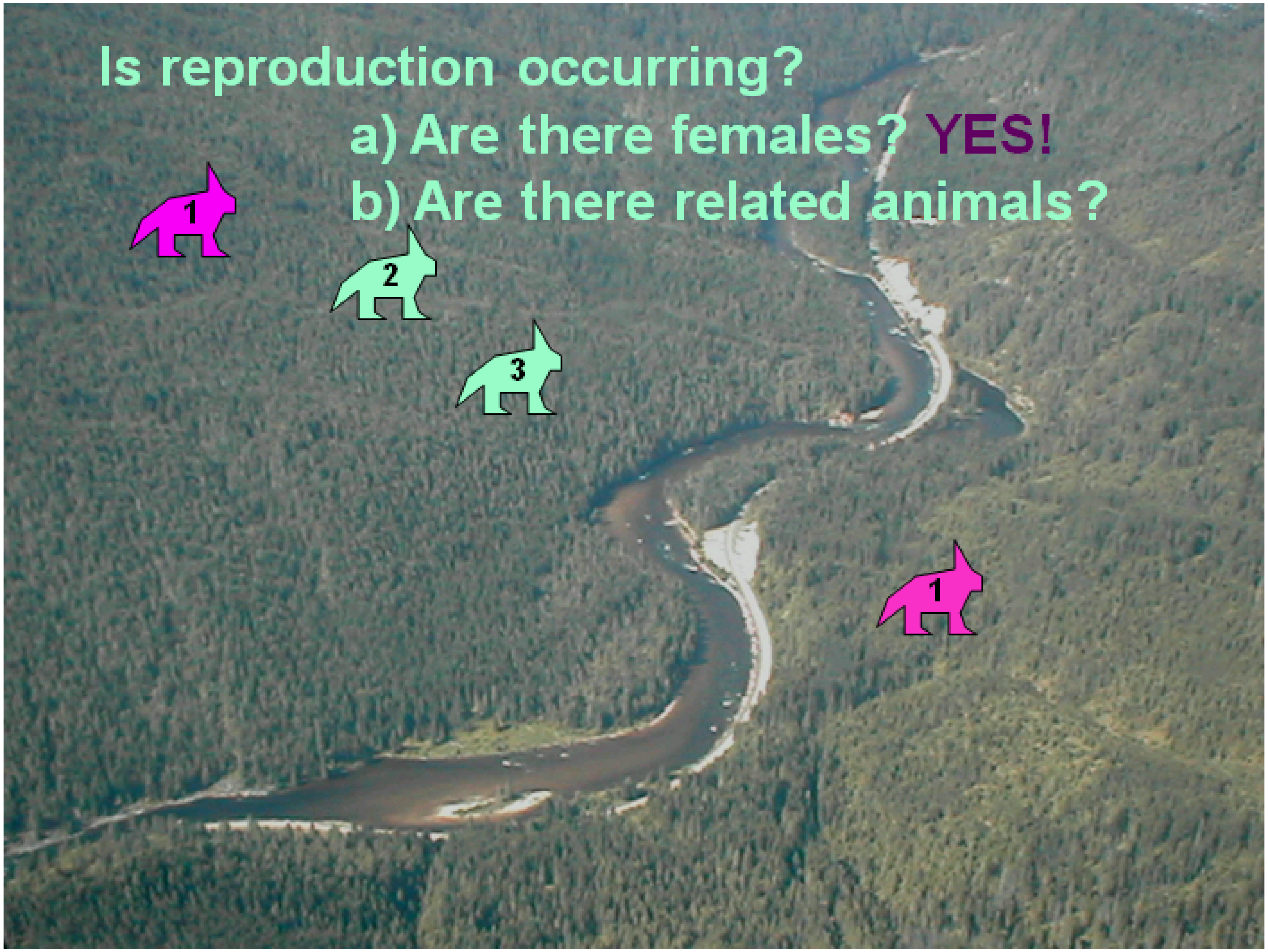
Gender Determination

- 1 of 3 Different genes typically used (*Zf, Amelogenin, SRY*)

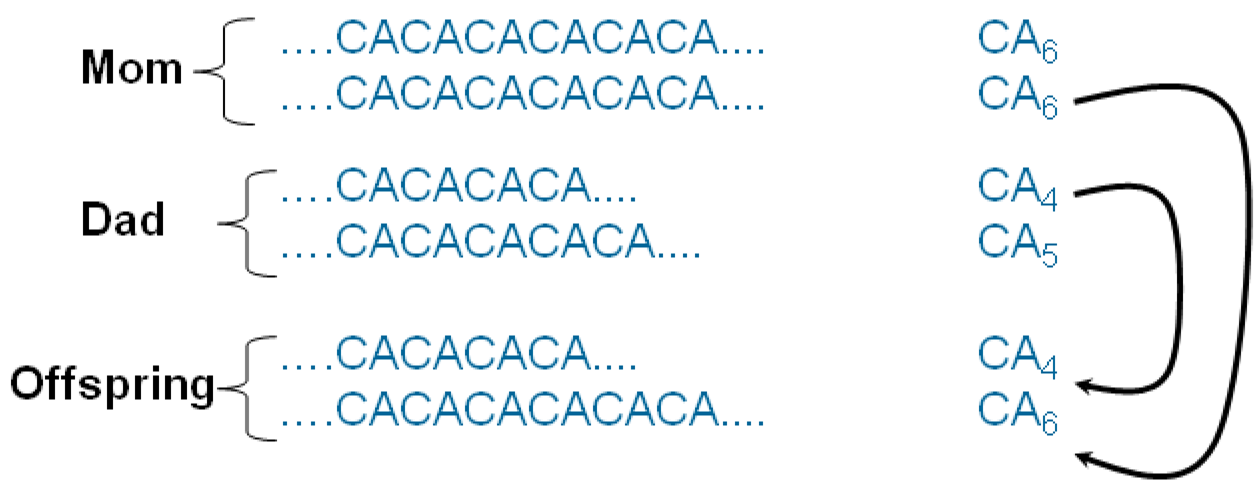


Slide 47

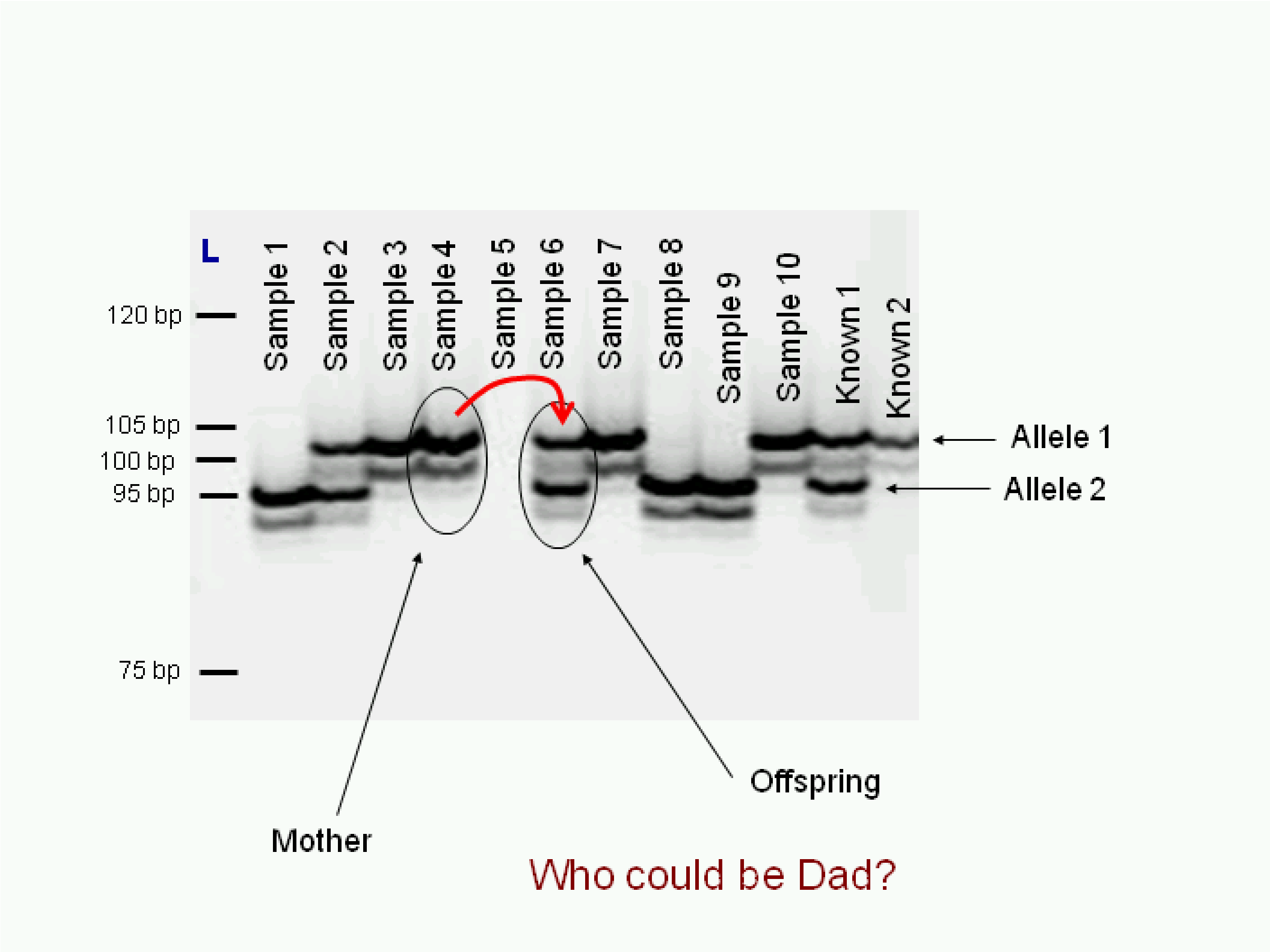

Is reproduction occurring?
a) Are there females? YES!
b) Are there related animals?
1
2
3
1

Slide 48

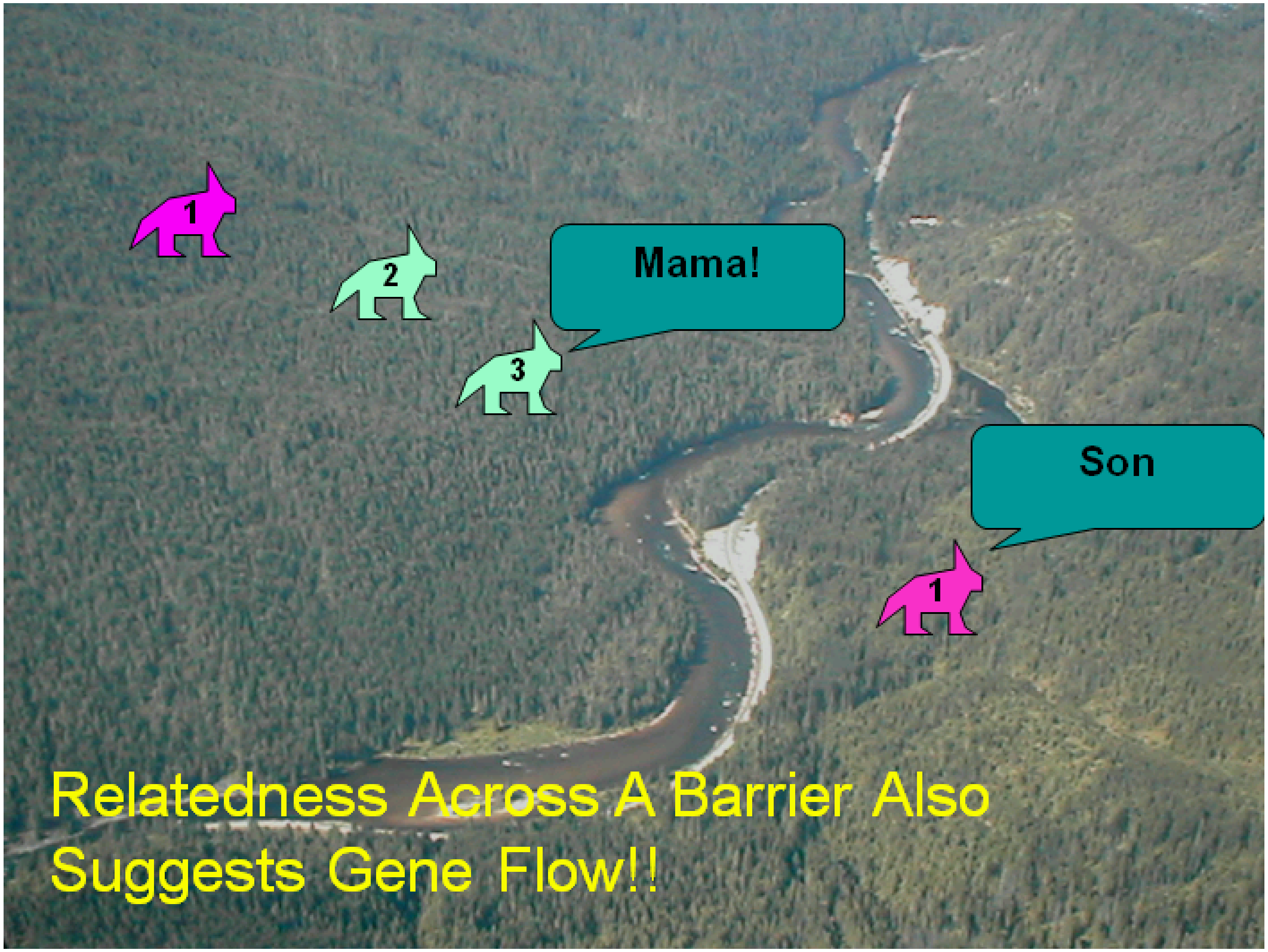
Microsatellite DNA



Slide 49


L
Sample 1
Sample 2
Sample 3
Sample 4
Sample 5
Sample 6
Sample 7
Sample 8
Sample 9
Sample 10
Known 1
Known 2
120 bp
105 bp
100 bp
95 bp
75 bp
Allele 1
Allele 2
Offspring
Mother
Who could be Dad?

Slide 50


1
2
Mama!
3
Son
1
Relatedness Across A Barrier Also
Suggests Gene Flow!!

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These Relatedness Understandings Are the Basis for Landscape Genetics

Slide 52

Review TRENDS in Ecology and Evolution Vol.18 No.4 April 2003 189

Landscape genetics: combining landscape ecology and population genetics

Stéphanie Manel[1], Michael K. Schwartz[2], Gordon Luikart[1] and Pierre Taberlet[1]

[1]Laboratoire d'Ecologie Alpine, Equipe Génomique des Populations et Biodiversité, UMR CNRS 5553, BP 53, Université Joseph Fourier, 38041 Grenoble Cedex 9, France
[2]Rocky Mountain Research Station, US Forest Service, 800 E. Beckwith, Missoula, MT 59801, USA

Step 1: Determine landscape features that may foster / hinder connectivity (hypotheses)

Step 2: Use genotype information to evaluate these features

Slide 53

Statistical Approaches to Landscape Genetics

I. When populations easily defined (aquatic weeds in pond)
   A. Fst
   B. Assignment Tests

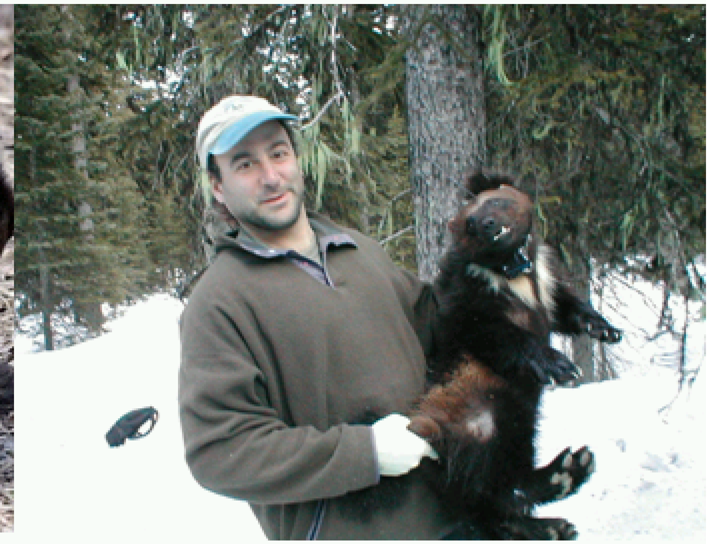
II. Landscape Genetics
   A. Mantel Tests / Regression
   B. Spatial Autocorrelation
   C. Bayesian Clustering
   D. Multivariate Analyses and Synthesis Maps
   E. Monmonier's Algorithm / Wombling
   F. GIS Analyses

Slide 54

Slide 55

>99% All Dens
In Spring Snow

>95% Summer Telemetry
In Spring Snow



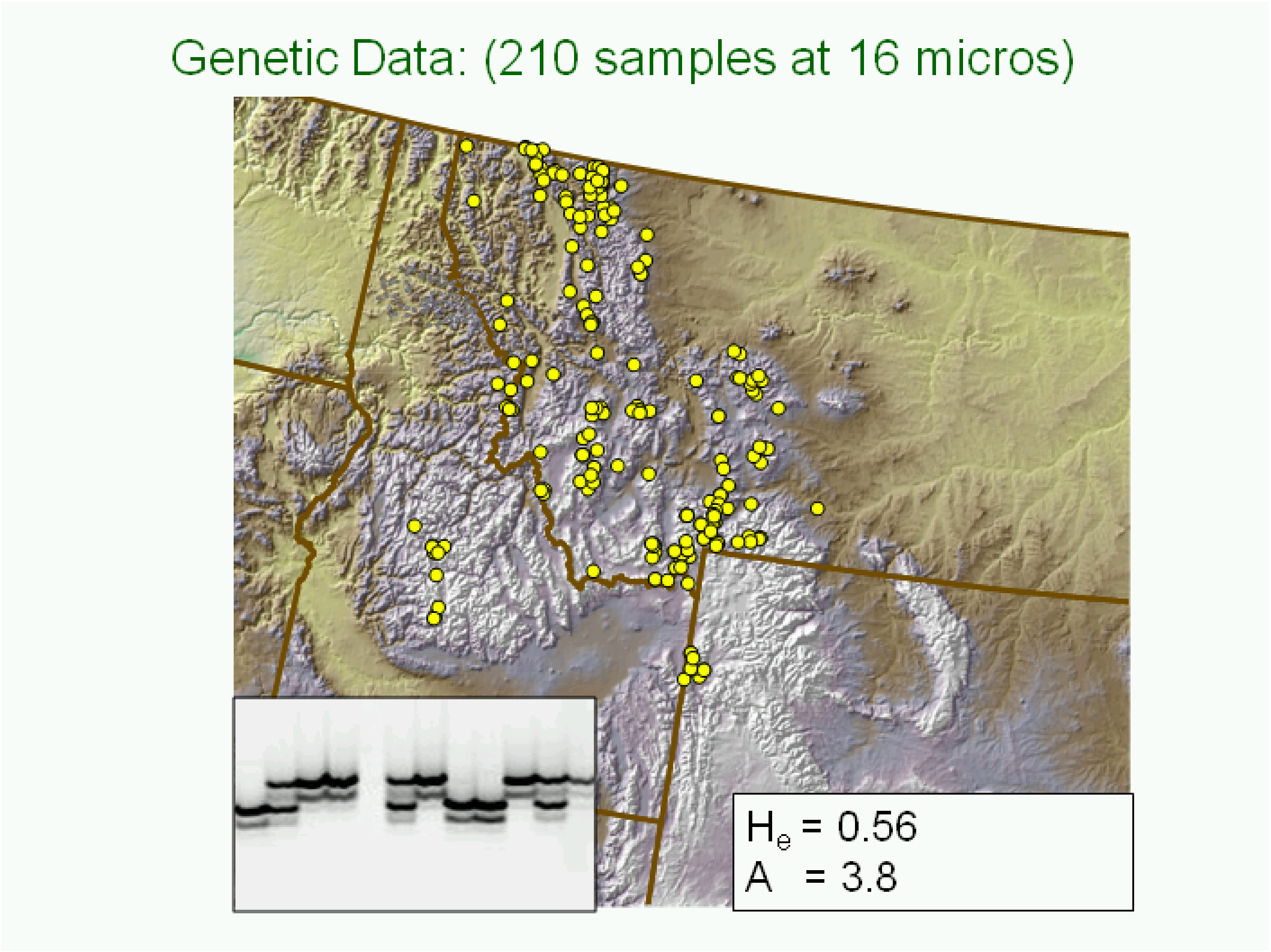
Do Wolverine Use Spring Snow For Movement?

Aubry et al. 2007, Copeland et al. 2010, Schwartz et al. 2007, McKelvey et al. In Review.

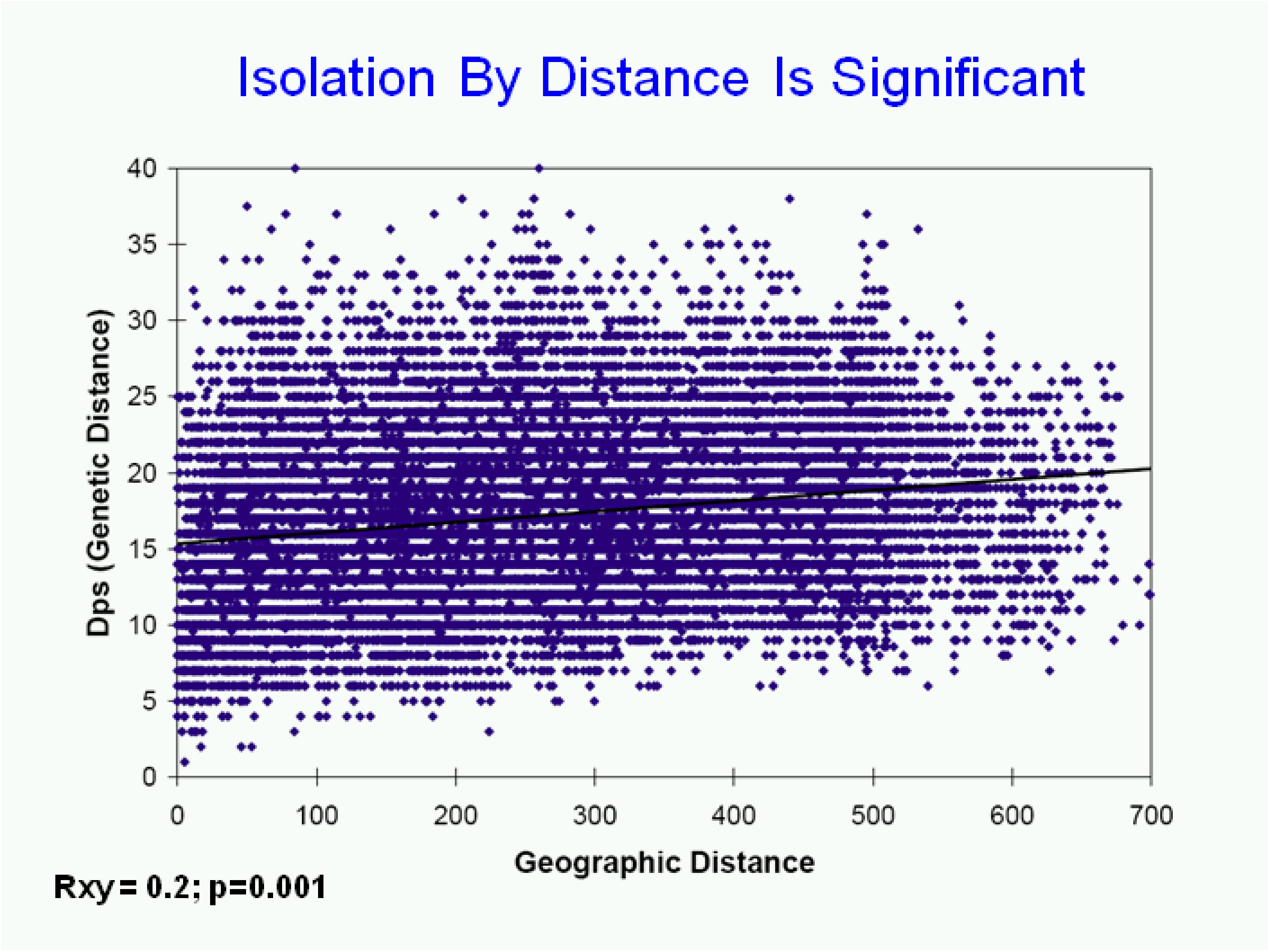
Slide 56


Does the Bioclimatic Niche (indicated by
spring snow) provide “corridors”
for movement and gene flow?
Schwartz et al. 2009

Slide 57



Slide 58


Isolation By Distance Is Significant
Dps (Genetic Distance)
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
700
Geographic Distance
Rxy= 0.2; p=0.001

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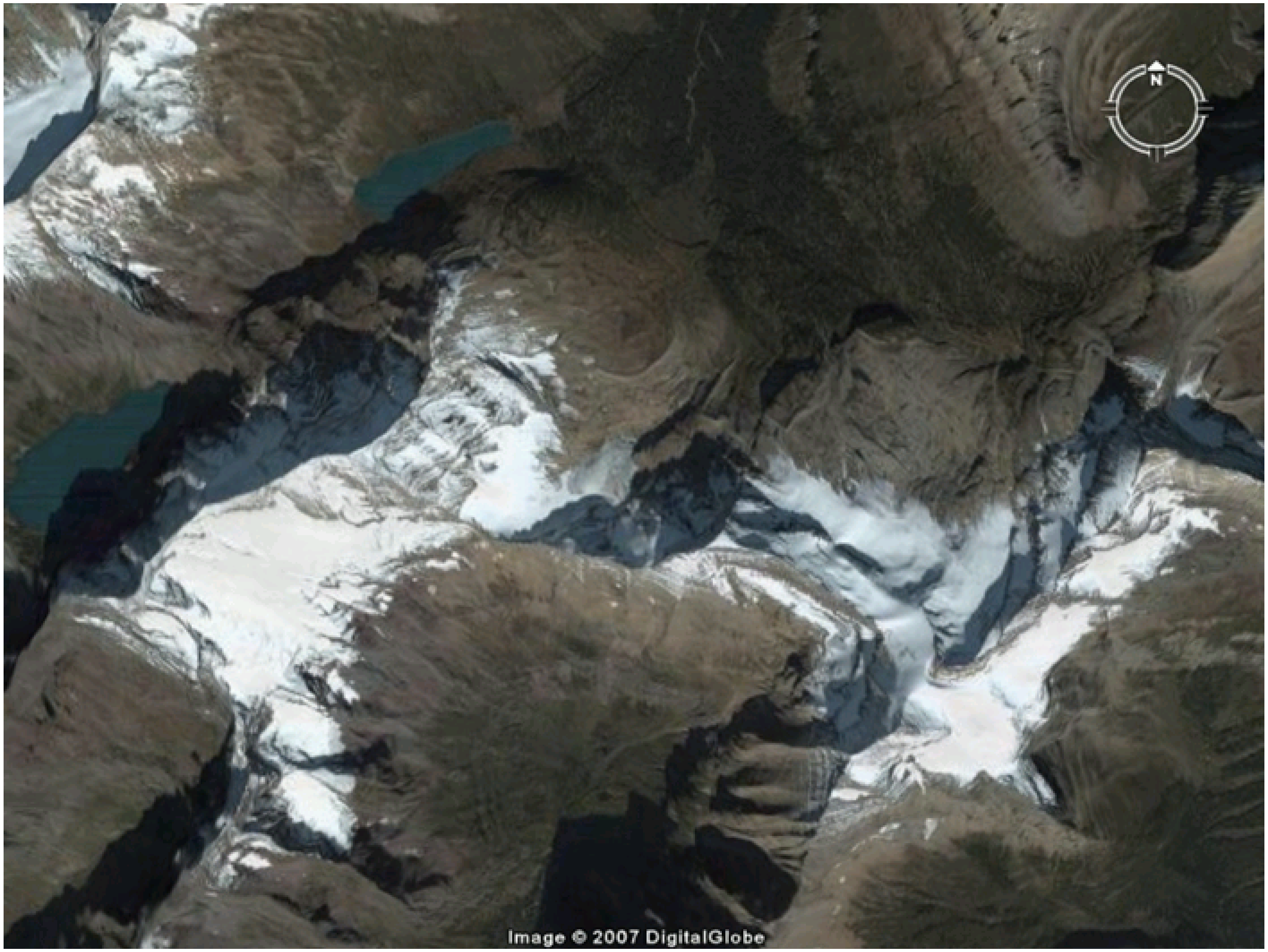
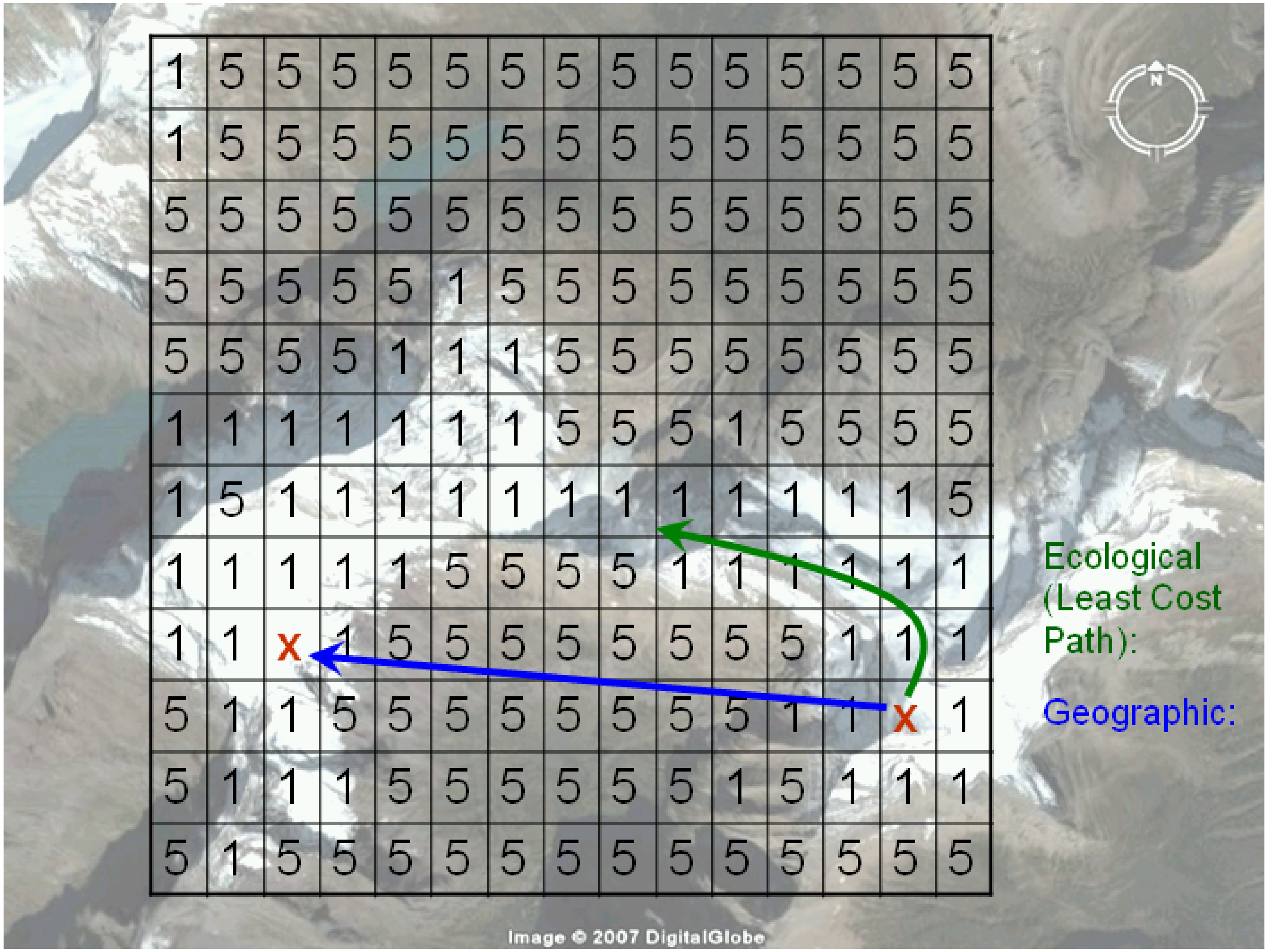


Slide 60



1 5 5 5 5 5 5 5 5 5 5 5 5 5 5
1 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 1 5 5 5 5 5 5 5 5 5
5 5 5 5 1 1 1 5 5 5 5 5 5 5 5
1 1 1 1 1 1 1 5 5 5 1 5 5 5 5
1 5 1 1 1 1 1 1 1 1 1 1 1 1 5
1 1 1 1 1 5 5 5 5 1 1 1 1 1 1
1 1 X 1 5 5 5 5 5 5 5 5 1 1 1
5 1 1 5 5 5 5 5 5 5 5 1 1 X 1
5 1 1 1 5 5 5 5 5 5 1 5 1 1 1
5 1 5 5 5 5 5 5 5 5 5 5 5 5 5
N
Ecological
(Least Cost
Path):
Geographic:
Image © 2007 DigitalGlobe

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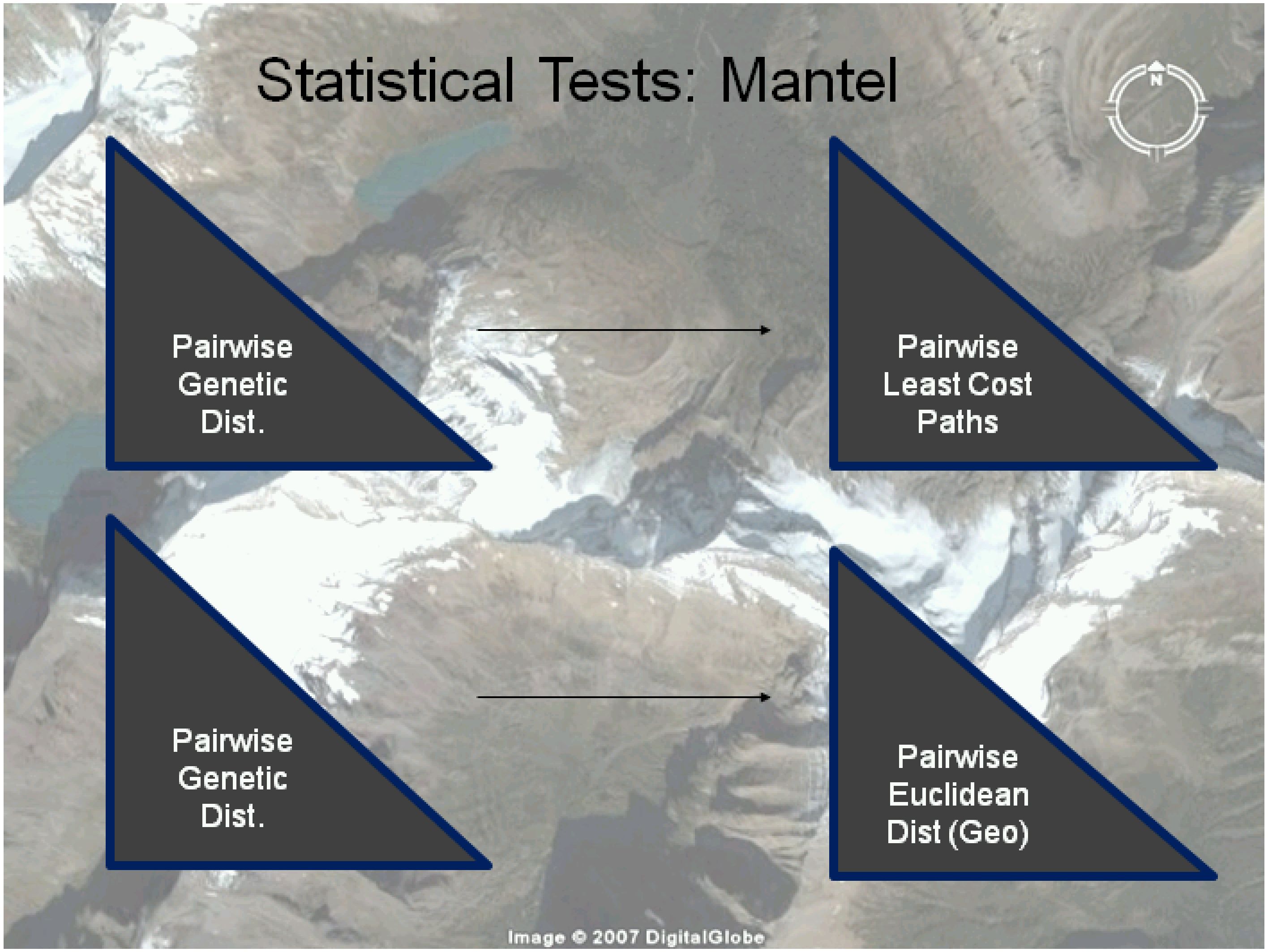
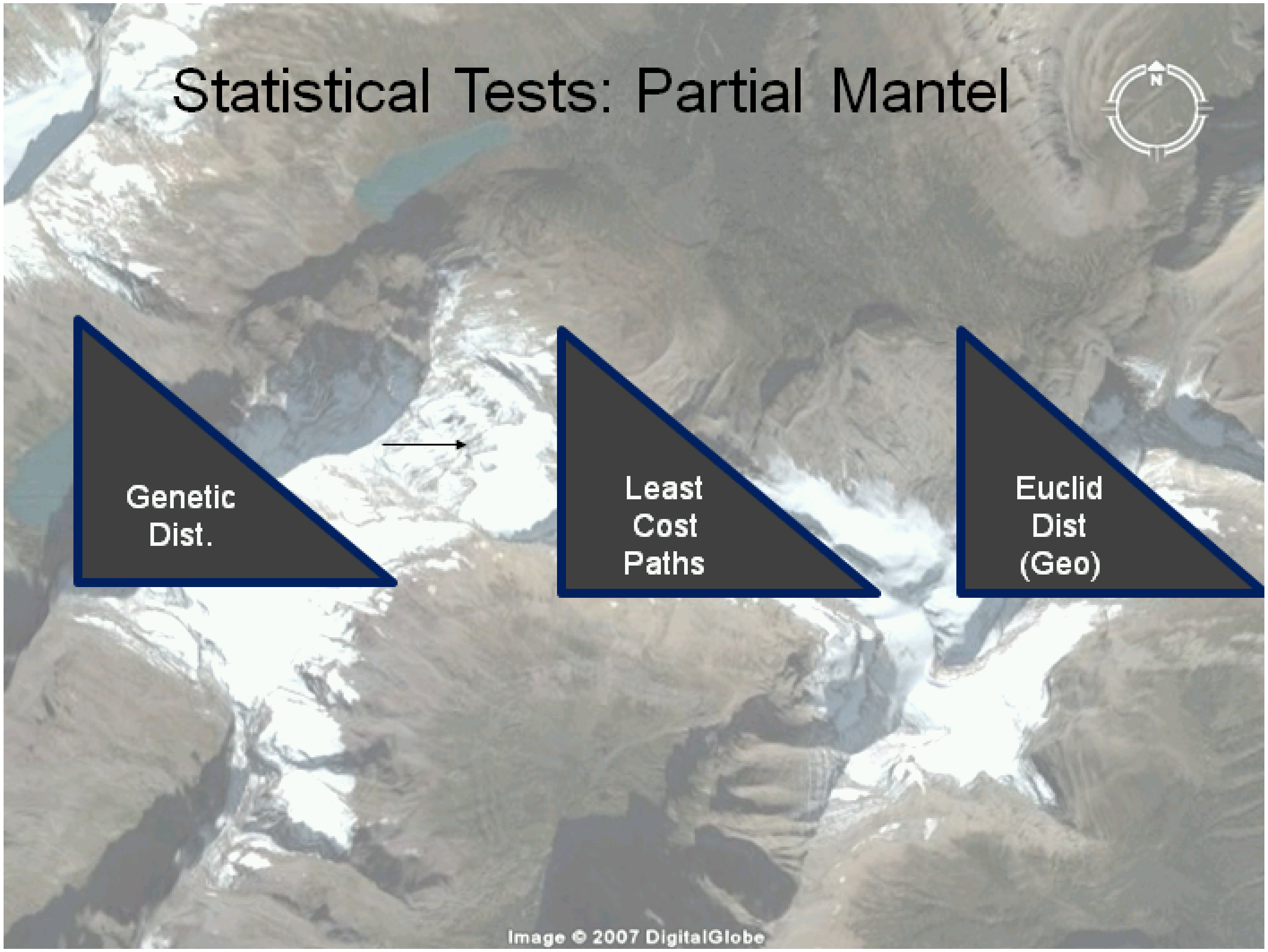

Statistical Tests: Mantel
Pairwise Genetic Dist.
Pairwise Least Cost Paths
Pairwise Genetic Dist.
Pairwise Euclidean Dist (Geo)
Image © 2007 DigitalGlobe

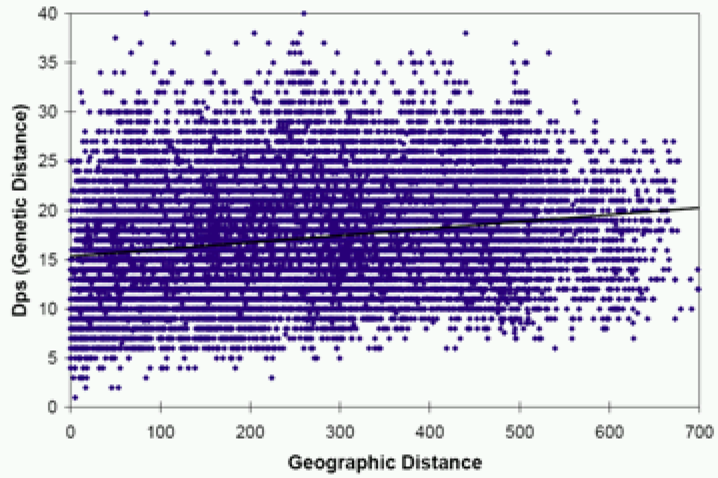
Slide 62


Statistical Tests: Partial Mantel
N
Genetic
Dist.
Least
Cost
Paths
Euclid
Dist
(Geo)
Image © 2007 DigitalGlobe

Slide 63

Results (Mantel)

Genetic vs. Geographic Distance – Significant
Genetic vs. Ecological Distance (R5) – Significant
Genetic vs. Ecological Distance (R10)– Significant
Genetic vs. Ecological Distance (R15)– Significant
Genetic vs. Ecological Distance (R20)– Significant



Slide 64

Results (Partial Mantel)

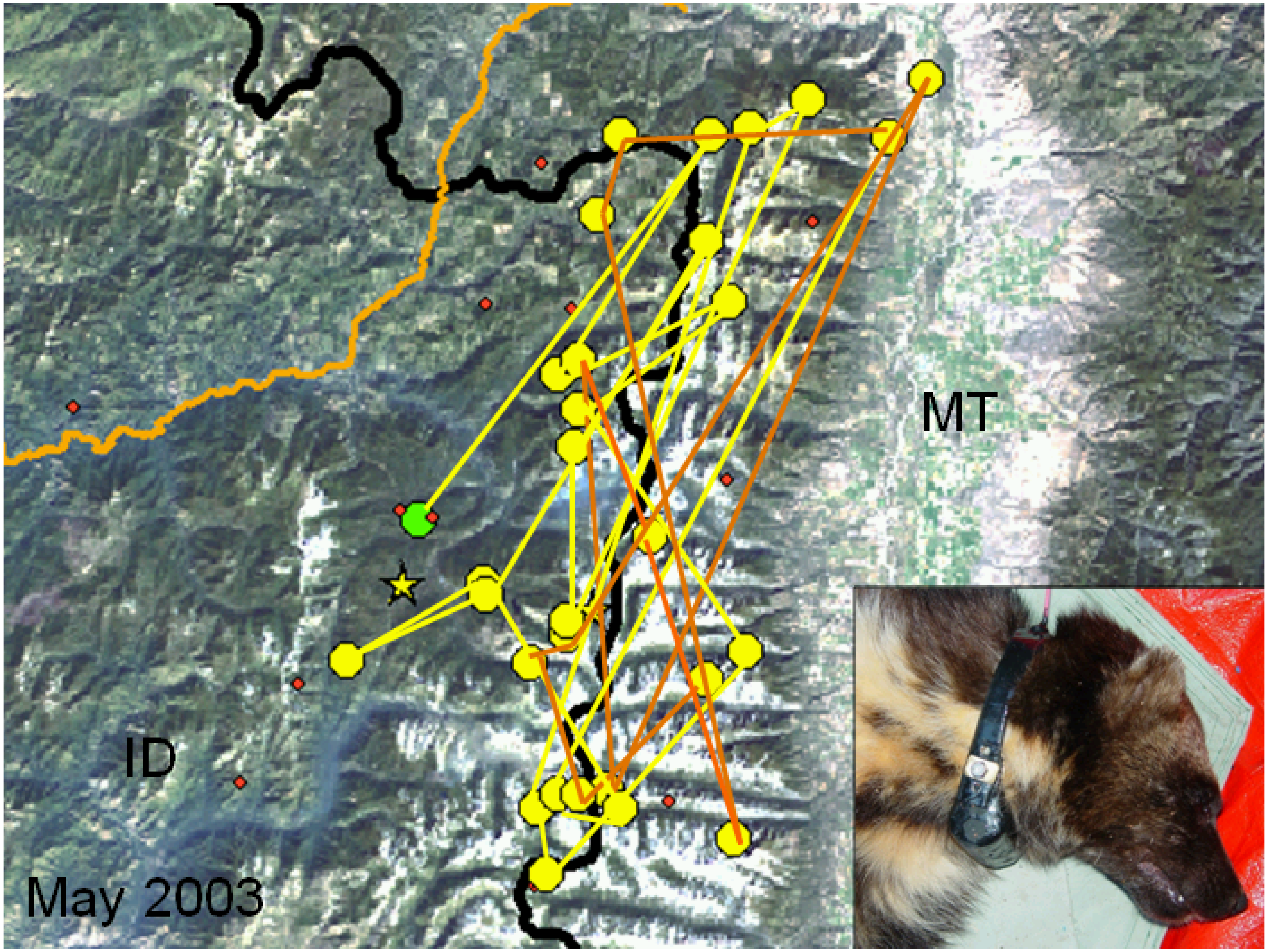
Genetic vs. Geographic.Ecological (R5-20) – p = 0.67 NS
Genetic vs. Ecological (R5-20).Geographic – p = 0.001

Landscape (geographic dist) has an independent effect on genetic distance, when controlling for geographic distance (nuisance)

Spring Snow Model Explains Movement

Slide 65

Slide 66



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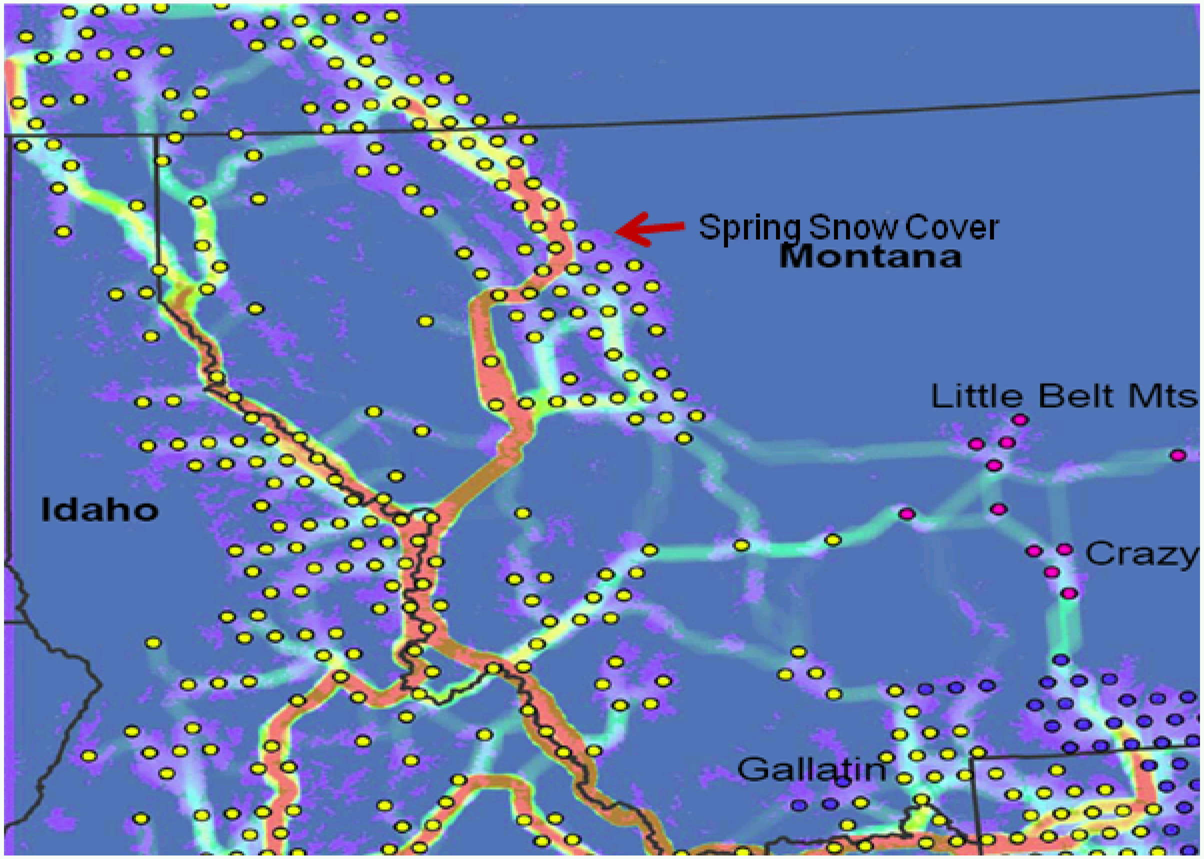
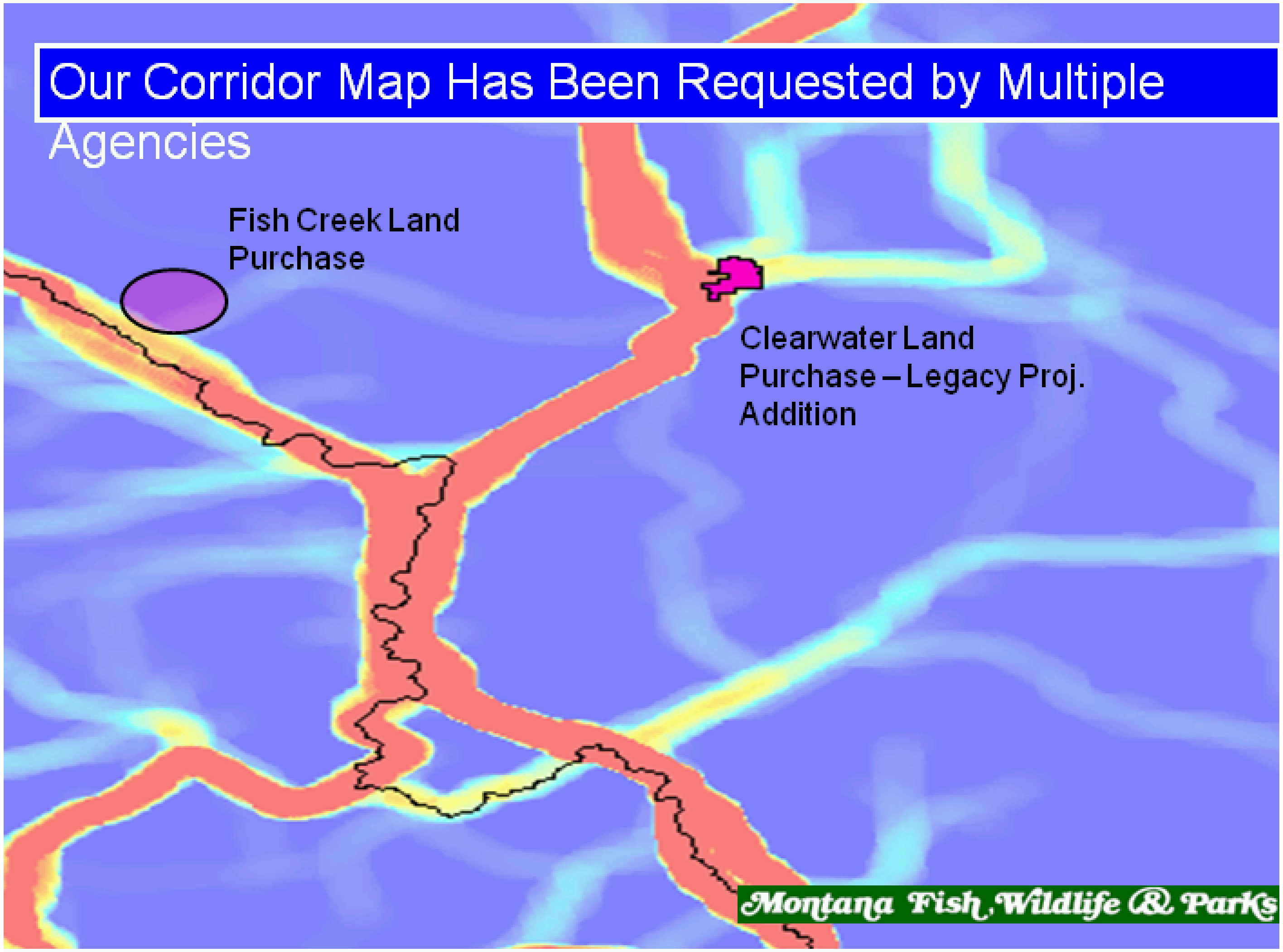
From These Empirical Findings We Derived Corridors

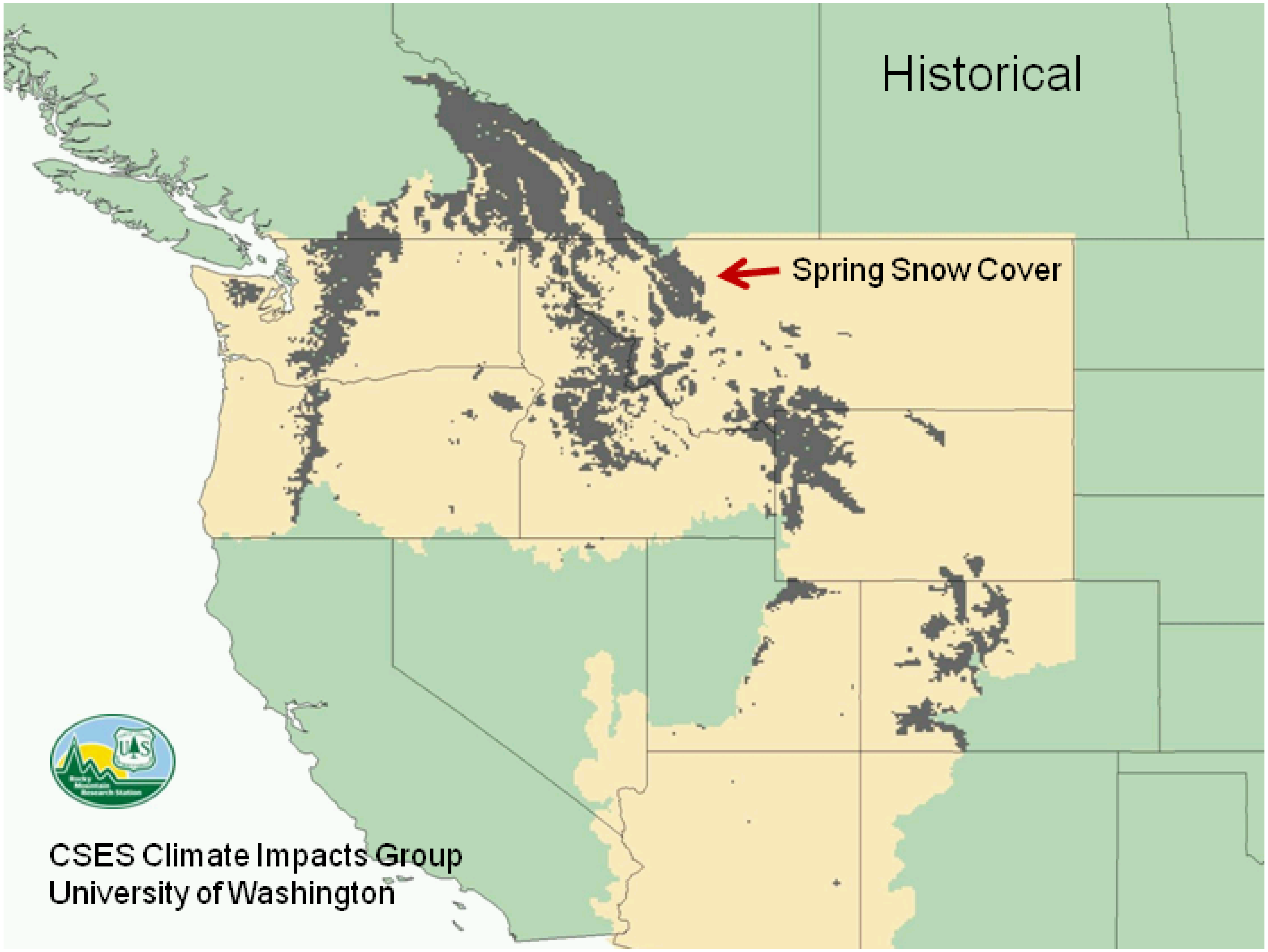


Schwartz et al. 2009

Slide 68


Our Corridor Map Has Been Requested by Multiple Agencies
Fish Creek Land Purchase
Clearwater Land Purchase – Legacy Proj. Addition
Montana Fish, Wildlife & Parks

Slide 69


Historical
Spring Snow Cover
CSES Climate Impacts Group
University of Washington

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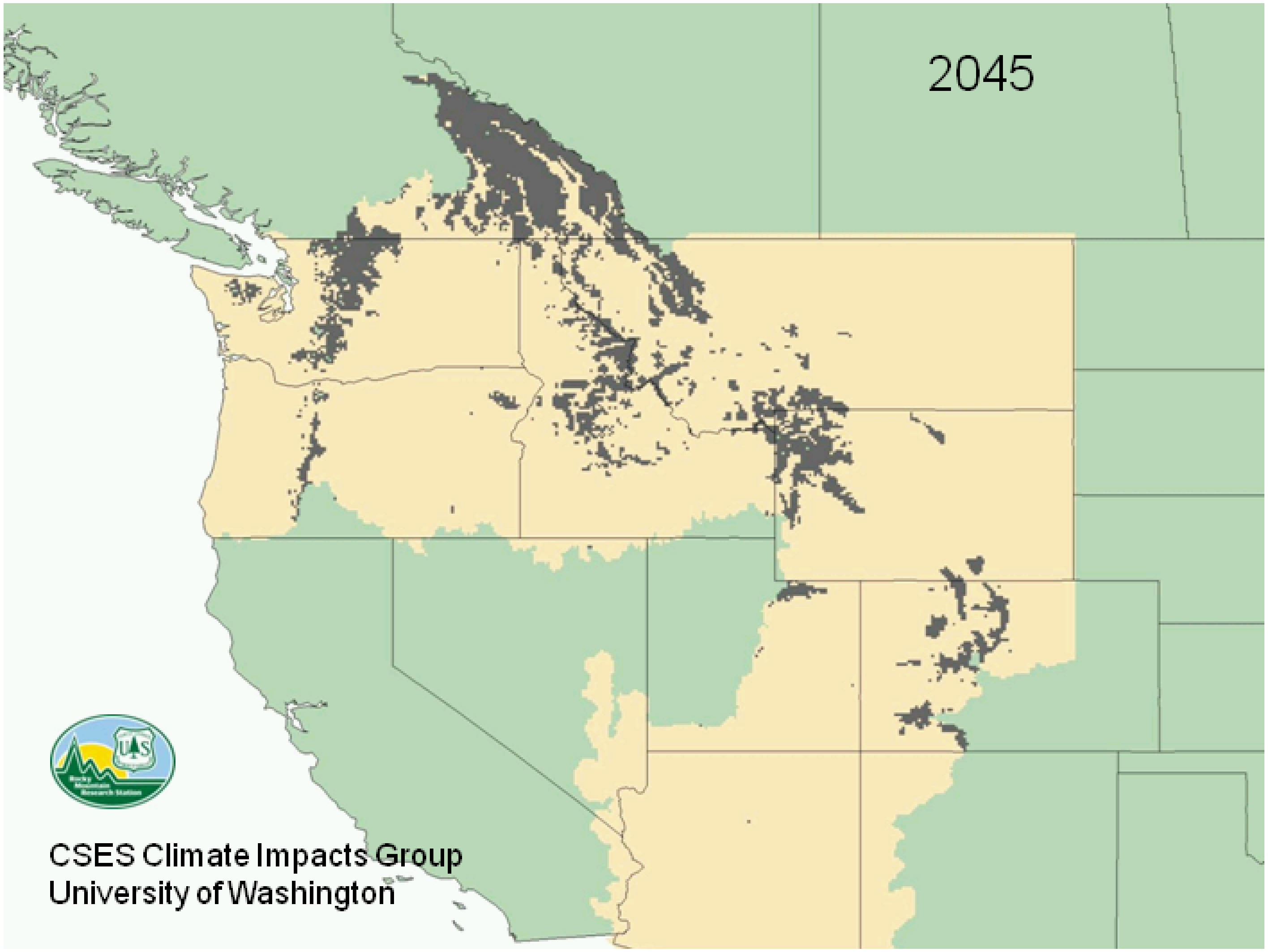

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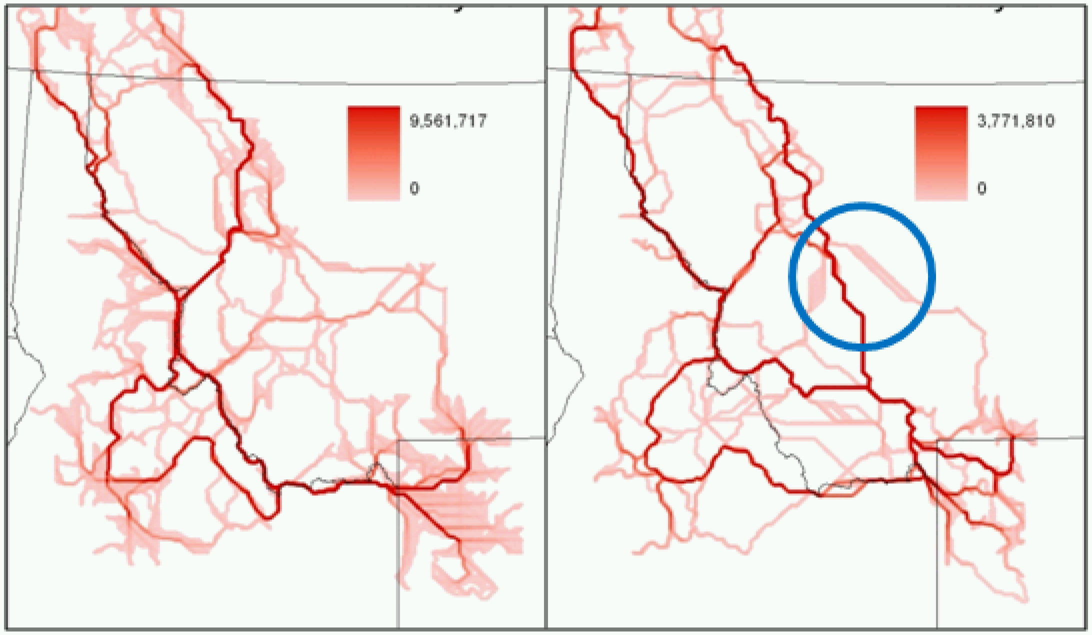
Empirically Based Corridors for Wolverines Now and Given Climate Change



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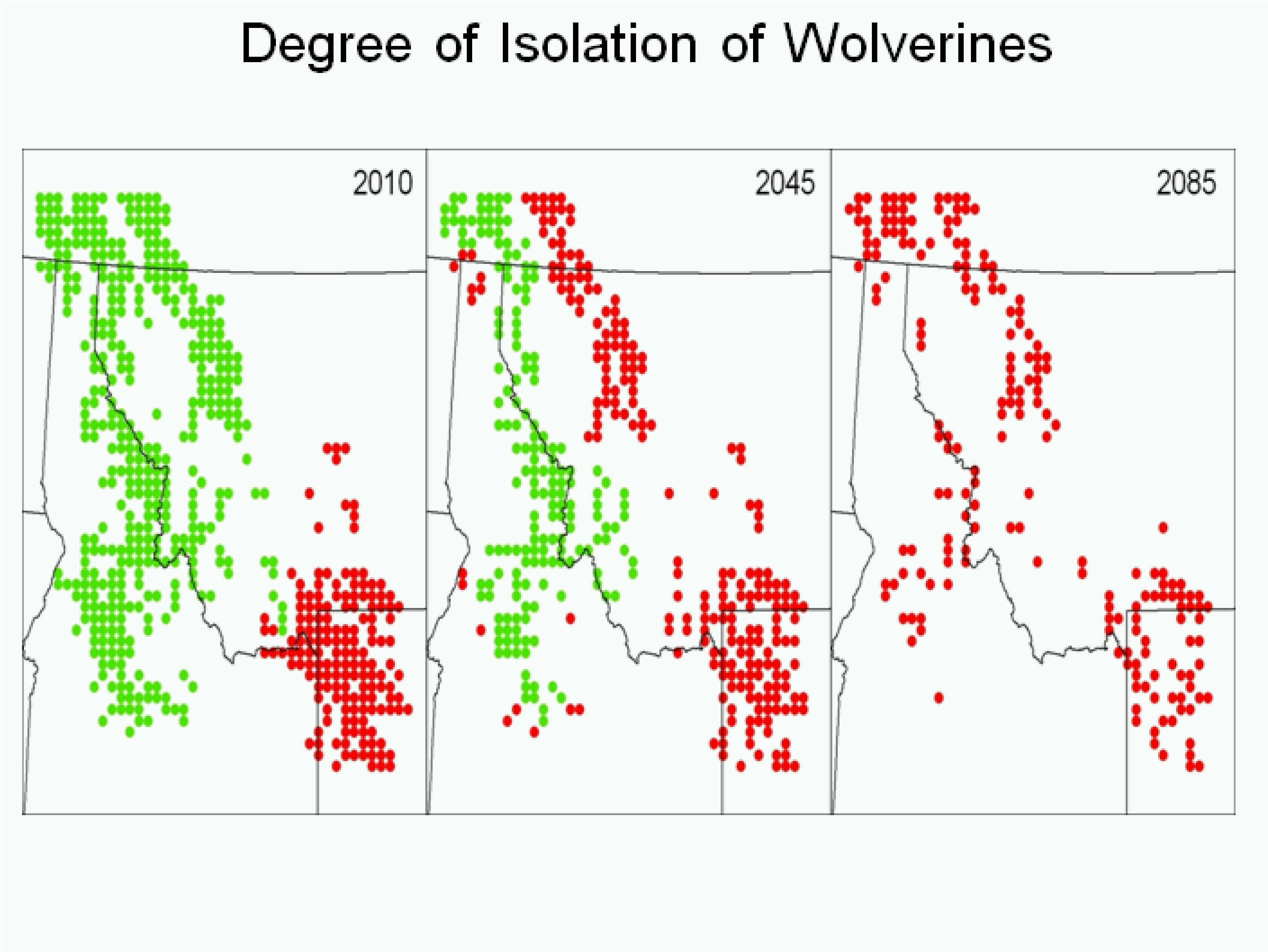

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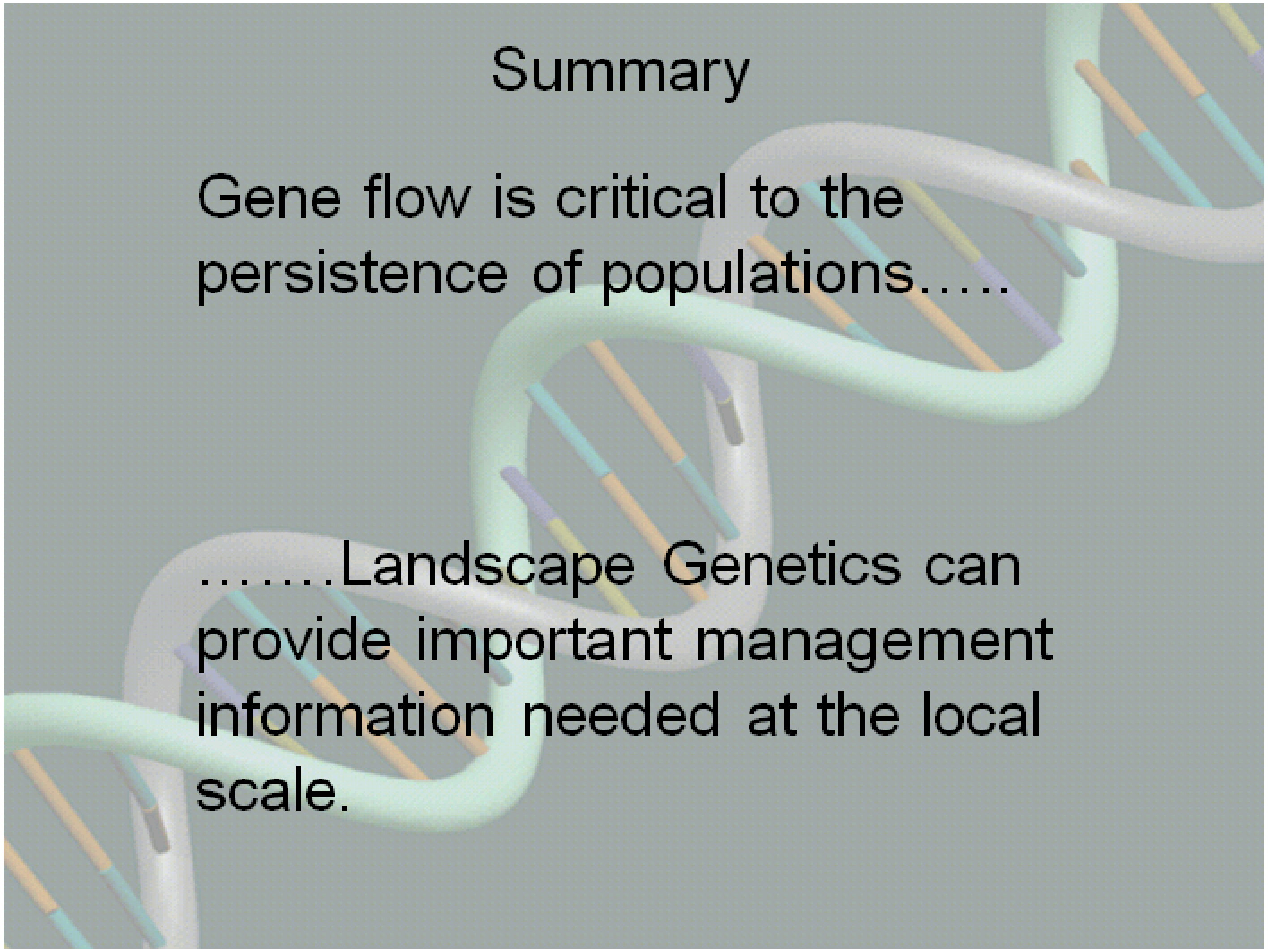
Summary
Gene flow is critical to the persistence of populations…..
…….Landscape Genetics can provide important management information needed at the local scale.

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