

# Species interactions, neighbourhood dynamics and complexity science: management options for North American *Abies* forests

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The genus *Abies*, or true firs, are commonly the more shade tolerant members of mixed-species forests in temperate, montane and boreal regions of North America (NA). At higher elevations and at tree-lines, *Abies* can be the dominant tree species in mixed forests and can even form single-species forests. In western NA, the genus *Abies* is represented by amabilis fir (*Abies amabilis*) and grand fir (*Abies grandis*) in temperate coastal British Columbia (BC), Washington and Oregon, while in inland mixed-conifer forests of the western United States, noble fir (*Abies procera*), white fir (*Abies concolor*) and California red fir (*Abies magnifica*) are found at medium and higher elevations. Subalpine fir (*Abies lasiocarpa*) is common in subalpine and boreal forests of the west. Balsam fir (*Abies balsamea*) is abundant in mixed conifer-broadleaved forests across central and eastern Canada and the eastern US. Lastly, Fraser fir (*Abies fraseri*) is a small tree with a limited distribution in the southern Appalachian mountains of the southeast US.

Foresters charged with managing forests with *Abies* species are being called upon to implement a wider variety of management systems to meet broader objectives such as sustaining the function and dynamics of ecosystems, maintaining ecosystem diversity and resilience or protecting sensitive species, while providing for a variety of ecosystem services of value to humanity. This will require moving toward a more flexible multi-scale perspective that considers tree- stand- and landscape-scale processes and their interactions. Science now views forest ecosystems as non-equilibrium social-ecological systems with interactions and feedbacks among climate, management and disturbance agents. *Abies* species and the multi-species forests they often inhabit do not lend themselves to the agricultural model of even-aged plantation forestry. Because of their high tolerance of shade, and other demographic attributes, *Abies* are well suited to mixed-species structurally complex stand management. Fir forests are heterogeneous, highly dynamic with biotic and abiotic elements that interact across different levels of organization with various feedback loops. Such forests are subject to ongoing change in conditions as the climate warms, and state shifts can be anticipated in response to threshold changes in external or internal drivers. In northern BC, contrary to expectations, we have found that subalpine fir in mid-rotation plantations has experienced less damage from recent warming trends than the more commonly managed lodgepole pine.

It is imperative that foresters constantly improve our approach to the science and practice of forest management. Dynamic change will be the rule rather than the exception. Forest managers must consider and evaluate the short- and long-term viability of specific practices in *Abies* forests within a framework that minimizes risk, reduces the chance of undesirable future outcomes and captures potential opportunities by working with interactions among species. Protection and production of more diverse forest values demands consideration of the fine-scale variability found within mixed-species *Abies* forests and an understanding of the spatial and temporal response of *Abies* species to manipulation. *Abies* management must focus on maintaining critical processes in mixed forests and on how tree populations and ecosystem processes interact to affect stand dynamics. I will suggest new approaches for silviculture that will allow foresters to better incorporate complexity into their management decisions for *Abies* forests.