

Seeds of Hope.

Sprucing up forest restoration with genomics

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HIGHLIGHTS

- GLOBAL ANTHROPOGENIC CHANGE THREATENS THE HEALTH AND PRODUCTIVITY OF FOREST ECOSYSTEMS.
- ASSISTED MIGRATION AND REFORESTATION ARE TOOLS TO HELP MITIGATE THESE IMPACTS.
- GENOMICS INFORMED APPROACH TO ASSIST IN DECISIONS REGARDING SEED SOURCE SELECTION FOR RESTORATION.
- POOLING OF MULTIPLE SEED SOURCES WITH HIGHER GENETIC DIVERSITY AND LOWER GENETIC LOAD IS A BETTER ALTERNATIVE TO IDENTIFYING A SINGLE SUPER SOURCE FOR REFORESTATION.



STUDY SYSTEM: RED SPRUCE (*PICEA RUBENS*)

- TEMPERATE CONIFEROUS TREE SPECIES THAT HAS EXPERIENCED WIDESPREAD DECLINE DUE TO ANTHROPOGENIC CAUSES SINCE THE LATE 19TH CENTURY.
- PRIME EXAMPLE OF A TREE SPECIES VULNERABLE TO RAPID CHANGES IN THE CLIMATE DUE TO ITS ISOLATED POPULATIONS AND LIMITED WITHIN-POPULATION GENETIC DIVERSITY IN THE SOUTHERN PART OF ITS RANGE.^{1,2}

SEED SOURCES POOLED AND SELECTED FOR HIGH GENETIC DIVERSITY AND LOW GENETIC LOAD FOR EARLY LIFE FITNESS

WHOLE-EXOME CAPTURE SEQUENCING WAS USED TO PROFILE THE GENOMIC DIVERSITY OF POTENTIAL SEED SOURCES FOR RESTORATION.

THE FULL DATASET CONSISTS OF SEQUENCED EXOMES FOR 339 INDIVIDUALS SAMPLED FROM ACROSS THE SPECIES RANGE.¹

GENETIC DIVERSITY (GD) WAS ESTIMATED BASED ON EXPECTED HETEROZYGOSITY ACROSS ALL SINGLE NUCLEOTIDE POLYMORPHISMS (SNPs), WHICH PROVIDES A FUNDAMENTAL MEASURE OF GENETIC VARIATION BASED ON THE FREQUENCY OF HETEROZYGOUS GENOTYPES EXPECTED UNDER HARDY-WEINBERG EQUILIBRIUM².

GENETIC LOAD (GL) MEASURES THE ACCUMULATION OF DELETERIOUS MUTATIONS IN THE POPULATION DUE TO GENETIC DRIFT. GL WAS CALCULATED AS THE NUMBER OF NON-SYNONYMOUS SNPs (P_N) AND THE NUMBER OF SYNONYMOUS (SILENT) SNPs (P_S), WEIGHTED BY THEIR CORRESPONDING FREQUENCIES (F_N AND F_S).

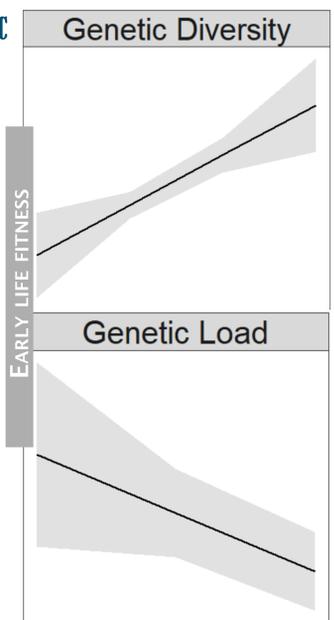
$$GL = \frac{P_N F_N}{P_S F_S}$$

GENETIC LOAD

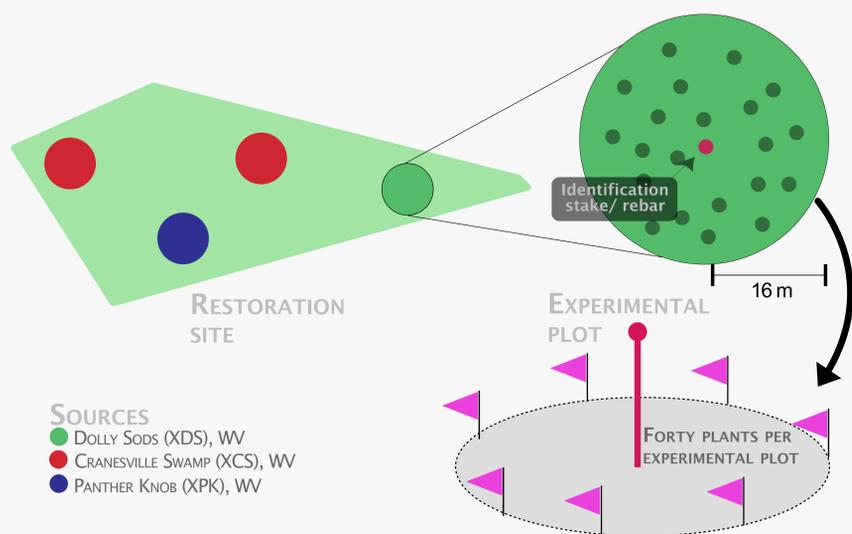
NON-SYNONYMOUS MUTATIONS

SYNONYMOUS MUTATIONS

CALCULATED UNDER THE WELL-SUPPORTED ASSUMPTION THAT THE MAJORITY OF NON-SYNONYMOUS MUTATIONS ARE DELETERIOUS³.



EXPERIMENTAL DESIGN



OVER 58 THOUSAND RED SPRUCE SEEDLINGS PLANTED IN 2021

UNDER THE REGIONAL ADMIXTURE PROVENANCING FRAMEWORK⁵, SEED SOURCES LOCAL TO THE RESTORATION SITE WERE SELECTED.

POOLED SOURCES WITH HIGH GD AND LOW GL WERE SELECTED FOR RESTORATION.

EXPERIMENTAL FRAMEWORK

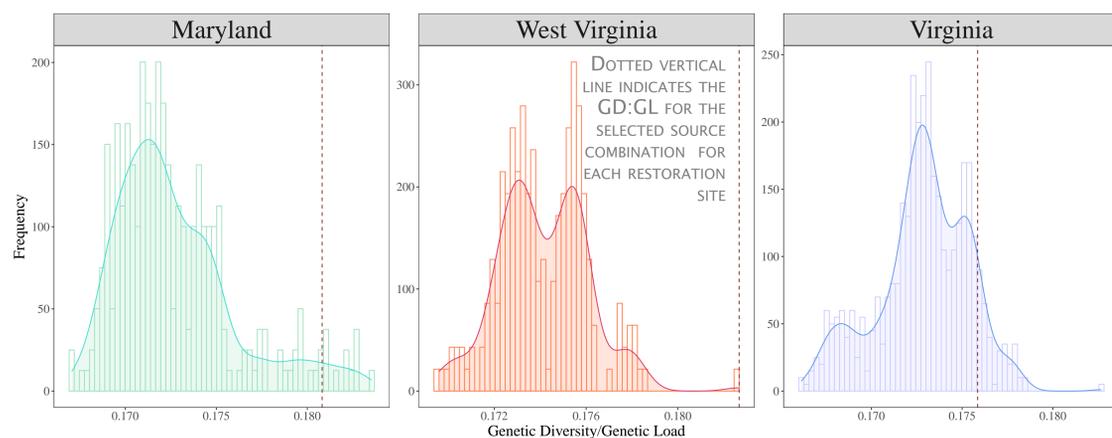
THE MONITORING PROTOCOL WAS INITIATED AT THE TIME OF PLANTING TO TRACK ESTABLISHMENT SUCCESS.

THE MONITORING DESIGN CONSISTED OF GEO-REFERENCED EXPERIMENTAL PLOTS STRATIFIED BY SEED SOURCE IN ORDER TO ASSESS THE SINGLE SOURCE VARIABILITY AT EACH SITE.

SURVIVORSHIP POST ONE-YEAR OF PLANTING WAS >50% ACROSS THREE RESTORATION SITES



GD:GL FOR THE SOURCE COMBINATIONS SELECTED FOR EACH RESTORATION SITE



COEFFICIENT OF EVOLVABILITY TO ANALYSE THE EFFECTS OF SOURCE SELECTION ON THE EVOLUTIONARY POTENTIAL OF TRAIT VARIANCE

$$CV_G = \sqrt{V_G} / \bar{x}$$

EVOLVABILITY

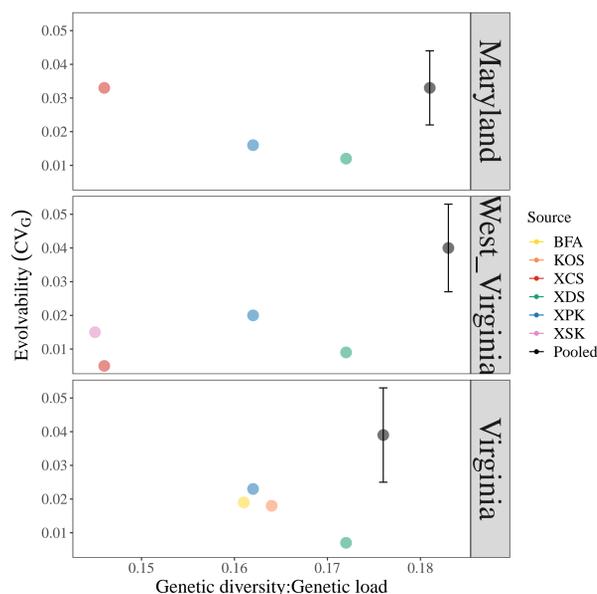
GENETIC COMPONENT OF TRAIT VARIANCE

TRAIT MEAN

EVOLVABILITY⁶ WAS MEASURED ON THE TRAIT VARIANCE OF THE SEEDLING HEIGHT POST ONE-YEAR OF PLANTING IN THE FIELD.

EVOLVABILITY HELPS ANALYZE THE EFFECT OF SINGLE VS POOLED SOURCES ON THE EVOLUTIONARY POTENTIAL OF TRAIT VARIANCE IN THE RESTORED POPULATIONS.

EVOLVABILITY FOR DIFFERENT SOURCES PLANTED AT EACH RESTORATION SITE AND THE BOOTSTRAPPED POOLED CV_G FOR SOURCE COMBINATIONS AT EACH SITE. THE X-AXIS SHOWS THE GD:GL ESTIMATES FOR THE SINGULAR AND POOLED SOURCES.



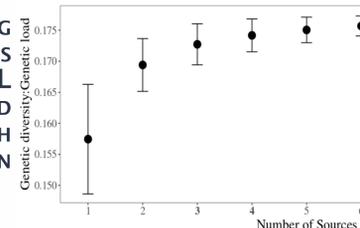
NO SUPER SOURCE TO THE RESCUE

POOLED SEED SOURCES EXHIBITED HIGHER EVOLVABILITY COMPARED TO SINGULAR SEED SOURCES ACROSS THE RESTORATION SITES

- THE LONGER TERM BENEFIT OF REGIONAL ADMIXTURE STRATEGY WILL LIKELY MANIFEST FROM THE OFFSPRING OF THESE RESTORATION PLANTINGS.
- THE MATING BETWEEN THE OFFSPRING HOLDS THE POTENTIAL TO RECOMBINE THEIR GENETIC VARIATION AND INCREASE THE ADAPTIVE POTENTIAL TO RESPOND TO CHANGING ENVIRONMENTS.

HOW MANY POPULATIONS ARE ENOUGH?

THE BENEFIT OF CHOOSING MULTIPLE SEED SOURCES TO MAXIMIZE GD:GL FLATTENS OUT AROUND 4-5 SOURCES, WITH DIMINISHING RETURNS ON HIGHER COMBINATIONS.



WHAT DOES THIS ALL MEAN FOR OUR PLANET?

THE CENTRAL APPALACHIAN SPRUCE RESTORATION INITIATIVE (CASRI) MEMBERS HAVE WORKED FOR YEARS TO RESTORE RED SPRUCE THROUGH EXPERIMENTAL PLANTING AND SILVICULTURAL TREATMENTS, THIS IS THE FIRST TIME SEED SOURCES WERE SELECTED BASED ON GENETICS.

THIS IS A STORY OF SUCCESSFUL PARTNERSHIP BETWEEN RESTORATION PRACTITIONERS AND BASIC RESEARCH SCIENTISTS TO ESTABLISH HEALTHY AND RESILIENT POPULATIONS TO COMBAT THE ADVERSE CLIMATE EFFECTS.



KNOW MORE ABOUT THIS PARTNERSHIP HERE

REFERENCES

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