How much genetic variation is “enough”? 

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Factors influencing genetic diversity

• Mutation
• Historical processes
• Genetic drift
• Migration
• Natural (and artificial) selection
Direct effects of genetic diversity

Studies that investigate the ecological consequences of genetic diversity are complicated by the variety of possible processes. These include genetic drift, mutation, migration, and selection (via abiotic factors). These processes can affect the mean and variance of phenotypic traits within focal species. The genetic diversity, represented as variance, can influence population fitness/performance, diversity & abundance of species on the same trophic level, and diversity & abundance of species on other trophic levels. These ecological properties then influence whole community & ecosystem properties.
Amount and distribution of genetic variation

Genetic diversity

- Annual
- Short-lived perennial
- Long-lived perennial

Genetic differentiation among populations

- Annual
- Short-lived perennial
- Long-lived perennial
Population size matter

- Population size is positively correlated with
  - genetic variation
  - reproductive fitness
- Reproductive fitness is in turn positively correlated with genetic variation

These correlations are actually stronger in rare plants - where genetic diversity is scarce.

No difference between different life history strategies.

Population size matter

Local adaptation is common in trees

In Figure 4, we summarize the $F_{ST}$ and $Q_{ST}$ information for many forest trees [table 1 of Howe et al. (2003) and additional studies; for the full list of references for Figure 4, see the Supplemental Material link in the online version of this article or at http://www.annualreviews.org/]. The traits are related to morphology, growth, timing of growth, and cold tolerance. The $F_{ST}$ estimates (horizontal bars) are low for all species. Most of the $Q_{ST}$ estimates are higher, which suggests that the quantitative traits are subject to diversifying selection. The comparison of $Q_{ST}$ estimates between traits, species, and studies is more complicated. The estimates of $Q_{ST}$ are highly dependent on the geographical range of sampling and the number of populations within the range. For instance, the estimates of $Q_{ST}$ for Scots pine bud set differ between studies, depending on the range and number of populations. The very low $Q_{ST}$ estimates for Sitka spruce are based on a large number of populations from a...
Local adaptation is common in trees

- Most tree species show extensive local adaptation
- Strongest evidence for local adaptation in key life history traits, such as phenology
- Local adaptation occurs despite little genetic differentiation among populations
Local adaptation will result in a lag under changing environmental conditions

- Climate change is predicted to occur on the time scale of a single generation of most forest trees
- Local adaptation will induce an “adaptational lag” in the face of a changing climate

**Figure 2** Genetic clines along gradient in mean annual temperature for mean Julian date of bud set ($r^2 = 0.94$) and for total height ($r^2 = 0.72$) for 17 populations of *Picea sitchensis* from across the species range (data from Mimura and Aitken 2007a). The horizontal arrow illustrates the range of magnitude of warming predicted from global circulation models from 1961 to 1990 climate normals to the 2080s for the central population at Prince Rupert, BC population (indicated with triangle; current mean annual temperature 7.1°C, predicted for 2080s CGCM A2X 10.8°C; CGCM B2X 9.8°C; Hadley GCM A2X 10.5°C, estimated using Climate BC (Wang et al. 2006a)).
Historical processes, genetic drift and gene flow

- Historical processes are important for explaining current day patterns of genetic diversity

- Fluctuations in population size occurring over as long as the last 0.5-1 MYA are important in explaining current day levels genetic diversity

Historical processes, genetic drift and gene flow

• Current day population sizes for most forest trees are very large, suggesting little influence of genetic drift

• Historical events such as retreat into glacial refugia and post-glacial reclamation are important for explaining current day genetic diversity

When and where does genetic diversity matter?

- In species that are predominantly outcrossing
- For species that exhibit measurable genetic diversity to begin with
- In highly variable environments or in environments subject to rapid anthropogenic change
- In communities or ecosystems that are dominated by one or a few primary habitat-providing species
Possible negative effects of low genetic diversity

- Low genetic diversity may limit fitness (or productivity) due to more intense competitive interactions
- Unpredictable genotype x environment interactions
  - even genetically uniform populations may yield variable end products
  - in forest trees, long rotation times makes predicting future environmental changes hard
- Pests and pathogens may spread more rapidly
- Possible negative consequences for associated communities
Direct and indirect effects of genetic diversity

Studies that investigate the ecological consequences of genetic diversity are complicated by the variety of possible processes underlying potential direct and indirect effects of genetic diversity per se; effects of natural selection, which depend on genetic diversity; and causal effects not directly related to genetic diversity per se.
Summary

- Forest tree populations are characterised by:
  - high levels of genetic diversity (>85-90%) within local populations
  - low genetic differentiation among populations (<10%)
  - high population differentiation in adaptive traits (phenology, frost tolerance etc.)
Summary, contd.

- Genetic variation is positively correlated with population size
- Amount and distribution of genetic variation in adaptive traits is poorly predicted from neutral genetic markers
- Genetic variation on “foundation” or “keystone” species can have cascading effects on associated communities