Introduction

Modern industrial societies are built on models of efficiency and neatness. Waste and messiness are seen as bad. And so it is with the industrial model of forestry, which appears to be widely accepted by many societies as an appropriate way to manage natural resources. Wildfires (especially those that are stand replacing), hurricanes, and other major disturbances are seen not as natural events and processes that generate biodiversity, but as catastrophes that destroy forests. They create messes that need to be cleaned up. If by cleaning up dead and dying trees after a disturbance, some money can be made from the timber, so much the better. This is the fundamental justification for postdisturbance ("salvage") logging. Indeed, the word *salvage* implies saving something, in this case saving money that otherwise would be lost if burned wood is left to decay. Many people who oppose large-scale logging of natural forests voice no objection to salvage logging of these same forests after a fire. Somehow, these "damaged" forests are no longer natural, or at least no longer as pretty in the eyes of many people. This seems to be the general perception around much of the world, as the internationality of the papers in this special section makes clear.

Natural resources agencies take advantage of the public's lack of esthetic appreciation for disturbed vegetation and its limited understanding of the ecological role of natural disturbance. As conservation scientists, we know that natural disturbances at various spatial and temporal scales and intensities are fundamental to the generation and maintenance of biodiversity in ecosystems across the world (Connell 1978; Pickett & White 1985; Platt & Connell 2003). Beyond that, and less appreciated by the public and even many environmentalists, naturally disturbed, unsalvaged, early successional forests are often the most biologically diverse of all forest conditions and are both more rare and more imperiled than old-growth forest in many regions (Noss et al. 2006).

In the first paper of the special section, we review the literature on impacts of postdisturbance logging worldwide. We point out that natural disturbances enhance ecological processes and biodiversity and can re-create some of the structural complexity and landscape heterogeneity of forests that were lost through past human management. Three general impacts of salvage logging are the alteration of stand structural complexity, changes in ecosystem processes, and changes in the composition and abundance of species. Importantly, the effects of salvage logging are generally different from the effects of logging in forests not affected by a major disturbance. In many cases, forest ecosystems are more strongly affected by postdisturbance logging than by the initial disturbance, yet the cumulative effects of combined natural and human disturbances have been poorly studied. Ecologically informed policies for postdisturbance management of forests need to be in place before major disturbances inevitably take place in order to avoid the ad hoc decision making that often leads to poorly planned and ecologically damaging salvage operations.

Foster and Orwig contrast the ecological effects of windstorms and invasive pests and pathogens in New England (U.S.A.) with the impacts of preemptive and salvage logging in that region. Their case study includes the largest salvage-logging operation in U.S. history—after the 1938 hurricane—and reviews a manipulative experiment that simulated the local effects of that hurricane. They also evaluate the controversial "protection forest" approach, in which silviculture is applied prior to major disturbance in an effort to reduce the susceptibility of forests to disturbance and stress. In keeping with the conclusion reached by Lindenmayer and Noss, they note that logging after natural disturbance often has more profound impacts on the ecosystem than the original disturbance. The natural disturbances they studied resulted in little disruption of biogeochemical processes and other ecosystem functions, whereas salvage logging exacerbated ecological change, resulting in pronounced effects on ecosystem composition, structure, and function. There was no indication that active or preemptive management can improve the resistance or resilience of forests; in fact, many forests seem to be more vulnerable to exogenous impacts after management. Foster and Orwig conclude that although there are often valid reasons to conduct salvage or preemptive logging (for instance, economic and safety concerns), from an ecological standpoint substantial benefits accrue from leaving forests alone when they are threatened or affected by natural disturbance.

The boreal forest of Canada is the largest and most intact forest on Earth, and amazingly enough it is still shaped largely by natural processes. In Canada, forest managers have embraced the "natural-disturbance model" as a

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guide to managing forests. Nevertheless, Schmiegelow and coauthors find a fundamental mismatch between the general acceptance of a natural-disturbance model and what actually happens in forest management. The most egregious mismatch concerns policies that encourage postfire salvage logging. The boreal forests of Canada are at risk of vastly increased logging of this sort. With heightened demands for obtaining revenue from boreal forests, fire now competes with logging for timber. Although standards exist for structural retention (i.e., leaving live and dead trees and other plant material on site) during timber harvesting, the conventional standards are limited to those implemented at a stand level and disregard the legitimate biological need to maintain postfire forests on a landscape scale. The proportion and size of live residual trees in burned boreal forests can be quite high and can increase with fire size, although the abundance of these residual trees is typically underestimated by forest managers. Many fires are inaccurately described as "severe" or "stand replacing," when in fact they contain substantial areas that are unburned or that burned at low or moderate severity. Burned areas typically contain many bird species associated with late-successional forests. Salvaged sites, on the other hand, take decades to recover their habitat value for forest songbirds and other species.

Hutto expands on the observation that burned forests are hotspots of biodiversity. He points out that snag-retention guidelines developed for green-tree forests are not properly applied to burned forests because the birds and other species closely associated with severely burned forests require vastly higher densities of snags than do most species found in unburned forests. For example, some 60% or more of bird species that nest in severely burned conifer forests of the western United States use snags as nest sites, and large snags are disproportionately valuable. Many woodpeckers also feed from snags. The life cycle of most wood-boring beetles is 2–3 years, so the window of opportunity for birds that feed on these beetles in postfire habitats is exceptionally narrow. Meeting the needs of these specialized species essentially precludes salvage logging over vast areas of burned forest. Recent legislation in the United States and Canada generally encourages salvage logging and fails to provide adequate snag-retention standards for burned forests. Recognizing that public opinion will not shift immediately to an appreciation of the ecological values of burned forests, Hutto recommends several measures to reduce the impacts of salvage logging. Nevertheless, he concludes that he is "hard pressed to find any other example in wildlife biology where the effect of a particular land-use activity is as close to 100% negative" as typical salvage logging.

Reeves and coauthors examine the salvage logging issue from an aquatic perspective, focusing on postfire logging in riparian areas of the western United States. Riparian areas are of high ecological and biodiversity value in these and other forests. Despite short-term impacts, aquatic and riparian organisms are generally well adapted to rapid recovery following fire, with fish populations, for instance, rebounding usually within a decade. The erosion that naturally follows wildfire contributes wood and coarse sediments to streams, which are vitally important for the long-term productivity of these systems. Logging or other human intervention appears unnecessary to sustain the biodiversity and productivity of naturally resilient aquatic networks after fire. Rather, postfire logging in riparian areas poses a number of potential (but poorly documented) threats, including the spread of invasive species and increased vulnerability of adjacent forests to insects and disease; it also has uncertain effects on the frequency and behavior of future fires. Reeves et al. recommend that in the face of uncertainty about the consequences of salvage logging for riparian areas, the prudent course is to increase monitoring efforts and to provide riparian areas the same protections, such as adequate streamside buffers, that they receive before fire. Non-fish-bearing streams may require the same level of protection as fish-bearing streams.

In the final paper, Lindenmayer and Ough take us to the montane eucalypt forests of southeastern Australia, where wildfire and clearcut logging are the major forms of disturbance. Intensive and extensive salvage logging after wildfire has been the normal course of events in these forests since the 1930s, yet the effects of such logging have been poorly studied (i.e., a common theme among all papers in this special section, highlighting the need for a precautionary approach). Nevertheless, among the well-documented impacts of such logging is the loss of large trees with hollows, which has significant implications for a variety of cavity-using vertebrates, including endangered marsupials. Based on information on life histories, Lindenmayer and Ough predict declines of a number of other plant and animal species, for example resprouting tree ferns and seed regenerators that respond positively to fire. In this region, policies are needed that exempt some areas, especially old-growth forests and sites that experienced partial damage from fire, from salvage logging. Also needed are ecologically sensible guidelines for retention of large living and dead trees and other biological legacies after fire, a recommendation that echoes those of Schmiegelow et al. and Hutto. In those areas that will be salvaged, careful efforts should be made to reduce the level of physical disturbance to sites.

The papers in this special section provide a strong argument for increased research and monitoring on the effects of natural disturbances and postdisturbance logging on forests. A call for more research is not a call for business as usual and certainly not a call for increased levels of salvage logging. To the contrary, available evidence points to often severe and long-lasting negative effects of postdisturbance logging on a wide variety of ecosystems and their biota. To log what is often the most biologically diverse and threatened forest condition in the landscape is fundamentally irrational. Legislation in several countries—most notably the United States, where bills before Congress would greatly expand salvage logging on public lands—should therefore be of great concern to foresters, ecologists, conservationist biologists, and any citizen who cares about the biological values of forests and the ecological services they provide. We hope this special section will help inform the debate.

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