Toward Meaningful Snag-Management Guidelines for Postfire Salvage Logging in North American Conifer Forests

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Abstract: *The bird species in western North America that are most restricted to, and therefore most dependent on, severely burned conifer forests during the first years following a fire event depend heavily on the abundant standing snags for perch sites, nest sites, and food resources. Thus, it is critical to develop and apply appropriate snag-management guidelines to implement postfire timber harvest operations in the same locations. Unfortunately, existing guidelines designed for green-tree forests cannot be applied to postfire salvage sales because the snag needs of snag-dependent species in burned forests are not at all similar to the snag needs of snag-dependent species in green-tree forests. Birds in burned forests have very different snag-retention needs from those cavity-nesting bird species that have served as the focus for the development of existing snag-management guidelines. Specifically, many postfire specialists use standing dead trees not only for nesting purposes but for feeding purposes as well. Woodpeckers, in particular, specialize on wood-boring beetle larvae that are superabundant in fire-killed trees for several years following severe fire. Species such as the Black-backed Woodpecker (*Picoides arcticus*) are nearly restricted in their habitat distribution to severely burned forests. Moreover, existing postfire salvage-logging studies reveal that most postfire specialist species are completely absent from burned forests that have been (even partially) salvage logged. I call for the long-overdue development and use of more meaningful snag-retention guidelines for postfire specialists, and I note that the biology of the most fire-dependent bird species suggests that even a cursory attempt to meet their snag needs would preclude postfire salvage logging in those severely burned conifer forests wherein the maintenance of biological diversity is deemed important.*

Keywords: Black-backed Woodpecker, cavity-nesting birds, crown fire, mixed-severity fire, *Picoides arcticus*, salvage logging, stand-replacement fire

Hacia Directrices Significativas para la Gestión de Raigones en la Cosecha de Salvamento en Bosques de Coníferas de Norte América

Resumen: *Las especies de aves en el oeste de Norte América que están restringidas a, y por lo tanto más dependientes de, bosques de coníferas severamente quemados durante los primeros años después de un incendio dependen en alto grado de la abundancia de raigones en pie para sitios de percha, sitios de anidación y recursos alimenticios. Por lo tanto, el desarrollo y aplicación de directrices apropiadas para la gestión de raigones es crítico para la implementación de operaciones de cosecha posteriores al fuego en las mismas localidades. Desafortunadamente, las directrices existentes diseñadas para bosques verdes no se pueden aplicar a la venta de salvamento post fuego porque las necesidades de las especies dependientes de raigones en bosques quemados no son similares a las necesidades de las especies dependientes de raigones en bosques verdes. Las aves en bosques quemados tienen necesidades de retención de raigones muy diferentes a las de especies de aves que anidan en oquedades que han fungido como el centro para el desarrollo de las directrices de gestión de raigones existentes. Específicamente, muchos especialistas post fuego utilizan árboles muertos en pie no solo para propósitos de anidación sino también para propósitos alimenticios. En particular, los pájaros carpinteros se especializan en larvas de escarabajos perforadores de madera que son superabundantes en árboles*

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muertos por fuego durante varios años después de un incendio severo. Especies como Picoides arcticus *están casi restringidas a bosques severamente quemados. Más aun, los estudios de cosecha de salvamento post fuego revelan que la mayoría de los especialistas post fuego están completamente ausentes de bosques quemados con cosecha de salvamento (aun parcial). Hago un llamado para el desarrollo y utilización de directrices de retención de raigones más significativas para especialistas post fuego, y noto que la biología de la mayoría de las especies de aves dependientes de fuego sugiere que aun un intento apresurado de satisfacer sus necesidades de raigones excluiría la cosecha de salvamento post fuego en estos bosques de coníferas severamente quemados en los que se considera importante el mantenimiento de la diversidad biológica.*

Palabras Clave: aves andantes en oquedades, cosecha de salvamento, fuego de dosel, fuego de reemplazo de árboles, fuego de severidad mixta, *Picoides arcticus*

Density and Temporal Dynamics of Snags in Conifer Forests

Snags are standing dead trees from which most leaves and limbs have fallen (Thomas 1979; Thomas et al. 1979) and are usually the result of death due to lightning, fire, wind, disease, or insects. The U.S. Forest Service (USFS), Forest Inventory and Analysis program, defines a snag as a dead tree that is at least 22.5 cm dbh and 2 m tall. However defined, snags occur naturally in forests and play a crucial role in the ecology of forested ecosystems. A given snag will persist in the forest for years and will provide nesting, foraging, and roosting habitat for numerous species (Thomas et al. 1979; Harmon et al. 1986; Bull 2002).

Snag densities and characteristics vary significantly with forest type (Scott et al. 1980; Harris 1999) and forest age (Cline et al. 1980; Spies et al. 1988; Ohmann et al. 1994; Flanagan et al. 2004). Nevertheless, the focus of discussion about snags and other kinds of coarse woody debris has been tied strongly to the issue of old-growth rather than young, postdisturbance forests. If one focuses on North American conifer forests born of fire, one realizes that snag densities are uniquely high in forests recently disturbed by stand-replacement fire (Harmon et al. 1986; Everett et al. 1999). Indeed, in burned forest 1 year after a fire, the mean basal area of snags has been predicted (Spies et al. 1988) and observed (Drapeau et al. 2002) to be four times that in burned forests more than 1 year after a fire. Nearly 70% of all snags in landscapes dominated by stand-replacement fires occur in forests that are <20 years old (Lehmkuhl et al. 2003).

The main source of recruitment of snags also varies with forest type and stage of succession. Specifically, disease, beetles, and lightning probably account for the creation of snags in most forest types of advanced ages (Spies et al. 1988). In contrast, most of the snags that occur in early postdisturbance forest conditions are created by the disturbance event itself (Drapeau et al. 2002). As a consequence of these differences in the way snags are created, relatively few snags are at advanced decay stages in early postfire forests, whereas the reverse is true in older forests, where most snags show more advanced stages of decay (Drapeau et al. 2002). Even though advanced-decay-stage snags may be relatively rare in early postdisturbance forests, such forests still harbor some snags produced by disease, insects, or lightning before the disturbance event, and they constitute some of the most important wildlife snags therein. Regardless of origin, all the snags in early postdisturbance forests represent important legacies that are passed from one forest generation to the next by virtue of having survived the disturbance event as standing organic structures (Franklin et al. 2000).

Snags as Important Wildlife Resources

Remarkably, at least one fourth of all bird species in western forests (McClelland et al. 1979) and perhaps even as much as 45% of native North American bird populations (Balda 1975; Scott et al. 1980) are snag-dependent; that is, they require the use of snags at some point in their life cycle. Of the 102 terrestrial vertebrate species that occur in Washington State, over half (56) nest or den only in (require) the boles of dead or dying trees (Wilhere 2003). Moreover, an astounding two thirds of all wildlife species use deadwood structures or woody debris for some portion of their life cycles (Brown 2002). Such facts are clearly the driving force behind the development of snag-retention guidelines for managed lands. For birds in severely burned forests, the importance of snags goes well beyond the nesting needs of cavity-nesting species. By my own calculations (Hutto 1995), at least 60% of the species that nest in severely burned conifer forests use snags as nest sites, and virtually all those species nest only in or on snags.

The most valuable wildlife snags in green-tree forests are relatively large, as evidenced by the disproportionate number of cavities in larger snags (Lehmkuhl et al. 2003), and are relatively deteriorated (Drapeau et al. 2002). In burned conifer forests, the most valuable wildlife snags are also significantly larger than expected owing to chance, and are more likely to be thick-barked (ponderosa pine [*Pinus ponderosa* P.& C. Lawson], western larch [*Larix occidentalis* Nutt.], and Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco]) than thin-barked (Englemann spruce [*Picea engelmannii* Parry ex Engelm.], true firs [*Abies* sp.], and lodgepole pine [*Pinus contorta* Dougl. ex Loud.]) tree species (Hutto 1995; Saab & Dudley 1998; Kreisel & Stein 1999; Powell 2000; Haggard & Gaines 2001). In addition, broken-top snags (trees that were already snags before the fire event) are used as nest sites in recently burned conifer forests disproportionately often by both primary and secondary cavity-nesting bird species (Hutto 1995; Saab & Dudley 1998; Haggard & Gaines 2001).

The high value of large, thick-barked snags in severely burned forests has as much to do with the feeding opportunities as it does the nesting opportunities they provide birds. The phenomenal numerical response of woodpeckers of numerous species (Fig. 1a) that occupy recently burned conifer forests during both the breeding (Harris 1982; Murphy & Lehnhausen 1998; Powell 2000) and nonbreeding (Kreisel & Stein 1999) seasons is most certainly associated with the dramatic increase in availability of wood-boring beetle larvae (Muona & Rutanen 1994; Rasmussen et al. 1996; Saint-Germain et al. 2004) that serve as a superabundant food resource for woodpeckers. A marked increase in numbers of seed-eating bird species after crown fires is also undoubtedly related to the increased availability of seed resources after cones of blackened pine, fir, and spruce species open in response to fire (Fig. 1b). This helps explain why, in contrast with snags in green-tree forests, valuable wildlife snags in burned conifer forests include not only relatively soft snags (used for nesting by both cavity-nesting and open-cup-nesting species) but also snags that are at the sounder end of the snag decay continuum because the latter are what both beetles and birds require for feeding purposes (Nappi et al. 2003) and what many bird species use for nesting purposes. Consequently, burn specialists such as the Black-backed Woodpecker (*Picoides arcticus*), which depends on snags for both feeding and nesting, settle in areas with higher snag densities than expected owing to chance (Harris 1982; Saab & Dudley 1998; Kotliar et al. 2002).

*Figure 1. (a) Marks on burned trees left by woodpeckers that fed extensively on wood-boring beetle larvae in the snags. (b) Clark's Nutcracker (*Nucifraga columbiana*), a postfire specialist that has evolved a sublingual seed pouch that can hold more than 100 seeds, is extracting seeds from an underappreciated seed source—severely burned ponderosa pine.*

Broader Ecological Context for Snags in Severely Burned Conifer Forests

Uniquely high snag densities characterize severely burned conifer forests, and that makes for unique ecological conditions as well. But to what extent do severely burned forests occur naturally in western North American landscapes? Some (e.g., Skinner 2002) argue that the snag densities in postfire conifer forests are unnaturally high or that crown fires themselves are an unnatural product of our well-intentioned but misguided fire suppression policies of the past. Most conifer forest types, however, include crown-fire events as part of their natural fire regimes, and most are well within the natural range of variation (Romme 1982; Johnson et al. 2001; Johnson et al. 2003). Even low-elevation ponderosa pine forests are typified by an unspecified amount of mixed-severity fire (Arno 2000; Arno & Allison-Bunnell 2002), and at least some crown-fire events are perfectly natural, if rare, occurrences in those forest types as well (Agee 1993; Brown & Sieg 1996; Shinneman & Baker 1997; Brown et al. 1999; Veblen 2000; Ehle & Baker 2003; Schoennagel et al. 2004).

Even if the spatial scale over which stand-replacement fires occur in the lower-elevation conifer forest types is greater now than in the historic past, that is not to say that the presence of crown fires represents a process that is unnatural. Severe fires are clearly natural, and they constitute an important part of the fire regimes associated with most western conifer forest types (Arno 1980;

Heinselman 1981; DeByle et al. 1987; Arno 2000). Nevertheless, because severe fires are infrequent and numerically rare relative to the number of low-severity fire events that occur in the lower-elevation conifer forests of the West, the presence and importance of severe fires is currently underappreciated (Shinneman & Baker 1997; Baker & Ehle 2001; Ehle & Baker 2003; Baker & Shinneman 2004). This failure to appreciate the natural role of severe events may lead to well-intentioned but misguided management. Specifically, although detailed descriptions of a given fire regime might acknowledge the presence of frequent to infrequent occurrences of severe events, a given regime (i.e., low-severity regime) tends to be labeled by the most frequent kind of fire instead of by what might be a less frequent but biologically important component of the regime. Consequently, fire management tends to be focused primarily on restoration of the more common and not the least common type of fire in a given system. Heinselman (1981, 1985) anticipated this problem more than 20 years ago, when he argued strongly that restoration efforts should include the maintenance of stand-replacement regimes and stand-replacement events within low-severity regimes in at least the more remote portions of our public lands.

Besides the growing body of evidence that large, infrequent events are ecologically significant and not out of the range of natural variation (Foster et al. 1998; Turner & Dale 1998), an evolutionary perspective also yields some insight into the "naturalness" of severely burned forests. Specifically, there are unique biological and physical attributes that are relatively restricted to severely burned forests, indicating that infrequent events are not only natural, but biologically important as well. In a review of all published information on the effects of fire on forest birds of western North America, Kotliar et al. (2002) found that nine bird species are typically more abundant in burned than in unburned forests, as evidenced by a meta-analysis of results involving species that occurred in at least three studies prior to 2002. That number of species grows to 14 if one considers data from species that occurred in fewer than three studies, and that number more than doubles if fire severity is taken into account in the analysis (Smucker et al. 2005). Earlier studies of severely burned conifer forests throughout western Montana (Hutto 1995) suggest that as many as 15 species are nowhere more abundant than in recently and severely burned conifer forest. Some of these species (Black-backed Woodpecker, American Three-toed Woodpecker [*Picoides dorsalis*], Olive-sided Flycatcher [*Contopus cooperi*], Clark's Nutcracker [*Nucifraga columbiana*], and Mountain Bluebird [*Sialia currucoides*]) are even relatively narrowly restricted in their habitat distributions to, and presumably relatively dependent on, burned forest conditions (Hutto 1995; Hobson & Schieck 1999; Nappi 2000; Kotliar et al. 2002).

The life cycles of most wood-boring beetle species are 2–3 years, so the window of opportunity for many bird species that use recently burned forest is extremely narrow. Indeed, populations of timber-drilling woodpeckers peak at perhaps 4 years after a burn and then decline to near zero another 6 years after that (Taylor & Barmore 1980; Hoyt & Hannon 2002; Kotliar et al. 2002). These bird responses are unique to severe fires. Therefore, although less severe understory fires may be more frequent, they may also be less critical to the maintenance of some bird populations. The naturalness and importance of crown fires is reinforced by the fact that the bird species that are always more common in burned than in unburned forests are also more common in the more severely than in the less severely burned portions of those forests (Kotliar et al. 2002; Smucker et al. 2005).

Information on bird response to severe fire represents only a fraction of the biological uniqueness associated with recently burned conifer forests in western North America, as indicated by the large number of additional examples (Agee 1993; Whelan 1995; Brown & Smith 2000; Smith 2000; Arno & Allison-Bunnell 2002; Fisher & Wilkinson 2005) of positive responses of both plants (e.g., various *Pinus*, *Ceanothus, Arctostaphylos, Ribes, Dracocephalum, Corydalis, Geranium,* morel mushroom) and animals (e.g., numerous beetle species, boreal toad [*Bufo boreas*], spotted frog [*Rana pretiosa*], deer mouse [*Peromyscus maniculatus*], moose [*Alces alces*]) to what continues to be labeled "catastrophic" fire. The dramatic positive response of so many plant and animal species to severe fire and the absence of such responses to low-severity fire in conifer forests throughout the U.S. West argue strongly against the idea that severe fires are unnatural. The biological uniqueness associated with severe fires could emerge only from a long evolutionary history between a severe-fire environment and the organisms that have become relatively restricted in distribution to such fires. The retention of those unique qualities associated with severely burned forest should, therefore, be of highest importance in management circles. Yet, everything from the system of fire-regime classification, to a preoccupation with the destructive aspects of fire, to the misapplication of snag-management guidelines have led us to ignore the obvious: we need to retain the very elements that give rise to much of the biological uniqueness of a burned forest—the standing dead trees.

Postfire Salvage Logging and Its Effect on Snag-Dependent Species

So what happens if all snags are removed from a recently burned forest (Fig. 2a)? Research results on the ecological effects of a complete salvage harvest are consistent and overwhelmingly negative (McIver & Starr 2000). With respect to the avifauna, data suggest that there is no way to conduct a complete salvage harvest and retain suitable

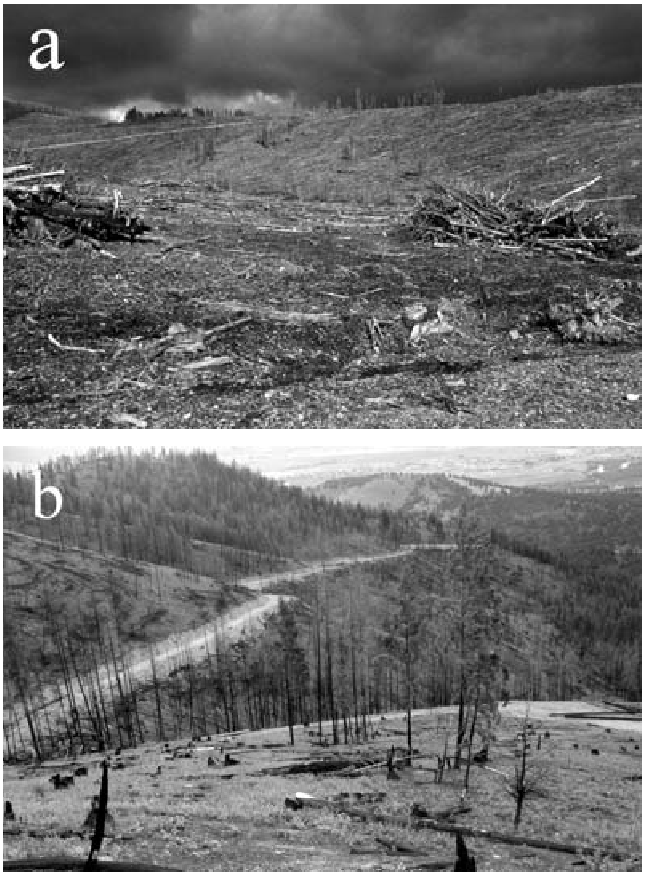

Figure 2. Burned forests that were (a) completely and (b) partially salvage logged.

conditions for species that would otherwise have occupied that patch of burned forest (Kotliar et al. 2002). This is especially true for bird species that depend on snags.

What about a less intensive, incomplete harvest (Fig. 2b)? The answer undoubtedly depends on the extent of harvest under consideration, and we currently lack data from a broad range of salvage intensities to be able to plot the precise relationship between snag density and bird density. Nonetheless, it is clear from existing data that incompletely logged burned forests still decrease the suitability of those forests for most cavity-nesting bird species (Kotliar et al. 2002). Most important, all existing studies of the effects of partial salvage logging on bird communities (Caton 1996; Hitchcox 1996; Saab & Dudley 1998; Haggard & Gaines 2001; Morissette et al. 2002) show negative effects on species that are most restricted to burned forests. For example, Black-backed and American Three-toed Woodpeckers are not only more abundant in uncut burned forests than in salvage-logged forests, they are frequently entirely absent from burned forests that have been incompletely salvage logged. The only bird species that may benefit from partial salvage logging (American Kestrel [*Falco sparverius*], Lewis's Woodpecker [*Melanerpes lewis*] and Western Bluebird [*Sialia mexicana*]) are not nearly as restricted in their distributions to burned forest conditions; they commonly occur in naturally open, unburned, low-elevation conifer forests as well (Saab & Dudley 1998; Haggard & Gaines 2001; Saab & Vierling 2001). Thus, it may be possible to develop methods of harvest that will mitigate negative effects on a handful of cavity-nesting bird species, but apparently not the most fire-dependent ones. In general, the very bird species that are most restricted to postfire conditions appear to be affected most negatively by postfire fuel-reduction logging or salvage logging (Kotliar et al. 2002; Morissette et al. 2002).

Perhaps there is a way to retain some of the ecological value associated with a burned forest in the face of partial salvage, and the finding that at least some species may benefit from partial salvage some of the time (Saab & Dudley 1998; Haggard & Gaines 2001; Kotliar et al. 2002) is encouraging. Nonetheless, the implementation of an adaptive-management cycle that is tightly coupled with a solid monitoring program will be needed to determine whether any level of salvage logging is compatible with the retention of the unique ecological values associated with severely burned forests (Robichaud et al. 2000; Hutto & Young 2002; Hutto 2004). So far, there are practically no data bearing on the effects of alternative styles of partial salvage logging because there has been neither the will nor the financial support needed to gain such knowledge.

Inadequacy of Current Snag Guidelines

Current snag-retention guidelines for most North American plant community types fall between 1 and 8 snags/ha. These guidelines emerged primarily from a consideration of the nesting requirements of cavity-nesting vertebrate species in the now classic *Blue Mountains* book (Thomas 1979). The retention of 8 snags/ha was judged to support 100% of the maximum population density of any of the woodpecker species that occur in the Blue Mountains area (Thomas 1979: Appendix 22). Bull et al. (1997) concluded that about 10 snags/ha in ponderosa pine and mixed-conifer forests should support viable populations of cavity-nesting birds. Thus, most current U.S. National Forest guidelines generally converge on the recommendation to retain 6–10 trees/ha, as do guidelines for Washington State, the Ontario Ministry of Natural Resources, the U.S. Army Corps of Engineers, and many other land-management agencies.

It has been acknowledged that snag guidelines should be sensitive to forest type and forest age because "the wildlife species that use snags are influenced by the stage of forest succession in which the snag occurs" and by the breakdown stage of the snag (Thomas et al. 1979). Moreover, snag types, sizes, and densities vary significantly with vegetation type (Harris 1999; Harmon 2002; White et al. 2002). Therefore, it follows necessarily that the desired snag types and densities will differ with both plant community type and successional stage and that we need as great a variety of guidelines as there are community types and successional stages (Bull et al. 1997; Everett et al. 1999; Rose et al. 2001; Kotliar et al. 2002; Lehmkuhl et al. 2003). Unfortunately, we have generally failed to adjust snag-retention recommendations to specific forest age, and nowhere is that failure more serious than for those special plant community types that were ignored in the development of the generic guidelines—recently burned conifer forests. Such forests are characterized by uniquely high densities of snags (Angelstam & Mikusinski 1994; Hutto 1995; Agee 2002; Drapeau et al. 2002), and snag use by most woodpeckers in burned forests requires high snag densities because they nest in and feed from burned snags.

These facts have been overlooked in the development and implementation of meaningful snag-management guidelines. Indeed, these guidelines have generally converged toward an average of 6–7 trees/ha because that number was deemed more than adequate to meet the nesting requirements of cavity-nesting wildlife species (Thomas et al. 1979:69). Snag guidelines were not originally developed with an eye toward non-nesting uses of snags or from an attempt to mirror snag densities that typically occur on unmanaged reference stands. Snag guidelines are still much narrower than numerous authors have suggested they ought to be, and we currently run the risk of managing coarse woody debris with uniform standards across historically variable landscapes, which is entirely inappropriate. Instead, we should be managing for levels of coarse woody debris that more accurately mirror levels characteristic of the natural disturbance regime (Agee 2002). Clearly, we need more data on what might constitute meaningful snag targets for all forest types and successional stages, and those targets should be set on the basis of reference conditions from natural postdisturbance forests, not from managed forest stands and certainly not from consideration of only a single aspect of an organism's life history.

Newer guidelines that are appropriate for snag-dependent species that occupy standing dead forests at the earliest stage of succession are beginning to trickle in (Saab & Dudley 1998; Haggard & Gaines 2001; Saab et al. 2002; Kotliar et al. 2002), and authors suggest that 200–300 snags/ha may better address the needs of wildlife in burned forests. The issue has yet to receive the serious management attention it deserves, but the comprehensive review of habitat needs of vertebrates in the Columbia River Basin (Wisdom et al. 2000) and the recently developed DecAID modeling effort in Washington and Oregon represent important efforts toward providing that kind of management guidance (Marcot et al. 2002).

Current Postfire Management Decisions Related to Snag Retention

The following points regarding management decisions apply to western forest types that experience crown fire as at least a minor component of their fire regimes (and that is virtually all western forest types).

(1) The USFS uses fire as a motivation to harvest trees. This is evident because in most cases where postfire logging is proposed they had not already sold green-tree harvests in those particular areas prior to the time of fire disturbance. Even though land managers are becoming more aware of the overwhelmingly negative ecological impacts of postfire salvage logging, the management has not shifted correspondingly toward less salvage harvesting. Instead, the most common justification for such harvests seems to have shifted recently from "salvaging" what economic value there might be to preventing another catastrophic fire (McIver & Starr 2000). Recent modifications of legislation and regulations by provincial governments in Canada (cited in Nappi et al. 2003) and by the U.S. government as well (Healthy Forests Restoration Act) expedite or even provide incentives for salvage logging. Such legislation provides no commitment to meaningful snag retention on burned forest lands. This failure to appreciate the value of burned forests to ecosystem sustainability is exacerbated by the fact that industrial lands (and most state lands) are, and probably always will be, completely salvage logged after fire because the value of those lands to those landowners lies entirely with the potential for short-term economic gain. The onus lies squarely on public land managers to provide the necessary protection of snag resources on burned forest land, and that has yet to happen.

(2) The usual agency response to questions about the amount or kind of burned trees to leave is that it does not really matter because they propose taking only a small proportion of what burned, so there must be plenty left for wildlife. Although that could be true, there is no scientific basis for such a conclusion. The volume of burned timber needed to enable populations to expand enough so that they can weather the next hiatus without fire in a particular area is unknown.

(3) If a partial salvage is proposed, the level of snag retention is generally based on a gross misapplication of current snag guidelines. In short, meaningful snag-management guidelines for burned forests are lacking

because the general public and the land management agencies that act on behalf of the public do not recognize the biological value of snags in burned conifer forests.

Toward Solutions

Any postfire salvage logging operation that requires a consideration of the maintenance of biological diversity will have to deal with the facts associated with salvage logging, which are unprecedented in terms of how consistently negative the ecological effects of salvage logging are. Because postfire bird communities soon after fire are biologically unique and the most unique elements are lost after any kind of salvage harvest, postfire salvage logging (especially a complete harvest; illustrated in Fig. 2a) is clearly ill advised. Even though existing science-based data suggest that very little, if any, salvage logging should be conducted in burned forests, salvage logging will not cease any time soon. So what guidelines should be followed in the meantime until education about the benefits of burned forests takes a greater hold on the public psyche? As a general guideline for any kind of timber harvesting (green-tree or salvage harvesting), public land managers should always strive to emulate natural processes with harvesting that occurs on public lands (Hejl et al. 1995; Hobson & Schieck 1999; Hejl et al. 2002; Kotliar et al. 2002; Arno & Feidler 2005). Thus, snag-retention guidelines for salvage sales should be no different; they should be based on an explicitly identified postharvest emulation target that reflects the kind of natural disturbance process and stand structure that one hopes to emulate through the harvest process.

On patches that are harvested, cutting should either be intense enough that the result will emulate a later stage of succession that corresponds with the proposed level of snag retention or cutting should be low enough in intensity that there will be no significant ecological effect. Clearly, the only way to extract higher wood volumes from salvage timber sales would be to claim to be mimicking not the earliest stage of succession but something more like a forest 10 years after a fire, where natural snag attrition due to blowdown might be used to justify a much smaller snag-retention target. In no case would a complete salvage harvest mimic any stage of natural forest succession.

Even if managers take relatively few trees and do a good job of mimicking the numbers and kinds of snags in, say, a forest 10 years after a fire, it should be clear that if the naturally occurring earliest stage of succession (a forest 0–5 years after a fire, which normally contains hundreds of burned snags per hectare) is not managed for, then managers will have failed to maintain an important component of biological diversity: all the unique plants and animals that depend on those first few years of natural (postfire) succession. The retention on the landscape of some burned forest 0–5 years after a fire at any one point in time should be a management priority because that is the narrow window of time during which the biologically unique early postfire conditions become established and persist. And because there is less of that forest age than what was historically available due to successful fire suppression during the past half century (Gruell 1983; Hessburg et al. 2000), these forests should be valued at least as much as the small amounts of old-growth that are left. These facts alone seem justification enough to remove all burned forests from consideration for harvest, but the opposite tendency currently prevails.

An alternative strategy might be to salvage harvest only that number of snags that would still allow the special ecological conditions (such as those that I have described herein for birds) to be retained. Unfortunately, the only way to mimic natural snag densities for harvests that seek to mimic the very earliest stage of succession (immediately after a fire) would be to leave close to the same number of burned trees per unit area that would occur through a stand-replacement disturbance event. The numbers of standing dead trees per hectare immediately following stand-replacement fire number in the hundreds, of course (Everett et al. 1999), so snag guidelines should recommend perhaps 50 times the number currently recommended in the most commonly used guidelines. On top of that, the densities of snags in patches used by birds for cavity nesting (Harris 1982; Saab & Dudley 1998) and feeding (Kreisel & Stein 1999) are significantly higher than what is randomly available in early postfire forests, so even if guidelines were built on "average" snag densities associated with recently burned forests, they might still fall short of the densities actually needed by these birds. I hasten to add that I am only scratching the surface of this issue by concentrating my attention on the needs of birds. Even more stringent guidelines might follow from a consideration of the needs of snag-dependent, pyrophilous insects and spiders, for example (Nappi et al. 2004).

A partial salvage harvest that produces little or no ecological damage will be difficult to achieve because of the sensitivity of early postfire specialists to any disturbance, as described earlier. Unfortunately, we currently have no data on the relationship between levels of harvest and ecological consequences, as measured by birds, plants, or whatever ecological response variable one wishes to use. This lack of information led me to suggest earlier (Hutto 1995) that the safest strategy (if salvage logging must occur) may be to take some and leave some large patches of untouched burned forest across the landscape. As others (Hannon & Drapeau 2005) have noted, the unknown with this approach, however, lies with the mystery of how much to leave. In response to this question, Nappi et al. (2004) make it clear in their recent paper dealing with the effects of salvage logging in the boreal forest that it is dangerous to rest the maintenance of biodiversity on the assumption that the unharvested portion may compensate adequately for the intensively salvaged portion of burned forests.

Conclusions

The ecological cost of salvage logging speaks for itself, and the message is powerful. I am 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 the typical postfire salvage-logging operation tends to be. If input from biologists is ever to have an influence on policy, this should certainly be one of those instances. Yet largely economic interests have apparently compelled legislators to ignore such facts and pass recent legislation in the United States and Canada that will serve to expedite salvage logging. Existing science-based data suggest that there is little or no biological or ecological justification for salvage logging. McIver and Starr (2000) note that because of this, the justification for salvage logging has begun to shift toward arguments related to rehabilitation or restoration, but those sorts of justifications also reflect a lack of appreciation that severe fires are themselves restorative events and that rehabilitation occurs naturally as part of plant succession (Lindenmayer et al. 2004). Interference with the natural process of plant succession by planting or spraying to speed the process of succession toward narrow timber-producing or old-growth goals, as some suggest (e.g., Sessions et al. 2004), is also incompatible with a holistic public-land-management goal of working within the constraints of a natural system. All things that characterize a severe disturbance event, including soil erosion and sometimes insufferably slow plant recovery, are precisely the things that constitute "rehabilitation" for those organisms that need those aspects of disturbance events at infrequent intervals to sustain their populations.

The profound failure of many decision makers to appreciate the ecological value of burned forests stems from their taking too narrow a view of what forests provide. The general belief that "dead and dying timber ought to be harvested and put to use" (Schwennesen 1992) prevailed prior to the infamous salvage rider of 1995 (U.S. Congress 1995), and it apparently still prevails today in many management circles. Land managers, politicians, and the public-at-large need to gain a better appreciation of the unique nature of burned forests as ecological communities, how sensitive the process of succession is to conditions immediately following the disturbance event (Platt & Connell 2003), and how important the legacy of standing deadwood is to the natural development of forests (Franklin et al. 2000). Nowhere are soils, special plants, or wildlife more sensitive to the proposition of tree harvesting than in a burned forest. And nowhere is the consideration of ecology more blatantly absent than in decisions to salvage log. Education to these facts is needed at all levels.

It is time for conservation biologists and enlightened land managers to educate others to the fact that there is an ecological benefit in staying out of forests that have been recently restored by natural stand-replacement fire. There are plenty of green-tree forest stands to harvest in a sustainable fashion while offering boons to local economies (especially in the urban interface), so economic arguments should not interfere with the responsible decision to celebrate the benefits of a natural restoration event when it happens and to harvest timber outside the biologically unique and rare severely burned forests.

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