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Review of science-based assessments of species vulnerability: Contributions to decision-making for assisted migration

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ABSTRACT

Assessing climate change impacts on forest species can significantly assist forest management planning. Recently, many tools have been developed for assessing species-specific vulnerability to climate change. These tools are question-based assessments that consider multiple criteria for individual species; the criteria are related to exposure and sensitivity to climate change. The following tools are discussed in relation to their use in Canada: (1) the NatureServe Climate Change Vulnerability Index; (2) the System for Assessing Vulnerability of Species to Climate Change (SAVS); (3) the Forest Tree Genetic Risk Assessment; (4) the Index for Predicting Tree Species Vulnerability; (5) ecological standards developed for the assisted migration of *Torreya taxifolia*; and (6) the Seeds of Success Program. These tools can all be applied to different forest species and they vary in such areas as their species-specific evaluation criteria, means for addressing uncertainty, and the integration of climate change models.

Key words: climate change, forest species, vulnerability assessments

RÉSUMÉ

Évaluer les effets des changements climatiques sur les essences forestières peut contribuer significativement à la planification de l'aménagement forestier. Récemment, plusieurs outils ont été élaborés pour évaluer la vulnérabilité des espèces aux changements climatiques. Ces outils d'évaluation reposent sur des questions et considèrent de nombreux critères associés à l'exposition et la sensibilité aux changements climatiques pour chacune des espèces. Les auteurs présentent les outils suivants : (1) l'indice de vulnérabilité aux changements climatiques NatureServe; (2) le système d'évaluation de la vulnérabilité des espèces aux changements climatiques (SAVS); (3) l'évaluation du risque génétique des arbres forestiers; (4) l'indice de prévision de la vulnérabilité des essences d'arbres; (5) les normes écologiques élaborées pour assister la migration de l'espèce *Torreya taxifolia* et (6) le programme Seeds of Success. Ces outils sont applicables à différentes espèces forestières. Ils varient sur le plan des critères d'évaluation spécifiques aux espèces, du traitement de l'incertitude et de l'intégration des modèles de changements climatiques. L'utilisation de ces outils pour évaluer la vulnérabilité des espèces forestières au Canada est explorée.

Mots clés : changements climatiques, espèces forestières, évaluation de la vulnérabilité

Introduction

Canadian forests are diverse, containing approximately 126 native tree species (Farrar 1995). These forests, which cover approximately half of Canada, face a variety of threats, including changes in land use, invasive pests, and climate change. Climate change is a significant risk to Canadian forests and adds an element of uncertainty to forest management (Johnston and Williamson 2007). Climate model projections predict that by 2011 areas such as eastern Canada will warm by 3°C to 5°C with increased precipitation (Dukes *et al.* 2009), whereas by 2050 in western Canada (primarily the Prairie Provinces) the mean temperature will increase by 2°C to 4°C with reduced precipitation (Schneider *et al.* 2009). Furthermore, with the projected climate changes over the next 100 years, it is likely that many tree species and populations will be unable to adapt to the projected new conditions (Aitken *et al.* 2008, O'Neill *et al.* 2008, McKenney *et al.* 2009). The potential impacts of climate change on Canadian forests are diverse, including an increase in the length and duration of droughts in certain regions (Dale *et al.* 2001), an increase in disturbances (e.g., higher frequency of forest fires with greater intensity [Flannigan and van Wagner 1991, Stocks *et al.* 1998]), and an increase in the severity and number of native and non-native pests and pathogens (e.g., mountain pine beetle [*Dendroctonus ponderosae*]; Kurtz *et al.* 2008). These disturbances have the potential to interact, increasing the complexity associated with predicting the impacts of climate change on forests. Given the scope and complexity of the potential changes, it is challenging to assess the impacts and the vulnerability that may be present at varying biological scales.

Vulnerability has numerous meanings and can be applied to the socioeconomic, financial, or biological status of an organism or an ecological system. In a biological context, vulnerability can be assessed over various scales, from species to the ecosystem and landscape levels. When used in the context of natural systems, stresses, exposure, and capac-

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