Chapter 5—Ecological consequences of the MPB epidemic for habitats and populations of wildlife

Authors: Beth Hahn, Vicki Saab, Barbara Bentz, Rachel Loehman, and Bob Keane

Presenters: Beth Hahn, Vicki Saab, Barbara Bentz, Rachel Loehman, and Bob Keane

Introduction

Wildlife biologists must balance a diverse array of ecological and social considerations in managing species and habitats. The challenges of managing species and habitats in dynamic landscapes are influenced by diverse factors, including natural disturbances, vegetation development, and anthropogenic-mediated changes, such as climate change, management activities, and land use. Mountain pine beetles (MPBs) can be viewed as an ecosystem engineer—a species that both directly and indirectly shapes landscapes by altering the composition, structure, and function of ecosystems. Although native wildlife species co-evolved with natural disturbances such as MPB outbreaks, in the shorter term these changes simultaneously create and eliminate certain habitats. Additionally, changes to ecosystems from MPB outbreaks interact with other processes such as fire, nutrient cycling, and sedimentation to further alter habitats.

Species-specific responses are expected to vary as a function of outbreak severity, time since the peak of tree mortality, and characteristics of the species, including life history traits, habitat associations, and foraging requirements (Saab and others 2014). MPB outbreaks cause both short- and long-term changes in the pattern, extent, and structure of habitats, with major implications for wildlife populations. For example, MPBs provide an extended food resource for some bird species, while reducing habitat in the short term for other species, such as the pine squirrel.

Managing forests to anticipate or mitigate the effects of the MPB epidemic on wildlife species is challenging. For instance, there are critical differences in the operative scales for responding to MPB outbreaks and managing forest resources and wildlife populations. Beetle-induced tree mortality may be high at the stand scale (Fig. 5.1), but most vertebrate populations exist across areas with magnitudes much larger than a single stand or watershed. Moreover, the "footprint" of interacting natural disturbances such as the MPB epidemic and fire is enormous compared to the footprint of most land management actions (see **Chapter 8**).

Wildlife management does not proceed in isolation from other considerations such as timber or recreation. Projects are designed and analyzed by interdisciplinary teams, and wildlife biologists contribute to this process by adding elements that either improve habitat or mitigate adverse impacts. Project design and analysis must comply with relevant law, regulation and policy (*e.g.*, National Forest Management Act, National Environmental Policy Act, and Endangered

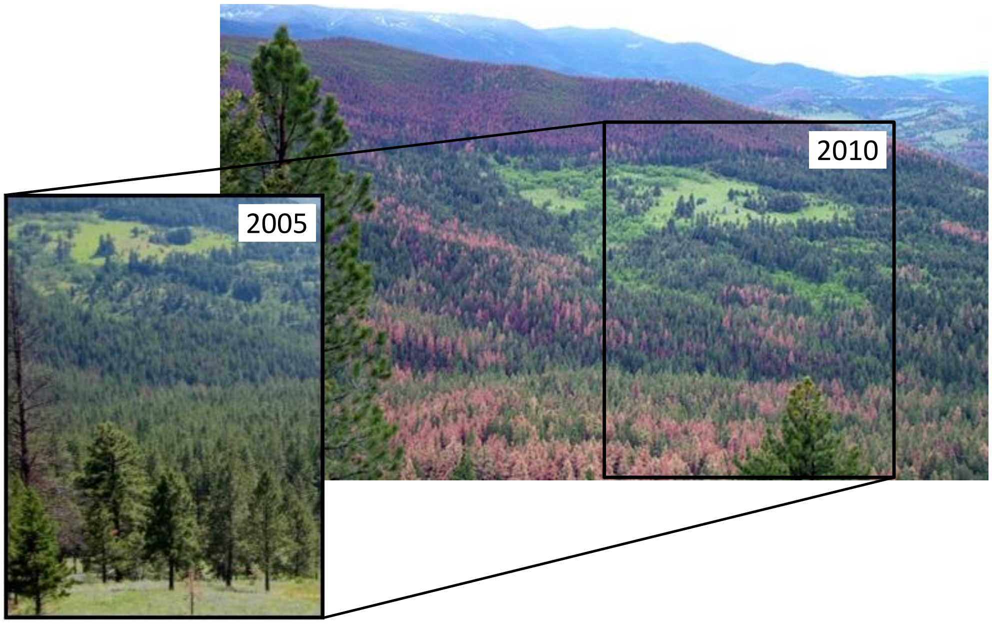

Figure 5.1. Tree mortality from the current MPB epidemic in the Elkhorn Mountains, Helena National Forest. Left photo shows pre-epidemic conditions in 2005; right photo shows the same site in 2010 (photos by V. Saab and Barbara Bentz, USDA Forest Service).

Species Act). Analysis requirements imposed by laws or regulations frequently differ from ecologically-relevant spatial and temporal scales (Ruggiero and others 1994; Block and others 2012). For instance, a Forest Service biologist will need to evaluate whether a 1,000-acre salvage harvest within a 15,000-acre project area will affect the persistence of sensitive species (*e.g.*, black-backed woodpecker) at the scale of the entire National Forest. An entire National Forest is much larger than the home ranges for different populations of black-backed woodpeckers (*cf.* Pierson and others 2010).

In this webinar, we used a case study approach to examine the ecological consequences of the MPB epidemic for wildlife habitats and species. We presented different methods for comparing spatial and temporal patterns of bird diversity, reproduction, habitat use, persistence, and foraging in relation to the MPB epidemic. We also presented modeling techniques for investigating wildlife responses to large-scale disturbance.

Research findings

Research finding #1: Life history traits can help predict the impact of disturbances on populations and habitats of wildlife species.

Management Implications

- The MPB epidemic created habitat for some species and eliminated habitat for others. Birds that eat beetles and/or build nests in snags will likely benefit for several years following the epidemic, whereas foliage gleaners may have lower occupancy levels relative to pre-epidemic conditions.
- Responses of bird guilds to disturbance change over time as vegetation recovers and alters habitat suitability.
- Areas with low, medium, and high levels of beetle-induced tree mortality provide habitat for different types of species.

Scientists with the Rocky Mountain Research Station are examining implications of the MPB epidemic for habitats and populations of small land birds. Birds make an ideal model for evaluating wildlife responses to the MPB epidemic because of their high sensitivity to disturbances (Saab and Powell 2005; Saab and others 2014). Guilds—groups of ecologically similar species—can be useful categories for predicting and examing bird responses to disturbance. Cavity-nesting birds that feed on larvae, and bark- and wood-boring insects are one guild (*e.g.*, woodpeckers), while foliage-gleaning birds that nest in open cup structures are another guild (*e.g.*, golden-crowned kinglet).

Responses of bird guilds to disturbance change over time as vegetation recovers and alters habitat suitability (Fig. 5.2). The first years after a disturbance are more favorable for cavity-nesting species because of the high abundance of snags for nesting. Populations of beetle-foraging specialists also peak four to five years after fire or MPB outbreaks due to elevated populations of bark and wood-boring insects (Saab and others 2007b; Davis and others 2012). Ground and aerial insectivores continue to increase for at least 12 years following a wildfire, particularly when there is a pulse of arthropods due to nutrient release after fire (Saab and others 2007b). Omnivorous, shrub-nesting species select habitats that form as snags begin to fall and shrubs establish. Canopy-nesting species and foliage gleaners are the last to colonize forests after disturbance because they depend on dense forest overstories.

Disturbance severity also influences the habitat of different bird guilds. Most foliage-gleaning (*e.g.*, chickadees) and log-foraging species (*e.g.*, pileated woodpecker) are abundant in unburned habitats. Sites experiencing low- and

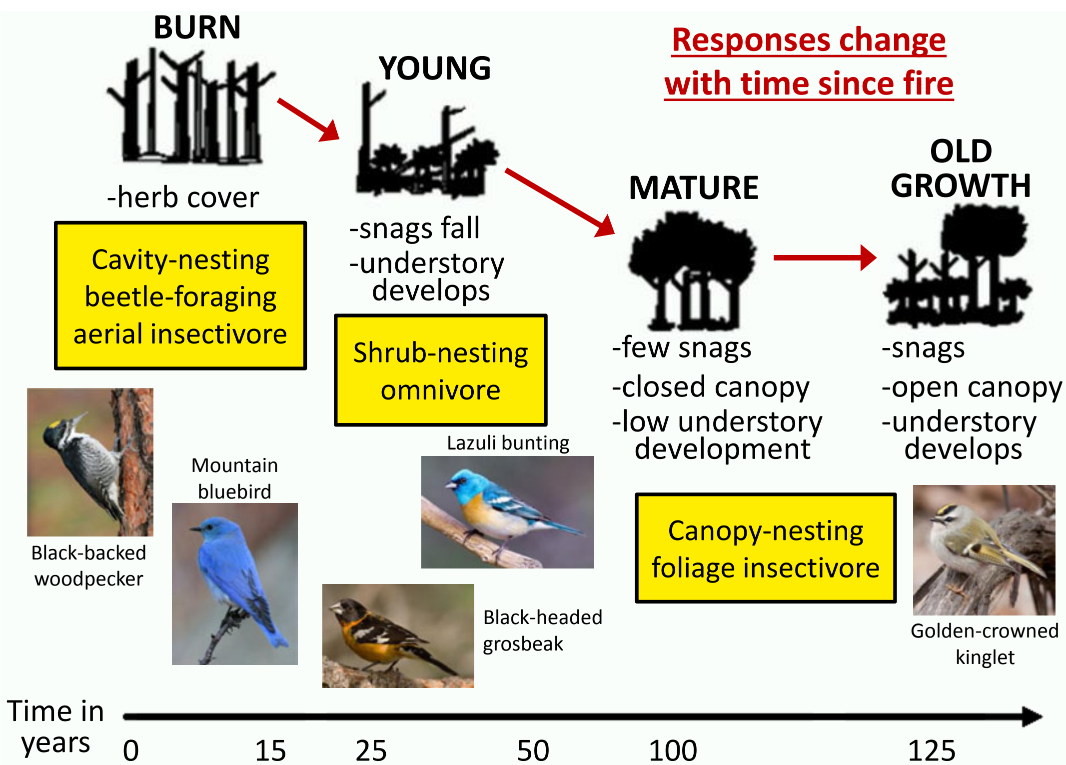

Figure 5.2. Generalized response of bird guilds to post-fire habitat conditions (figure from Saab and others 2007a, modified from Hannon and Drapeau 2005).

mixed-severity fires provide habitat for species benefiting from snag creation and the retention of some live trees for foraging. These species include cavity-nesters that feed on pine seeds (*e.g.*, white-headed woodpecker) and species that glean insects from bark of living trees. At locations subject to moderate and high severity fires, wood drillers (*e.g.*, black-backed woodpeckers) and aerial insectivores (*e.g.*, mountain bluebird) predominate.

Compared to post-fire conditions, data on species and guild responses to insect outbreaks are relatively sparse. Research in the Elkhorn Mountains on the Helena National Forest assessed changes in bird occupancy, nest density, and habitat suitability using data collected before and during the MPB epidemic (Mosher 2011; Saab and others 2014). Occupancy levels were substantially different before and during the MPB epidemic for 30 percent of the species measured. Bark insectivores had a strong positive response, while foliage gleaners had a weak negative response to the epidemic (Mosher 2011). Nest densities for cavity-nesting birds increased, primarily for beetle-foraging species (American three-toed woodpecker, hairy woodpecker, and downy woodpecker). In contrast, nest densities of species that do not forage on beetles remained similar to pre-epidemic levels (Saab and others 2014).

Researchers also modeled nesting habitat suitability for American three-toed woodpeckers. This species responded most favorably to the MPB epidemic in terms of increased occupancy and nest density. Highly-suitable habitat was abundant across the study area following the MPB epidemic (Vicki Saab, USDA Forest Service, *unpublished data*). With more research, habitat suitability models could be developed for additional species to inform management decisions that balance multiple objectives.

Research finding #2: Beetle-killed trees provide an important foraging resource for some bird species immediately following MPB outbreaks.

Management Implications

- Bird species that eat beetles can actually lower the local density of MPB in years with endemic and post-endemic population sizes.
- Large diameter snags are particularly important foraging resources for woodpeckers, with the greatest foraging value occurring 4-5 years after MPB outbreaks.
- Anywhere from 70-90 percent of snags fall within 5 years of a MPB outbreak. Higher fall rates are generally associated with warmer and wetter conditions.

One of the research objectives at the Elkhorn Mountain sites was to estimate how long trees killed by MPBs are a foraging resource for birds. After initial tree attack, MPB larvae and adults develop within a tree for one year before emerging to attack another live tree. A large number of wood-boring insects subsequently infest beetle-killed trees. A single tree can provide a food resource for woodpeckers over several years. At the Elkhorn sites, preliminary results show that woodpeckers preferentially foraged on beetle-attacked trees with large diameters (>9” dbh). These trees are of greatest foraging value in the first 4-5 years following an attack, although infested trees can provide forage up to

14 years after their death (Barbara Bentz, USDA Forest Service, *unpublished data*). Beetle-foraging bird species can actually influence the local density of some MPB populations during endemic and post-epidemic population phases (Fayt and others 2005).

The snag-fall rate will influence the time that a tree is a foraging resource for birds. There is high variability in snag persistence following beetle-induced tree death. Anywhere from 70-90 percent of snags fall within 5 years of a MPB outbreak. The rate that trees fall may be related to climate, soil moisture, tree species, and the speed of bole decay. Higher fall rates are generally associated with warmer and wetter conditions, as well more open forest structures due to lower wind resistance (Mitchell and Preisler 1998; Lewis and Hartley 2006).

Research finding #3: Models can help project changes in wildlife habitat over time and at different spatial scales.

Management Implications

- Model projections at landscape scales are necessary for species that have large home ranges or migrate throughout the year. Smaller-scale projections are more appropriate for species that depend on specific within-stand structures and composition.
- The future is not set in stone, so models can help assess the impact of different management decisions under a range of potential conditions (*e.g.*, climate scenarios).
- Linking site-specific research projects with broader-scale monitoring programs will be essential to derive robust, multi-scale inferences while also leveraging limited resources.
- Understand the assumptions and limitations of models. For example, some datasets are less reliable than others, and this can greatly influence the reasonableness of model predictions.
- Qualitative modeling approaches, such as scenario planning, are often helpful when future conditions are dynamic and largely unknown and/or when quantitative data is not available.

Wildlife managers rely on empirical data and model predictions to estimate wildlife population sizes and habitat suitability. Setting wildlife management priorities for a particular landscape, such as recovery efforts for federally-listed species, requires information at different spatial and temporal scales. Research on implications of the MPB for wildlife can help managers prioritize critical restoration projects, inform project design criteria (*i.e.,* retention, thinning, salvage, and replanting), and identify sites and habitats that should be left in an “unmanaged” state.

Modeling allows managers and researchers to examine interactions among ecological processes (*e.g.*, the MPB epidemic, climate change, and wildfire) and other landscape influences (*e.g.*, management actions and land use changes), and the effect of these dynamic interactions on wildlife habitat. The FireBGCv2 model is useful to exploring long-term trends in landscape conditions, such as the quality of bull trout habitat under different disturbance regimes (Keane and others 2011; Holsinger and others *in review*).

Models are useful for projecting wildlife habitat at sites or times for which there are no empirical observations, and for exploring different landscape configurations (*e.g.*, connectivity and management treatments) over large spatial and long temporal scales. For example, researchers used an extensive stream network database to develop a model of suitable stream habitat for bull trout, a threatened species under the Endangered Species Act, under current and projected climate changes (Rieman and others 2007; Isaak and others 2010). This model is especially helpful to managers because it provides robust inference at both watershed and landscape scales.

Modeling efforts can describe a range of potential future conditions, such as multiple climate scenarios. For example, researchers can couple models of MPB survival with projections of temperatures in future decades to predict future MPB populations across the western United States (Bentz and others 2010). Managers can use simulated future conditions as tools for multi-decadal planning and conservation.

In addition, models can assess ecosystem responses at different spatial and process scales, such as landscape-scale shifts in species abundance, composition, or carbon balance and stand-level vegetation recovery resulting from dynamic climate-vegetation-disturbance interactions (Fig. 5.3). Forest Service researchers and managers are currently developing an integrated, dynamic model to predict changes in bird habitat suitability based on the likelihood of fire and MPB outbreaks. The model incorporates the role of temperature on the developmental phenology of the MPB, as well as the influence of climate on host tree defenses.

Understanding the assumptions and limitations of models, including appropriate spatial and temporal scales, is critical to management applications. Uncertainty

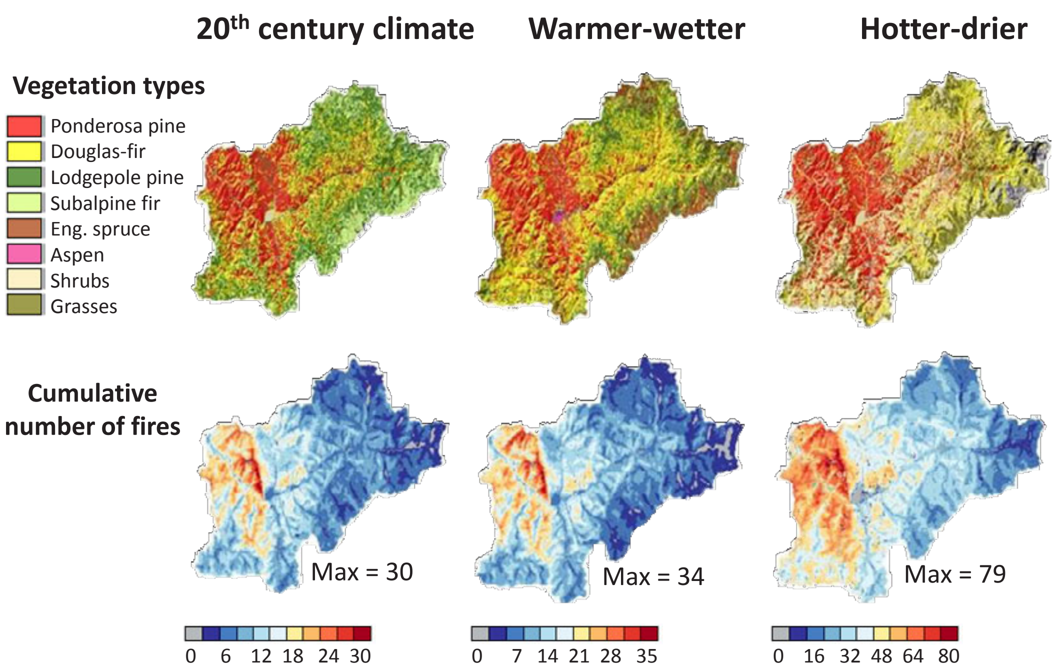

Figure 5.3. Climate-driven changes in vegetation types and fire regimes simulated using the FireBGCv2 model for the East Fork of the Bitterroot River, MT (Holsinger and others in review).

in model predictions can be especially high for short-term projections over large landscapes. In addition, the resolution of available data might be too coarse for predicting changes in habitat components important to wildlife species (*e.g.*, distribution of snags).

Habitat suitability indices can inform short-term management decisions, but mechanistic models that incorporate landscape dynamics are needed to support long-term planning. For example, models have been developed to simulate the effects of climate change scenarios on the distribution of 135 tree species and 150 bird species in the eastern United States (Iverson and others 2011). These models are helpful for projecting the locations of high-quality habitats under potential future conditions. However, they should only be applied at very coarse scales, much larger than the typical management project scale.

Management Implications

- Our understanding of wildlife responses to the MPB epidemic is much more limited than our understanding of post-epidemic vegetation responses and fire hazards responses. Managers and researchers need to identify information gaps and uncertainties.
- Scenario planning and simulation modeling are useful approaches to support decision-making in the face of future dynamic ecosystem conditions.
- Managers and researchers from different disciplines need to collaborate to develop models that incorporate multiple disturbance trajectories, different patterns of vegetation change, and alternative management treatments to estimate a range of possible future conditions (see Chapter 8).

Literature cited

Bentz, B.J., R. Jacques, C.J. Fettig, E.M. Hansen, J.L. Hayes, J.A. Hicke, R.G. Kelsey, R.G., J.F. Negrón, and S.J. Seybold. 2010. Climate change and bark beetles of the Western United States and Canada: Direct and indirect effects. BioScience 60:602-613.

Block, W.M., V.A. Saab, and L. Ruggiero. 2012. Putting science into action on Forest Service lands. Pp 49-62 in J.P. Sands, S. J. DeMaso, M. J. Schnupp, and L. A. Brennan (eds). Wildlife Science: Connecting Research with Management. CRC Press: Boca Raton, FL.

Davis, R.S., S. Hood, and B.J. Bentz. 2012. Fire-injured ponderosa pine provide a pulsed resource for bark beetles. Canadian Journal of Forest Research 42:2022-2036.

Fayt, P., M.M. Machmer, and C. Steeger. 2005. Regulation of spruce bark beetles by woodpeckers – a literature review. Forest Ecology and Management 206:1-14.

Hannon, S.J. and P. Drapeau. 2005. Bird responses to burning and logging in the boreal forest of Canada. Studies in Avian Biology 30:97-115.

Holsinger, L.R., R.E. Keane, D. Isaak, L. Elby, and M. Young. In review. Stream temperatures increase under future climates regardless of fire management for a northern Rocky Mountains watershed using simulation modeling. Submitted to Ecological Modeling.

Isaak, D.J., C.H. Luce, B.E. Rieman, D.E. Nagel, E.E. Peterson, D.L. Horan, S. Parkes, and G. Chandler. 2010. Effects of climate change and wildfire on stream temperatures and salmonid thermal habitat in a mountain river network. Ecological Applications 20:1350-1371.

Iverson, L.R., A.M. Prasad, S.N. Matthews, and M.P. Peters. 2011. Lessons learned while integrating habitat, dispersal, disturbance, and life-history traits into species habitat models under climate change. Ecosystems 14:1005-1020.

Keane, R. E., R. A. Loehman, and L. M. Holsinger. 2011. The FireBGCv2 landscape fire and succession model: A research simulation platform for exploring fire and vegetation dynamics. General Technical Report RMRS-GTR-255. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 137 pp.

Lewis, K.J. and I.D. Hartley. 2006. Rate of deterioration, degrade and fall of trees killed by mountain pine beetle. BC Journal of Ecosystems and Management 7:11-19

Mitchell, R.G. and H.K. Preisler. 1998. Fall rate of lodgepole pine killed by the mountain pine beetle in central Oregon. Western Journal of Applied Forestry 13:23-26.

Mosher, B.A. 2011. Avian community response to a mountain pine beetle epidemic. Montana State University, Bozeman, MT. 61 pp.

Pierson, J.C., F.W. Allendorf, V. Saab, P. Drapeau, and M.K. Schwartz. 2010. Do male and female black-backed woodpeckers respond differently to gaps in habitat? Evolutionary Applications 3:263-278.

Rieman, B., D. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the Interior Columbia River Basin. Transactions of the American Fisheries Society 6:1552-1565.

Ruggiero, L.F., G.D. Hayward, and J.R. Squires. 1994. Viability analysis in biological evaluations: Concepts of population viability analysis, biological population, and ecological scale. Conservation Biology 8:364-372.

Saab, V.A. and H.D.W. Powell. 2005. Fire and avian ecology in North America: Process influencing pattern. Studies in Avian Biology 30:1-13.

Saab, V., W. Block, R. Russell, J. Lehmkuhl, L. Bate, and R. White. 2007a. Birds and burns of the Interior West: Descriptions, habitats, and management in western forests. General Technical Report PNW-GTR-712. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 23 pp.

Saab, V.A., R.E. Russell, and J.G. Dudley. 2007b. Nest densities of cavity-nesting birds in relation to postfire salvage logging and time since wildfire. Condor 109:97-108.

Saab, V.A., Q. Latif, M. Rowland, T. Johnson, A. Chalfoun, S. Buskirk, J. Heyward, and M. Dresser. 2014. Ecological consequences of mountain pine beetle outbreaks for wildlife in western North American forests. Forest Science 60. [online] URL: http://dx.doi.org/10.5849/forsci.13-022.

Meet the chapter presenters and authors

Barbara Bentz has served as a Research Entomologist with the Rocky Mountain Research Station in Logan, UT since 1991. Her research interests include the biology, ecology, and management of MPBs. Barbara's recent research has focused on modeling climate change influences on MPBs populations and the interactions between fire and MPBs. Barbara can be reached at bbentz@fs.fed.us; 435-755-3577.

Beth Hahn is the Branch Chief of Wilderness Science at the interagency Aldo Leopold Wilderness Research Institute, in Missoula, MT. Previously, she worked as the Regional Wildlife Ecologist for the Northern Region of the Forest Service stationed in Missoula, MT. In that capacity, she worked on a variety of multi-scale inventory and monitoring programs, habitat analyses, and plan revision and amendments. Reach Beth at bhahn@fs.fed.us; 406-542542-3244.

Bob Keane is a Research Ecologist with the Rocky Mountain Research Station at the Missoula Fire Sciences Lab. Bob's recent research includes 1) developing ecological computer simulation models for the exploring landscape, fire, and climate dynamics, and 2) investigating the ecology and restoration of whitebark pine. Reach Bob at rkeane@fs.fed.us; 406-329-4846.

Rachel Loehman is a Research Ecologist with the Rocky Mountain Research Station at the Missoula Fire Sciences Lab. Rachel's research includes spatial modeling of climate change effects on ecosystem processes, climate drivers of wildfire, and disturbance ecology. Reach Rachel at raloehman@fs.fed.us; 406-829-7386.

Vicki Saab is a Research Wildlife Biologist with the Rocky Mountain Research Station in Bozeman, MT. Her research interests include disturbance ecology and avian ecology, with an emphasis on cavity-nesting birds and other small landbirds. Her research focuses on avian distributions and demographics in relation to wildfires, MPB epidemics, and forest restoration activities. Vicki can be reached at vsaab@fs.fed.us; 406-994-5032.