

PONDEROSA PINE GENETICS: A WEST-WIDE STUDY OF ISOLATED POPULATIONS OF PONDEROSA PINE

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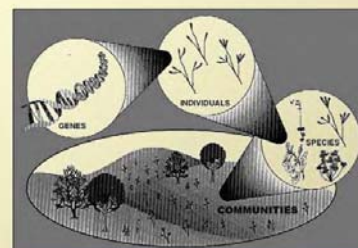
1

Importance?

- Ponderosa pine is one of the most widespread conifer species in the Western U.S.
- It is one of the most economically important conifer species
- It is one of the most ecologically important conifer species
- It is considered by some one of the species that may be affected by climate change and in need of adaptive strategies

Conservation Biology

- Emphasizes the maintenance of native gene pools as an important function in maintaining ecosystem and species integrity and adaptation in the face of change
- The greatest risk to widespread species such as ponderosa is not to the species' existence, but to the integrity of the native gene pools



- NSF-DEB-9815500 - Final Report: "... results underscore the growing need to focus more on genotypes than species in biogeographic modeling and ecological forecasting"

3

Ponderosa Pine Subspecies

Geographic and Environmental Conditions

1. North Plateau

Ponderosa Pine - *Pinus ponderosa* subsp. *Ponderosa*. Cool, relatively dry summers; cold, snowy, moist winters

2. Rocky Mountains

Ponderosa Pine - *Pinus ponderosa* subsp. *Scopulorum* -. Warm, relatively moist summers; very cold, fairly dry winters



4

4 / 5 NOTES:

Modern forestry research identifies four different taxa of Ponderosa Pine, with differing botanical characters and adapted to different climatic conditions. These have been termed "geographic races" in forestry literature, while some botanists historically treated them as distinct species. In modern botanical usage, they best match the rank of subspecies, but not all of the relevant botanical combinations have been formally published.

The distributions of the subspecies, and that of the closely related Arizona Pine (*Pinus arizonica*) are shown on the map. The numbers on the map correspond to the taxon numbers above and in the table. The base map of the species range is from Critchfield & Little, *Geographic Distribution of the Pines of the World*, USDA Forest Service Miscellaneous Publication 991 (1966).

Before the distinctions between the North Plateau race and the Pacific race were fully documented, most botanists assumed that Ponderosa Pines in both areas were the same

Ponderosa Pine Subspecies

Geographic and Environmental Conditions



- 3. Southwestern Ponderosa Pine - *Pinus brachyptera*** - Hot, relatively moist summers; mild winters
- 4. Pacific Ponderosa Pine - *Pinus benthamiana*** Hot, dry summers; mild wet winters

5

Initial Steps – 2005

- The first genetic testing of ponderosa pine was done in conjunction with the USFS National Genetics Laboratory (NFGEL) in 2005.
- The study was designed to answer several questions primarily focused on old ponderosa plantations on BLM lands in Colorado and USFS lands in Utah, their source and why some of these were declining and dying
- This led to the first national ponderosa pine genetic database



6

2005 – Collection and Study Sites



7

Round 2 – 2007

- Hypothesis: Disjunct / isolated ponderosa pine stands have more genetic diversity than widespread connected stands due to their isolation
- 6 native pine collection sites, 2 each in Wyoming, Nevada, and Utah



8

Findings – 2007

- The analysis did not support a previously held hypothesis that ponderosa pine genetics had a gradual ecocline movement from home refugia
- New genetic relationships were discovered:



9

- PIPO from Utah's Great Basin (Wah Wah Mountains) were found to be related to PIPO in Wenatchee, Washington [green line]

- The first documented transition zone of North Plateau PIPO with Southwest PIPO was found in the mountains just north of Las Vegas, Nevada (Sheep Range) [red line]
- A paternal relationship was found between PIPO in Nevada's Grant Range and Wyoming's West Big Horn Mountains [blue line]

Findings – 2007



10

Round 3 – 2008 / 2009

- Due to significance of findings, the decision was made to expand sampling to help determine genetic movement
- An Assistance Agreement was signed by the Wyoming BLM State Office and NFGEL in 2008 for this project
- 25 additional sites were selected for sampling

11

Round 3 – 2008 / 2009

Interagency collaborators include:

- Bureau of Land Management – collection, funding for analysis of 29 samples in FY08/09/10
- US Forest Service – collection, funding for analysis of FY07 samples + 6 in FY08/09
- US Fish and Wildlife Service – collection
- National Park Service – collection
- Nevada Division of Forestry – collection
- The Nature Conservancy – collection
- College of Southern Nevada – collection
- Department of Defense / US Army - collection

12

New Collections

2008/2009

- Wyoming, 2 sites
- Nebraska, 1 site
- Arizona, 3 sites
- Montana, 1 site
- Utah, 5 sites
- Colorado, 2 sites
- Nevada, 5 sites
- California, 1 site
- Oregon, 2 sites
- New Mexico, 2 sites
- Montana, 1 site

2010

- Utah, 2 sites
- Nevada, 4 sites
- Washington, 1 site
- California, 1 site
- Arizona, 1 site

2011

To be determined

13

Native Collection Sites through 2010



14

Current Status

- Due to reconstruction at NFGEL, the 2008/09/10 data will not be analyzed until sometime in mid 2010.
- The Botany Department at University of Wyoming is assisting to add additional micro-satellite markers to the analysis with the potential of expanding to 12+ microsatellite markers (human DNA is normally measured with 14!)

15

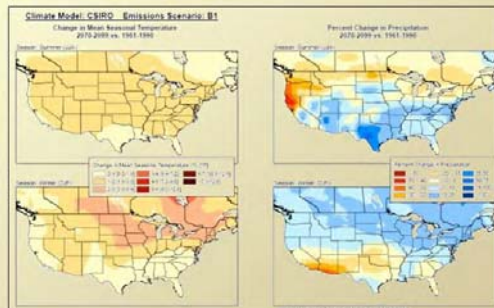
A New Project objective has been Added

- Track migration routes of ponderosa pine over the ages utilizing genetic markers
- This will help build knowledge base for future adaptive strategies in the context of climate change

16

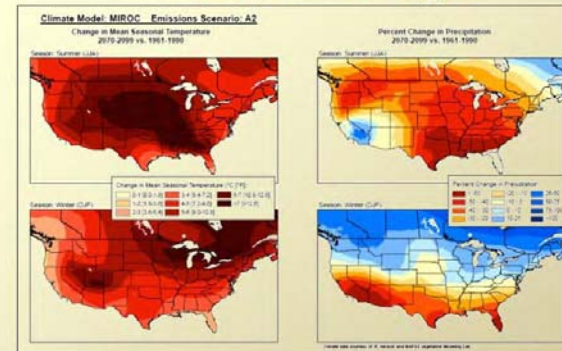
Climate Change

- Best case scenario: moderate temperature increases year round through most of western US
- Moderate seasonal precipitation changes through much of western US with some significant changes along west coast and southern Arizona



17

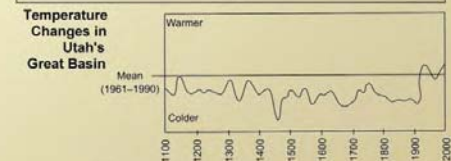
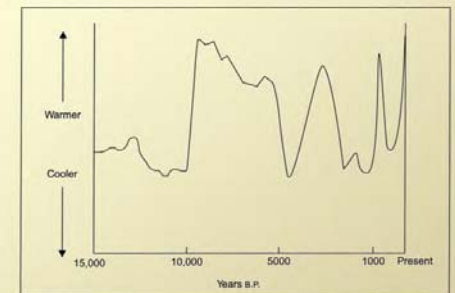
Climate Change



- Worst case scenario: Extreme temperature increases year round
- Significant seasonal changes in precipitation patterns

18

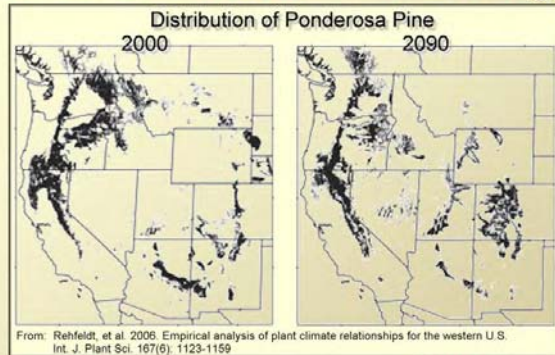
Climate Change, The Last 15,000 Years



from: Simms, Steven R. 2008. Ancient Peoples of the Great Basin and Colorado Plateau. Left Coast Press, Inc. Walnut Creek, CA. 383pp.

19

Ponderosa Distribution Changes



PIPO losses:

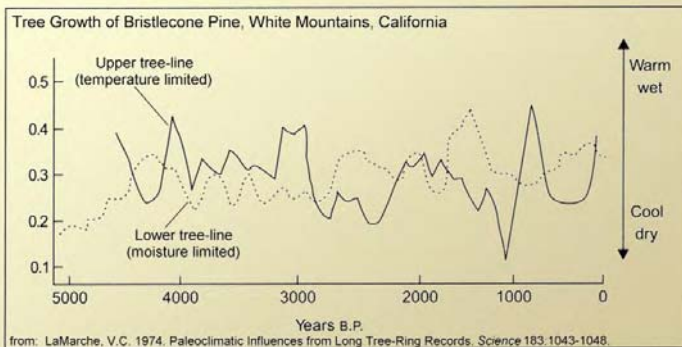
Montana, Idaho, E. Washington,
E. Oregon, Arizona, New Mexico,
N. California

PIPO gains:

Nevada, Utah,
Colorado,
E. California

20

Vegetation Development and Climate



21

Vegetation Development and Climate

- The vegetation that is on the landscape now developed during the "Little Ice Age" (about 1350 until 1920)
- Under all the climate change scenarios there is no return to the conditions of the "Little Ice Age"
- Ponderosa pine has documented movement and adaptation on the landscape for over 12,000 years, including many periods of hotter and drier weather which are the closest approximations that we have for what will happen under climate change scenarios. This Holocene adaptation may be key in future ponderosa pine climate change adaptation

22

22 NOTES:

650 BP (1350AD) abrupt change to persistently less arid conditions lasts until 1920 AD.

1050 to 650 BP – Medieval Climate Anomaly (Medieval Warm Period) – severe multi-decadal droughts – Wah Wah PIPO established at this time.

8,000-4,000 – Altithermal Period (mid-Holocene) period of warmer conditions.

10,000 BP – Insolation maximum – Early Holocene – most solar radiation, i.e. hot and dry minimal effective summer moisture. PIPO recorded in Yellowstone NP, PIPO found in packrat middens in Sheep Range S. NV

Importance of Tracking Genes

- Tracking genetic movement during the Holocene (last 12,000 years) under hotter and drier conditions can give us knowledge of which genotypes may expand/contract their range
- Important for maintenance of migration paths
- Important for determining *in situ* vs. *ex-situ* plantings
- Charlet (2007) hypothesizes that the Great Basin was not only a sink but also a source of conifer migration
- Several ponderosa stands sampled appear already to be undergoing localized extinction – West Big Horns, Wyoming and Grant Range, Nevada

23

23 NOTES:

Charlet 2007 - *Aliso* 24, pp. 31–61, 2007, Rancho Santa Ana Botanic Garden (David Charlet is professor of biology, Community College Southern Nevada, Henderson, Nevada)

Extinction comes when the environment changes sufficiently to approach or exceed the environmental tolerances of the species or population.

Invasion/extinction plays out primarily in the juvenile phase. Adults of many species have broader environmental tolerances. Extinction proceeds from the reduction or cessation of recruitment followed by the senescence of existing adults. This is generally a gradual process with populations disappearing from all but the most favorable sites with the ultimate elimination from the latter by stochastic processes (incl. climate variability or disturbance).

Silvicultural Considerations and Strategies

- Develop strategies of near-term vs. long-term adaptation
- Revise concepts of Desired Future Condition
- Maintain species composition and structural heterogeneity at stand and landscape levels
- Manage refugia for sensitive species
- Maintain genetic diversity
- Assisted migration
- Interspecies competition
- Evaluate potential elevational segregation of ponderosa pine varieties in Nevada

24

Immediate Management Uses of Study Information

- Identifying and prioritizing stands of ponderosa pine for treatment based on genetic diversity
- Use genetic assessment (localized genotypes) as one decision making criteria in prioritizing vegetation treatments to maintain the structure, function and diversity of ponderosa forests on the landscape
- Identify local native gene pools for seed collection. Use after disturbance to keep these local genotypes on the appropriate place on the landscape
- Collect and maintain seeds and genetic information from diverse genotypes for use in *ex situ* plantings or hybridization with other genotypes approaching the edge of environmental tolerances

25

Long Term Management Actions

- Determine future adaptive management strategies for ponderosa pine by:
- Developing action plans based on Holocene age genotype movement for migration routes
- Using information to determine the feasibility of *ex-situ* or *in-situ* plantings to keep ponderosa pine on the landscape
- Determining the need and location of migration paths (assisted or natural) for ponderosa genotype movement in response to climate change
- Using findings to adjust ponderosa pine seed zones
- Determining potential “common garden” experiment locations to assist in long term non-deterministic management decisions

26

Potential Scientific Findings

- Determine origins of PIPO var. ponderosa – common thought is it survived the Pleistocene in Pacific coast refugia
- Potentially answer questions about Washoe pine and its status as a species vs. a morphological variant of ponderosa pine
- Expand overall knowledge of general plant movement and adaptation in the Holocene to compare with predicted climate change
- Test Charlet’s hypothesis of Great Basin conifer movement for validity (adaptation and movement in response to previous climate changes)
- Identify genetically unique stands of ponderosa
- Establish protocols for study of other conifers

27

27 NOTES:

Var. scopulorum movement in the SW and up thru Wyoming is documented thru packrat middens for the past 12,000 years. Basically nothing is known about var. ponderosa – it is thought to have come from Pleistocene refugia along the Pacific coast.

Because of the finding of the relationship between Wenatchee (less heterozygous) and the UT (Wah Wah) genotype (more heterozygous) there is already some credence to this Charlet’s hypothesis – the greater the heterozygosity, generally the closer to the home refugia.

Future Potential Scientific Uses (beyond scope of current project)

- Increase available database for future studies – SNP genetic testing to identify adaptive genes within ponderosa pine
- Assist in developing process based models for ponderosa – only niche based available now
- Determine if hybridized ponderosa varieties have the capabilities to utilize both summer and winter predominate moisture regimes

SNP = “Single Nucleotide Polymorphisms”

28

28 NOTES:

SNP = “Single Nucleotide Polymorphisms”

A SNP (pronounced snip) is the difference in the DNA between individuals of a species. The SNP marker is actually just a change of a single base (or nucleotide) between the individuals. So at any one SNP, some individuals could have an ‘A’ base, others ‘T’, others ‘C’, etc. Because there are so many possible SNP markers, with a lot of lab work (and having matching information on morphological or physiological traits from the same trees), the SNPs could be tied to adaptive traits (so SNPs would be able to measure the plants ability to respond to the environment).

Field Sample Collection

Sites may be scouted during the growing season, but collection of samples is done during the dormant season



Grant Range, Nevada



Wah Wah Mountains, Utah

GPS coordinates are recorded
Tips of branches with good dormant buds area collected from each tree

29

Field Sample Collection



Book Cliffs, Utah

Trees are aged, diameters and heights measured

Some old trees cannot be sampled because branches cannot be reached to collect buds



Paradise Mountains, Utah

30

Field Sample Collection

Collection focuses primarily on the oldest trees on the site, as these trees will have the longest genetic legacy. Among other items associated vegetation and whether a site has regeneration are noted.



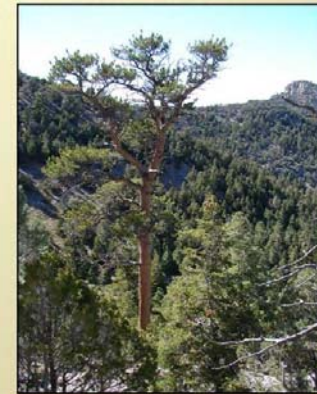
This sample dates to the year 1075 at the stump - the tree is still living
[The sample was collected by Stanley Kitchen as part of a fire history study]

31

Field Sample Collection



The oldest trees found to date are in Utah's Wah Wah Mountains



Although not particularly large, these two are approaching 1,000 years in age

32

Finis!



Spring Mountains, Nevada

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