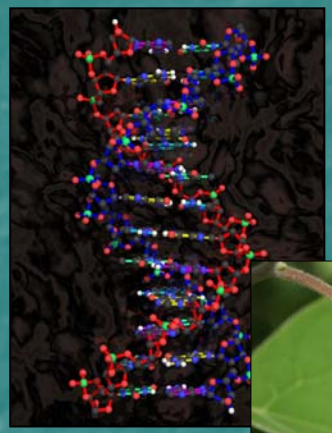
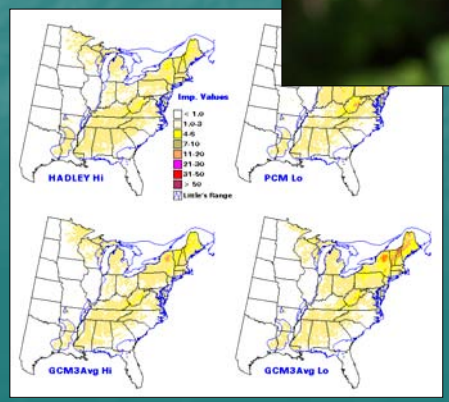
Forest Tree Genotypic Responses to Climate Change





Kevin M. Potter

Climate Change and Forest Health Focus Group

FHM Annual Workgroup Meeting
February 13, 2008

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FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

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Overview

1) Why should we care about the genetic context of climate change?
2) How might forest tree species respond genetically to climate change?
3) What species are at greatest risk?
4) How might FHM monitor genetic variation in the midst of climate change?

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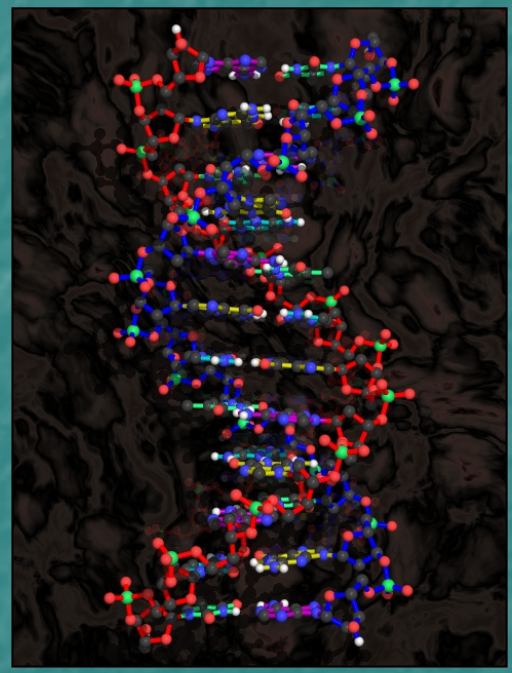
Climate Change and Genetics

1) Genetic variation = evolutionary potential to adapt to changing environmental conditions

2) Conditions associated with climate change may decrease genetic variation in some species



DNA (Northern Illinois University)

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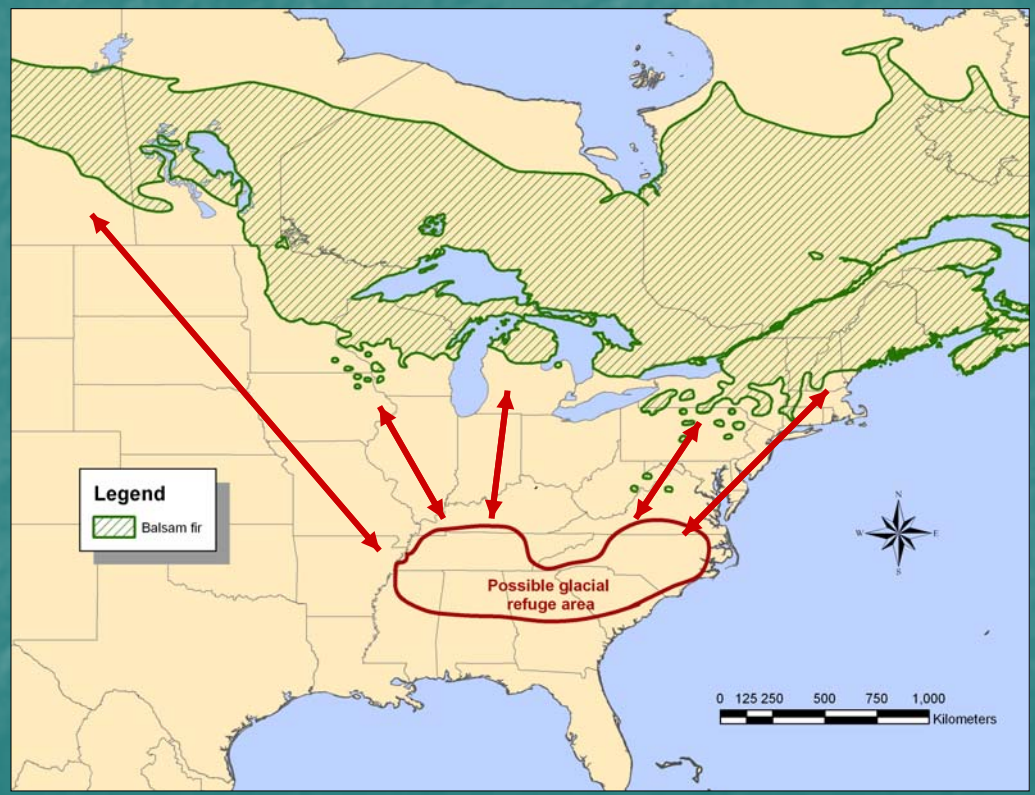
This Has Happened Before...

- One known North American tree species extinction during Quaternary
- Will about now?
  - Current changes are at least one order of magnitude faster
  - Habitat is now fragmented in many places



Potential Genetic Responses

1) Toleration/adaptation
   - Existing adaptability to climate conditions
   - Regeneration of future stands that are better adapted

2) Migration
   - "Wholesale redistribution of genotypes across the landscape" (Rehfeldt et al. 1999)
   - May have negative genetic consequences

3) Population extirpation/species extinction
   - Some species/populations may be unable to adapt or migrate
   - For others, genetic degradation may increase susceptibility to other stressors (pests, pathogens, etc.)

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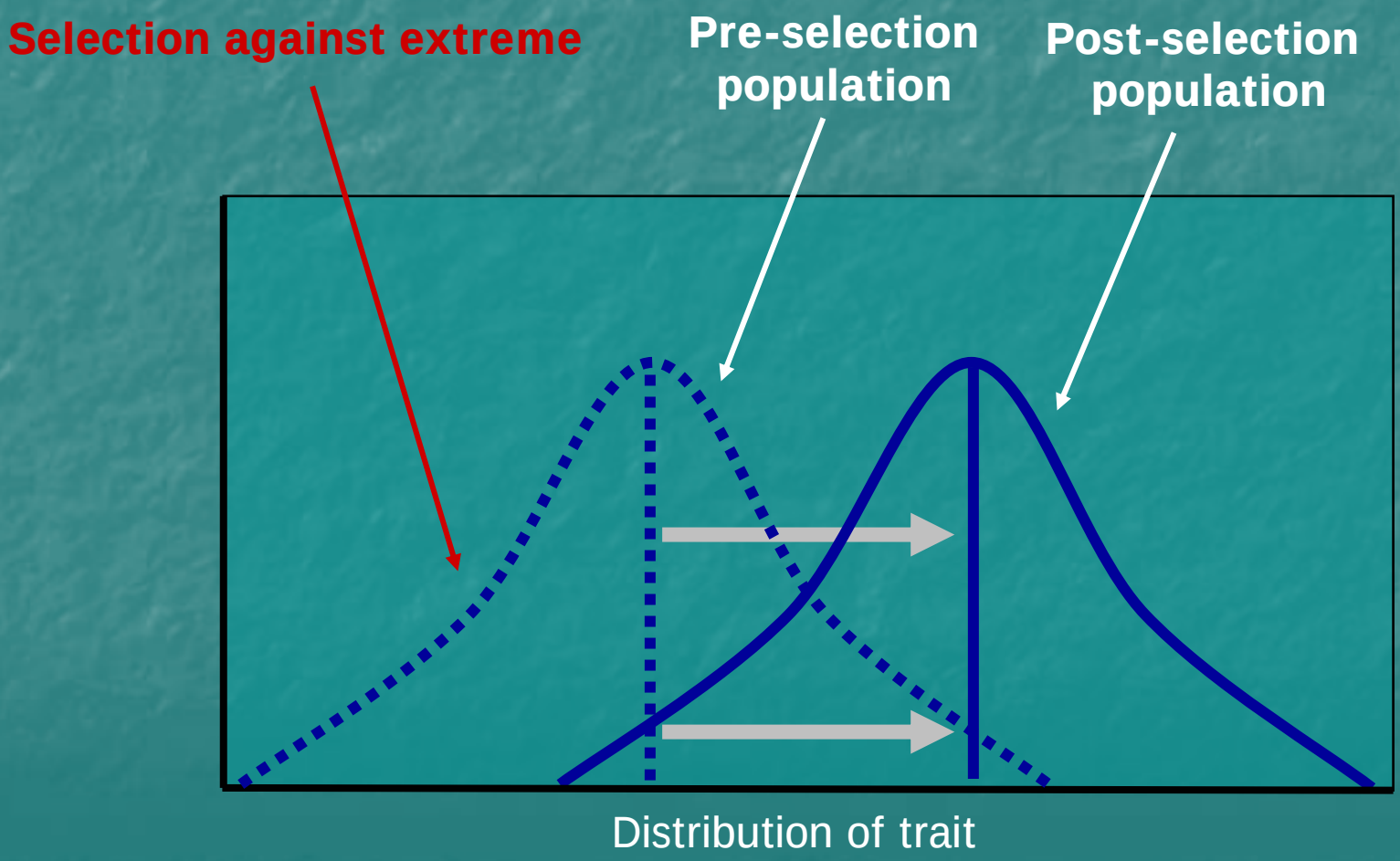
Adaptation



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Adaptation

- Will critical traits evolve fast enough?
  - Are trees rapidly evolving species (Petit et al. 2004)?
  - Trees long-lived: adaptation will take 1-13 generations, or 100-1,000 years (Rehfeldt *et al.* 1999)
- Strong selection could reduce genetic variation
  - May increase vulnerability to other stressors
- Effects of selection are difficult to predict
  - Complex combinations of selective factors
  - Climate may act on traits that are genetically linked

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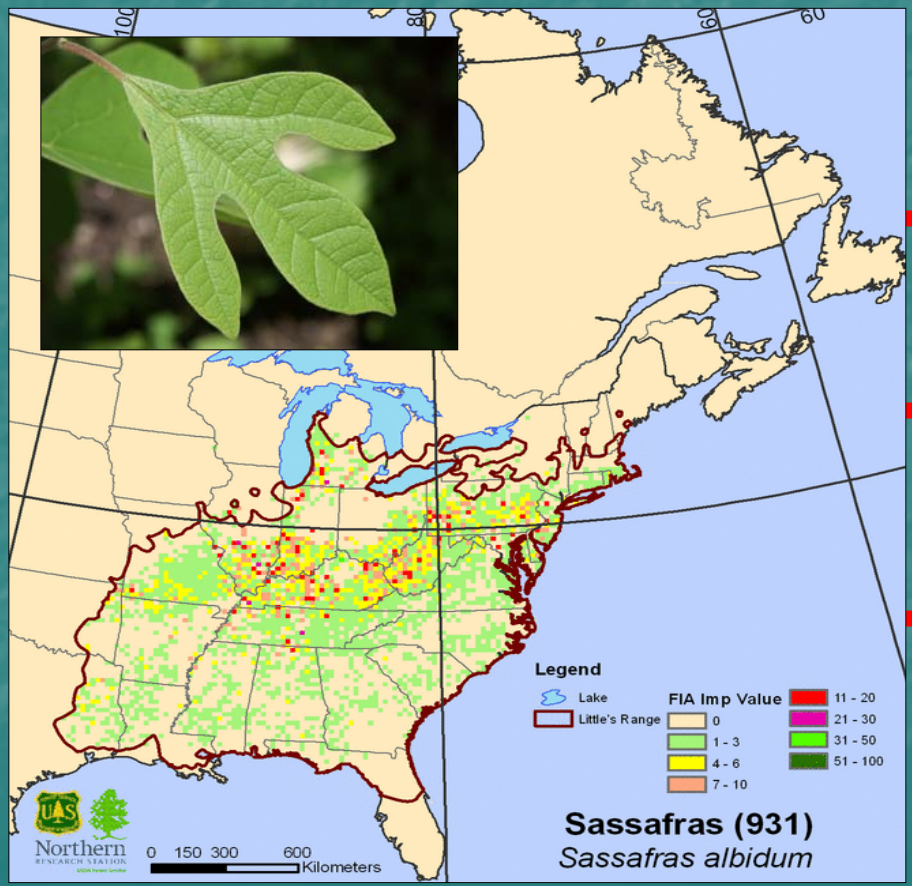
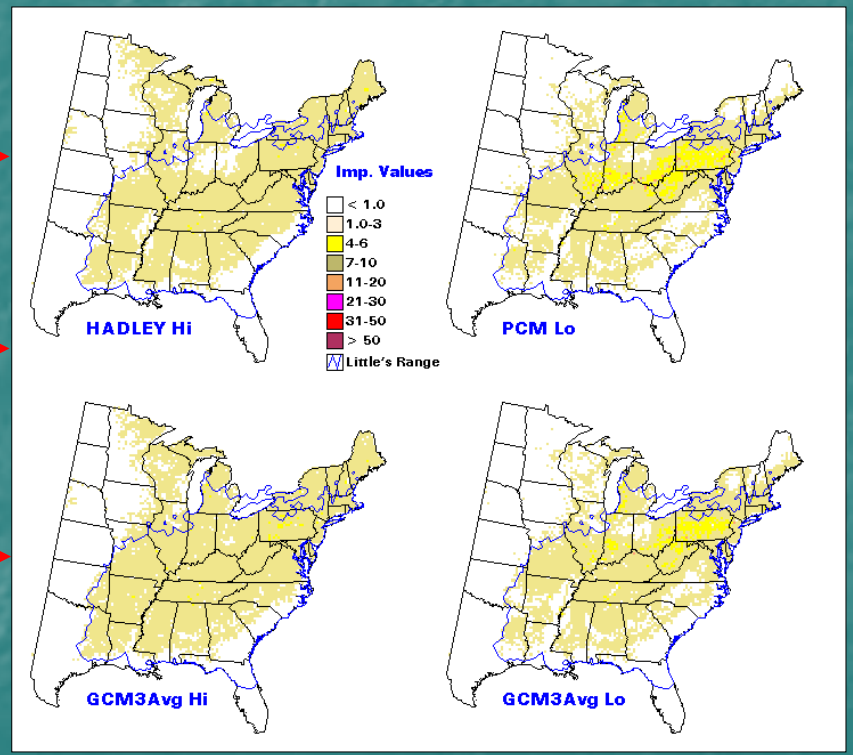
Migration



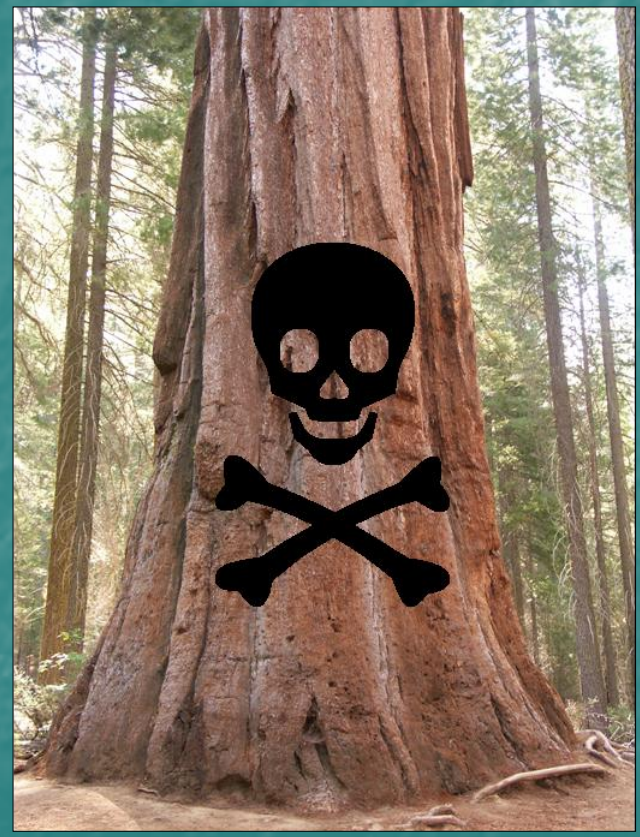


Migration

- Founder effects: newly established colonies are often inbred and lack genetic variation
  - May form a genetic barrier to other individuals that follow
- Trailing edge populations may be extirpated
- Migration could be problematic for some species
  - Will climate conditions change too fast for species to reach suitable habitat?
  - Will fragmentation impede effective migration?

Extirpation/Extinction

- Some species and populations may not be able to migrate or adapt
  - Species restricted to mountaintops or narrow soil conditions, etc.
- Population-size reduction in many species and populations
  - Inbreeding, genetic drift, decreased variation
  - Degraded species may be at greater risk



Giant redwood (*Sequoiadendron giganteum*), Yosemite National Park, Calif.

Genetic Degradation Risk Factors

Intrinsic factors	Extrinsic factors
Limited range	Extensive fragmentation
Small/disjunct populations	Pest/pathogen infestation
High elevation habitat	Large shift of range with CC
Long lifespan	Over-exploitation
Long time to reproduction	
Low fecundity	
Habitat specialization	
Limited seed/pollen dispersal	
Low species-wide variation	

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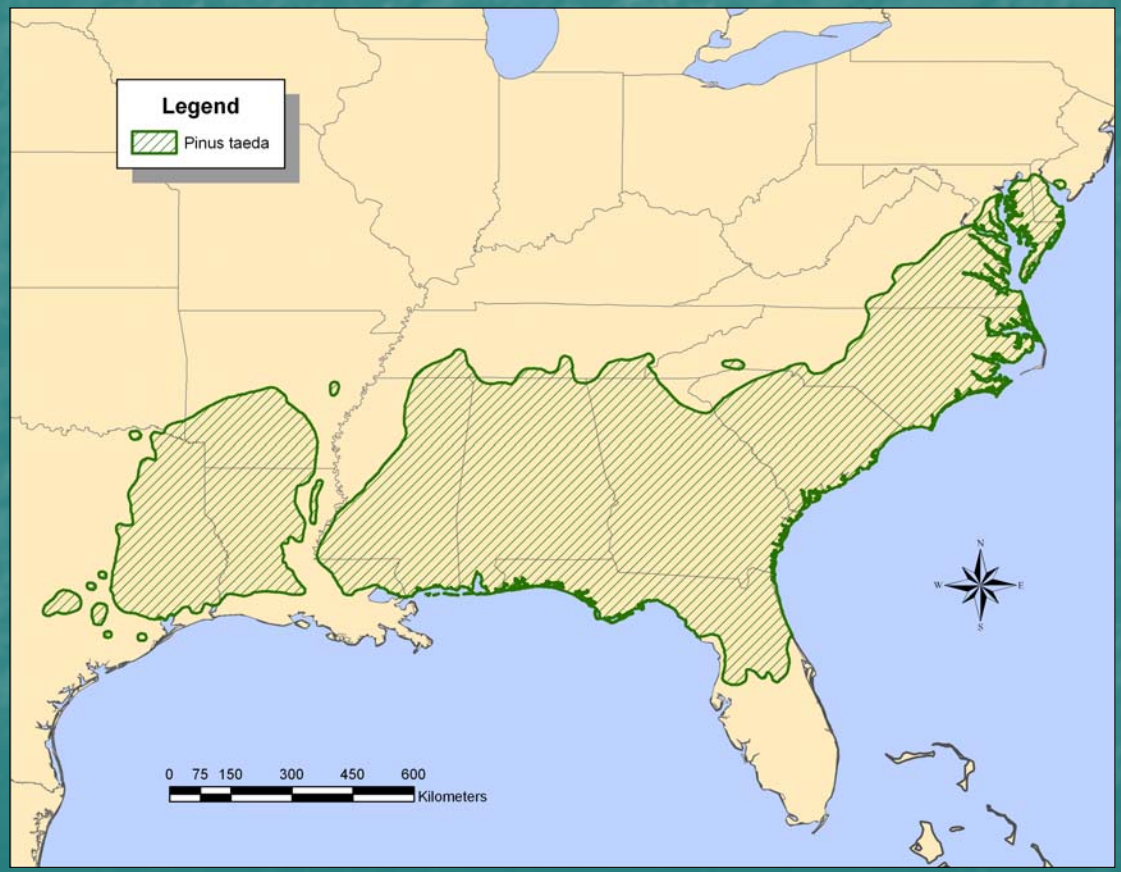
Not At Risk: Loblolly Pine



Loblolly pine (*Pinus taeda*), Raleigh, N.C.

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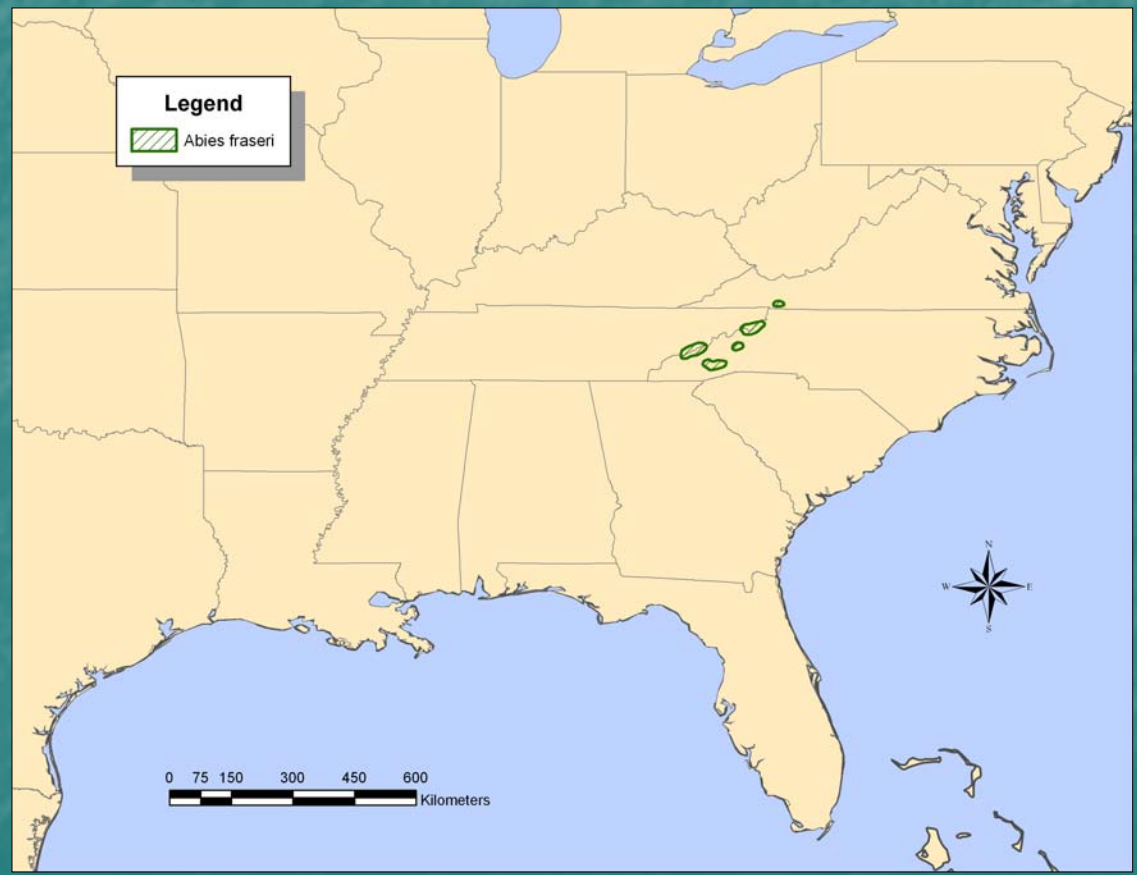
At Risk: Fraser Fir

Fraser fir (*Abies fraseri*), Mount Rogers, Va.



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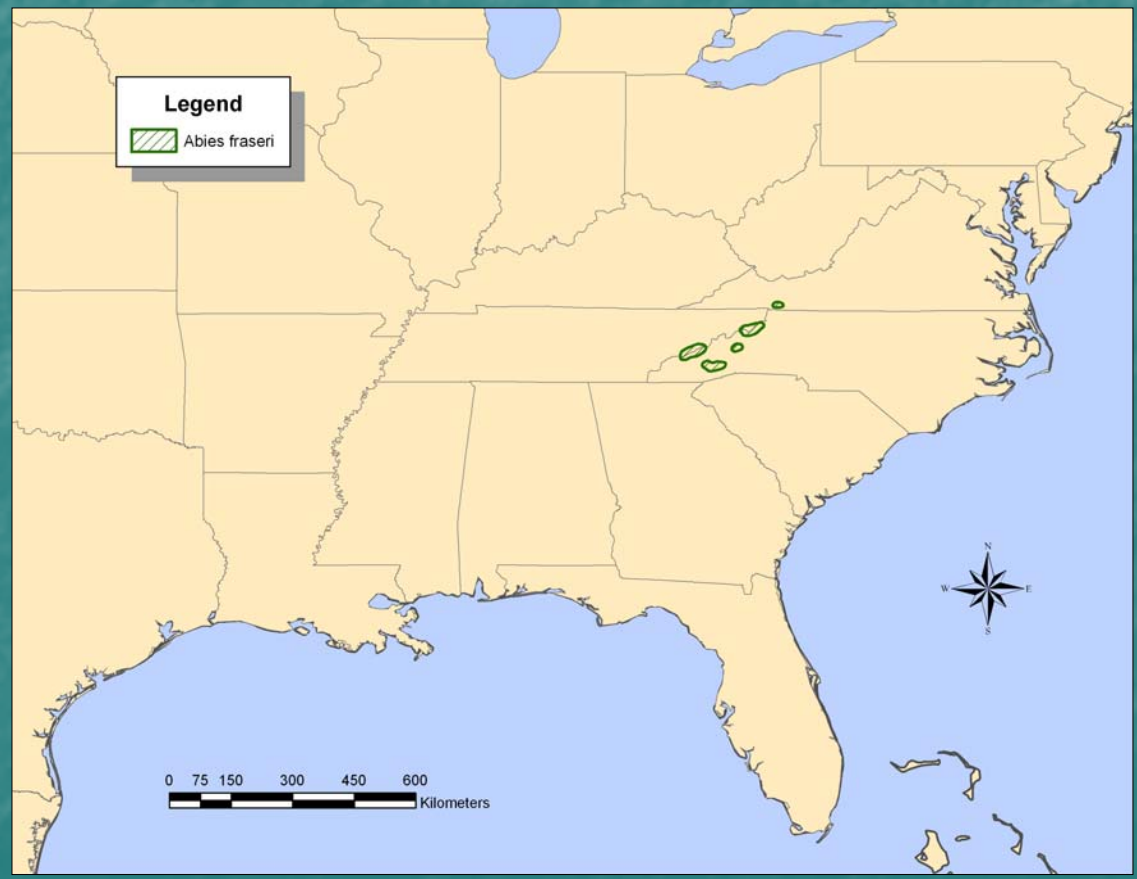
At Risk: Fraser Fir

Balsam woolly adelgid,
Cataloochee Balsam, N.C.



FHM Recommendations

- Reconsider Montreal Process Criteria and Indicators approach to genetic diversity
- Criterion 1: Conservation of biological diversity
  - Two genetic diversity indicators
    1) Number of forest-dependent species that occupy a small portion of their former range
    2) Population levels of representative species from diverse habitats monitored across their range

FHM Recommendations

- Develop indicators of genetic diversity, such as those proposed by Brown *et al.* (2000)

1) Population size, numbers and physical isolation
2) Environmental amplitude and distribution of species
3) Reproductive success
4) Genetic diversity at marker loci within individuals and populations
5) Inter-population genetic structure
6) Quantitative genetic variation

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FHM Recommendations

- Select indicator species, based on:
  - Geographic representation (ecoregion, latitude, etc.)
  - Size of species range
  - Continuous vs. disjunct population structure
  - Life history (lifespan, age to reproduction, etc.)
  - Dispersal ability
  - Habitat specialization (high elevation, wetland, etc.)
  - Habitat fragmentation
  - Existing population genetic knowledge

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FHM Recommendations

- Monitor species using demographic indicators
  - Establish baseline conditions
  - Consider increasing FIA sampling intensity when necessary (esp. for species with small ranges)
  - EM and ISM projects?
- For species that appear susceptible to genetic degradation, apply genetic indicators
- Feed results of monitoring efforts into models such as Iverson and Prassad's