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Review and synthesis

Evolution-based approach needed for the conservation and silviculture of peripheral forest tree populations

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ABSTRACT

The fate of peripheral forest tree populations is of particular interest in the context of climate change. These populations may concurrently be those where the most significant evolutionary changes will occur; those most facing increasing extinction risk; the source of migrants for the colonization of new areas at leading edges; or the source of genetic novelty for reinforcing standing genetic variation in various parts of the range. Deciding which strategy to implement for conserving and sustainably using the genetic resources of peripheral forest tree populations is a challenge.

Here, we review the genetic and ecological processes acting on different types of peripheral populations and indicate why these processes may be of general interest for adapting forests and forest management to climate change. We particularly focus on peripheral populations at the rear edge of species distributions where environmental challenges are or will become most acute. We argue that peripheral forest tree populations are "natural laboratories" for resolving priority research questions such as how the complex interaction between demographic processes and natural selection shape local adaptation; and whether genetic adaptation will be sufficient to allow the long-term persistence of species within their current distribution.

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Peripheral populations are key assets for adaptive forestry which need specific measures for their preservation. The traditionally opposing views which may exist between conservation planning and sustainable forestry need to be reconciled and harmonized for managing peripheral populations. Based on existing knowledge, we suggest approaches and principles which may be used for the management and conservation of these distinctive and valuable populations, to maintain active genetic and ecological processes that have sustained them over time.

Contents

1. Introduction

Geographically peripheral populations have regularly attracted the attention of ecologists and geneticists who have sought to understand processes that limit geographical ranges (Gaston, 2009; Kawecki, 2008; Lenormand, 2002). Because they are found at the edge of distribution areas and may represent ecologically marginal habitats, peripheral populations are "natural laboratories" for understanding how demography and genetic processes such as natural selection shape local adaptation and either prevent or facilitate colonization of new habitats. Whether peripheral populations can evolve depends on complex interactions between gene flow, selection, genetic drift, immigration and intrinsic population growth rate. The relative contribution of each process, depends on local and historic conditions as well as on life-history traits (Abeli et al., 2014; Alberto et al., 2013; Alleaume-Benharira et al., 2006; Benavides et al., 2013; Eckert et al., 2008; Lira-Noriega and Manthey, 2014; Peterman et al., 2013; Ursenbacher et al., 2015).

Whereas ecologists and geneticists tend to agree with Lesica and Allendorf (1995) that peripheral populations are valuable for conservation, conservationists and conservation planners often do not put a high value on peripheral populations unless they belong to a species that is itself threatened (e.g. Leppig and White, 2006; Steen and Barrett, 2015). Because of their often slower growth, poorer wood quality and lower economic value, peripheral forest tree populations are usually not recognized and managed as valuable forestry assets either (Lindner et al., 2010). This is unfortunate because peripheral populations often contain unique genetic resources, which may ultimately prevent species extinction (Channell and Lomolino, 2000; Holliday et al., 2012; Kawecki, 2008). This is frequently true at the "rear edge" (i.e. the low-latitude limit) of species geographic distributions where populations have often persisted over long periods of geological time and experienced a complex evolutionary history (for Europe, see Hampe and Petit, 2005).

The value of peripheral populations is starting to be recognized as global climate change is now being placed at the forefront of many habitat management plans and included in emerging national and international forest adaptation strategies. For example, genetic resources found at low latitude in Europe and around the Mediterranean are currently receiving renewed interest as planting material (forest reproductive material, FRM) for higher latitudes in Europe (Konnert et al., 2015).

The fate of peripheral populations is indeed of particular interest in the context of climate change (Mátyás et al., 2009; Valladarès et al., 2014; Allen et al., 2015). These populations may (i) be where the most significant evolutionary changes will occur within the distribution range, (ii) face increasing extinction risk, or (iii) be the source of migrants for the colonization of new areas at leading edges or (iv) of genetic novelty for reinforcing standing genetic variation throughout the distribution range (Alleaume-Benharira et al., 2006). Deciding which strategy to implement for conserving and sustainably using the genetic resources of peripheral populations is a challenge with substantial future consequences. Additionally, conservation, on the one hand, and, on the other, sustainable use of forest tree species and of their genetic resources are often driven by different societal goals (Fady et al., 2016). Both approaches need to be reconciled and harmonized for managing peripheral populations.

Here, we first review the genetic and ecological processes acting on different types of peripheral populations and discuss why these processes may be needed for adapting forests and for forest management under climate change. We particularly focus on peripheral populations at the rear edge of species distributions where environmental changes are or will become most acute. We then discuss and suggest silvicultural and conservation approaches and principles, which may be used for the management of these valuable populations, in order to maintain active the genetic and ecological processes that have sustained them over time. We conclude by highlighting that peripheral