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CENTRAL ISSUE

Restoration of the American Chestnut will involve the planting of hundreds to thousands of trees at each of thousands of locations:

ARE PARTICULAR FOUNDING GEOMETRIES PREFERRED OVER OTHERS?
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Undergraduate Student
Melanie Simkins
Environmental Studies
Ohio Plant Biotechnology Consortium
INTENSE COMPETITION

HERBIVORES

PATHOGENS
ALLÈE EFFECTS

REPRODUCTION
NUMBER OF COLONIZERS
GEOMETRY OF ESTABLISHMENT
INTERACTING FACTORS

SPATIONUMERIC
FOUNDING EFFECTS
SPATIONUMERIC FOUNDING EFFECTS:

PROFOUND OR INSIGNIFICANT IN RESTORATION PROJECTS OR EVOLUTIONARY PROCESSES?
SEAGRASS RESTORATION: OPTIMIZED FOUNDER SPACING?

RESTORATION IS COSTLY

1. Propagule collection, storage, and/or pre-germination treatment
2. Travel to and from the introduction site
3. Site preparation
4. Planting the species
5. Provisioning seeds or growing seedlings
6. Protecting the initial plantings
7. Post-planting monitoring: population size and genetic diversity
8. Depending on the monitoring: population manipulation or supplementation
9. Propagule harvesting for new plantings
10. Introducing a species may involve disturbance of the habitat

GOAL: TO MAXIMIZE POPULATION GROWTH AND GENETIC DIVERSITY RETENTION
FAGACEAE

Quercus
The Oaks

Fagus
The Beeches

Castanea
The Chestnuts
12 species
North temperate
WHY STUDY THE AMERICAN CHESTNUT?

- Previously one of the most important trees of eastern North America
  - American chestnuts may become extinct due to an introduced blight
- Efforts to breed blight resistant chestnuts are underway
  - Optimized reintroduction strategies
American Chestnut Facts

- Tallest, most massive flowering tree in Eastern North American flora
- Covered over 2 million acres of land
- Often dominant: often contributed > 25% of the available basal area
- Important hardwood species in forest ecosystems
- Important, fast-growing commercial timber
WHY STUDY THE AMERICAN CHESTNUT?

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The Chestnut Blight

- pathogenic fungus *Cryphonectria parasitica* (formerly *Endothia parasitica*) of the Ascomycota (sac fungi)

- Introduced in the early 1900’s on Asian nursery stock
  - Highly virulent to *C. dentata*

- At present over 3 to 4 billion trees have succumbed
Why Study the American Chestnut?

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- American chestnuts may become extinct due to an introduced blight
- Efforts to breed blight resistant chestnuts are underway
  - Optimized reintroduction strategies
AMERICAN CHESTNUT  X  CHINESE CHESTNUT

SELECT RESISTANT OFFSPRING:  X  AMERICAN CHESTNUT

SELECT RESISTANT OFFSPRING:  X  AMERICAN CHESTNUT

SELECT RESISTANT OFFSPRING:  X  AMERICAN CHESTNUT

RESULT AFTER 10 REPETITIONS:  99% AMERICAN CHESTNUT WITH BLIGHT RESISTANCE
WHY STUDY THE AMERICAN CHESTNUT?

• Previously one of the most important trees of eastern North America

• American chestnuts are approaching extinction due to a blight

• Efforts to breed blight resistant chestnuts are underway

• Are there more optimal reintroduction strategies?
NEWGARDEN

COMPUTER PROGRAM

ESTABLISH VIRTUAL PLANT POPULATIONS

USER DEFINED CONDITIONS

ANALYZE FOR POPULATION GROWTH AND GENETIC DIVERSITY RETENTION THROUGH TIME

PROCESS DRIVEN, NOT EQUATION DRIVEN
PRESERVE SIZE AND SHAPE

CORRIDORS

EXCHANGE BETWEEN PRESERVES
AVERAGE DENSITY AT K

PRESERVE: 2000 GRID POINTS ON A SIDE
5 M BETWEEN GRID POINTS
10 KM X 10 KM PRESERVE
4,000,000 GRID POINTS
MINIMAL DISTANCE BETWEEN CHESTNUT TREES:

5 M
OR
16.4 FT
FOUNDERS

SPECIFY NUMBER: 169

SPECIFY GENETIC DIVERSITY OF SOURCE POPULATION:
20 LOCI, EACH WITH 100 ALLELES
APPROXIMATELY 2000 ALLELES AMONG
THE FOUNDERS

SPECIFY THE AGE OF EACH FOUNDER: 13

SPECIFY THE SEX OF EACH FOUNDER: BISEXUAL

SPECIFY GEOMETRIC PLACEMENT
ON GRID SYSTEM:
VARIABLE
REPRODUCTIVE RATE

SPECIFY RATE OF OFFSPRING PRODUCTION PER ELIGIBLE PARENT

MATINGS CHOSEN RANDOMLY AMONG ELIGIBLES

POISSON DISTRIBUTION:
AGE SPECIFIC REPRODUCTION

FOR EACH AGE, CAN DESIGNATE:

- OFFSPRING PRODUCED
- POLLINATIONS OCCUR
OFFSPRING DISPERSAL

LEPTOKURTIC

CAN SPECIFY PERCENTAGE DISTRIBUTED TO EACH DISTANCE
POLLINATION

RELATIVE RATE OF DELIVERY FROM DIFFERENT DISTANCES
RATE OF SELFING

- 0% TO 100%

- WHICH INDIVIDUALS SELF CHOSEN RANDOMLY

CHESTNUTS: 0% SELFING
MORTALITY

- DISPERSAL TO SAME GRID POINT
- PRE-EXISTING INDIVIDUAL
- DISPERSED OFF GRID
- ANNUALS
- PERENNIALS: AGE SPECIFIC MORTALITY
CAN SPECIFY NUMBER OF GENERATIONS

EACH NEW GENERATION = COHORT BEGINS AT EACH ROUND OF MATING
INPUT ONE SET OF TRIAL CONDITIONS
SPECIFY REPLICATE RUNS (100)
MEAN OUTPUT VALUES ACROSS ALL RUNS

STANDARD DEVIATION

T-TEST  P < 0.05

BONFERRONI CORRECTED
FOR EACH GENERATION
SUMMARY STATISTICS ARE REPORTED FOR:

- ALL INDIVIDUALS IN THE POPULATION
- ONLY THOSE INDIVIDUALS IN THE LATEST COHORT
DERIVE STATISTICS FROM SEPARATE SECTORS
POPULATION GROWTH

TOTAL NUMBER OF INDIVIDUALS
FOR THE ENTIRE PRESERVE OR FOR SECTORS
PER GENERATION
GENETIC DIVERSITY

HETEROZYGOSITY = GENE DIVERSITY

Ho  = OBSERVED H
He  = EXPECTED H

AA  AB  AB  BB  50% HETEROZYGOUS
AA  QC  FG  FF  50% HETEROZYGOUS
GENETIC DIVERSITY

NUMBER OF UNIQUE ALLELES IN FOUNDERS

UNIQUE FOUNDING ALLELES RETAINED THROUGH GENERATIONS

SENSITIVE METHOD TO DETECT GENETIC DIVERSITY LOSS

IMPORTANT TO FUTURE OF POPULATION
GENETIC DIVERSITY

F STATISTICS

INBREEDING POPULATION SUBDIVISION

\[ |F| \]

0.0 TO 0.05          LOW
0.05 TO 0.15         MODERATE
0.15 TO 0.25         HIGH
> 0.25               VERY HIGH
1.0                  COMPLETE

Sewall Wright
RESULTS
PRIMARY MECHANISM

MORE ESTABLISHMENT POINTS AVAILABLE

LESS “COMPETITION” FOR ESTABLISHMENT POINTS

DENSITY DEPENDENT POPULATION GROWTH
NEWGARDEN
Preserve Design

169 founders
13 x 13 grid points
1 space between founders

1000 x 1000 grid points
5m distance between grid points: 5km x 5km reserve

Founder population diagonally inset at given distances

Inset Distances
Results

Basic Conditions Trial: Population Growth over 100yrs

Mean Population Size

Year

a Corner  b 100 Grid Pts
c 200 Grid Pts  d 300 Grid Pts
e 400 Grid Pts  f 500 Grid Pts
Results

Basic Conditions Trial:
Allele Retention over 100yrs

![Graph showing allele retention over 100 years with different conditions: Corner, 100 Grid Pts, 200 Grid Pts, 300 Grid Pts, 400 Grid Pts, 500 Grid Pts.](image-url)
Seed & Pollen Dispersal Experiments

**Null:** Varying offspring and pollen dispersal distances does not affect population growth or allele retention of developing American chestnut populations.

Table I. Pollen and offspring dispersal distances from or to each distance frame

<table>
<thead>
<tr>
<th>Frame dimensions (in grid points)</th>
<th>0-5</th>
<th>6-12</th>
<th>13-21</th>
<th>22-30</th>
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</thead>
<tbody>
<tr>
<td>Trial Description</td>
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<td></td>
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<tr>
<td>Basic conditions</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Offspring less distant</td>
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<tr>
<td>Offspring least distant</td>
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<tr>
<td>Offspring more distant</td>
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<tr>
<td>Pollen less distant, offspring more distant</td>
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<td>Pollen more distant, offspring least distant</td>
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<thead>
<tr>
<th>Trial Description</th>
<th>Pollen % to</th>
<th>Offspring % from</th>
<th>Pollen % to</th>
<th>Offspring % from</th>
<th>Pollen % to</th>
<th>Offspring % from</th>
<th>Pollen % to</th>
<th>Offspring % from</th>
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<tbody>
<tr>
<td>B</td>
<td>25</td>
<td>60</td>
<td>25</td>
<td>30</td>
<td>25</td>
<td>4</td>
<td>25</td>
<td>6</td>
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<tr>
<td>C</td>
<td>25</td>
<td>90</td>
<td>25</td>
<td>5</td>
<td>25</td>
<td>3</td>
<td>25</td>
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<td>5</td>
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<td>3</td>
<td>80</td>
<td>2</td>
</tr>
</tbody>
</table>
Fig 3.
Seed & Pollen Dispersal: Population Size vs. Inset Distance at year 100

Results
Results

Fig 4.
Seed & Pollen Dispersal: Number of Alleles vs. Inset Distance at year 100

- **A**: Basic conditions
- **B**: Offspring less distant
- **C**: Offspring least distant
- **D**: Offspring more distant
- **E**: Pollen less distant, Offspring more distant
- **F**: Pollen more distant, Offspring least distant
Figure 1. Mean Population Growth over 100 Year period for Founders Planted at the Reserve Corner. Mean population sizes for each age of American chestnut populations founded at the grid point distance origin with differing initial population size. (a – 169 founders, b – 225 founders, c – 361 founders, d – 441 founders, e – 529 founders) These comparative trials span 101 generations at the basic offspring and pollen dispersal conditions (25% to and from each frame respectively).
Figure 2. Mean Allelic Retention over 100 Year period for Founders Planted at the Preserve Corner. Mean number of founding alleles retained across 101 generations for trial populations located at the reserve origin differing only in the number of founders planted (population sizes shown in Figure 1). (a – 169 founders, b – 225 founders, c – 361 founders, d – 441 founders, e – 529 founders) The “basic” conditions of offspring and pollen dispersal distances were used for these trials (25% to or from each frame respectively).
CENTRAL ISSUE

Restoration of the American Chestnut will involve the planting of hundreds to thousands of trees at each of thousands of locations:

ARE PARTICULAR FOUNDING GEOMETRIES PREFERED OVER OTHERS?
IMPLICATIONS FOR CONSERVATION GENETICS AND RESTORATION BIOLOGY

AMERICAN CHESTNUT
Castanea dentata
Fagaceae
RESTORATION IMPLICATIONS:
PROMOTE POPULATION GROWTH
AND
GENETIC DIVERSITY RETENTION

-DISTANCE FROM BORDER
-GEOMETRIC PATTERN OF INTRODUCTION:
  HOW MANY FOUNDERS?
  GEOMETRY OF FOUNDERS?
-RISK ASSESSMENT
-NEED TO KNOW BIOLOGY: DENSITY, DISPERSAL, MORTALITY, ETC.
-MODEL ESTABLISHED POPULATIONS
  SUPPLEMENTATION
  DISPERSAL
  THINNING
  HARVEST PROPAGULES
WHAT’S NEXT?
SEED BANK MODULE
FIELD EXPERIMENTS
NEWGARDEN with supplementary material available for free at:  
Http://math.uc.edu/~pelikan/NEWGARDEN/


