Some Ecological Considerations Regarding the Future Range of Variability of Lodgepole Pine Ecosystems in Colorado and Wyoming

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Colorado Forest Restoration Institute

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Introduction

As residents and visitors drive and hike through the mountainous areas of Colorado and Wyoming, they will notice large swaths of lodgepole pine landscapes that are undergoing a major transition courtesy of very small beetles. There is growing evidence that this very small beetle is able to provide us with this service courtesy, in turn, of a changing climate. This extensive and ongoing mountain pine beetle (MPB) outbreak has resulted in large numbers of dead lodgepole pine trees across Colorado and other areas of the western United States. The visual and ecological impact on these changed landscapes has resulted in questions about what it means for the future of our forests and communities. In the short term, there are many efforts underway to mitigate the risk of falling trees and fire around roads, power lines, communities and other vital areas. However, for the long term, residents and organizations have questions that ultimately boil down to one: in the future, what will these landscapes look like to our children and grandchildren?

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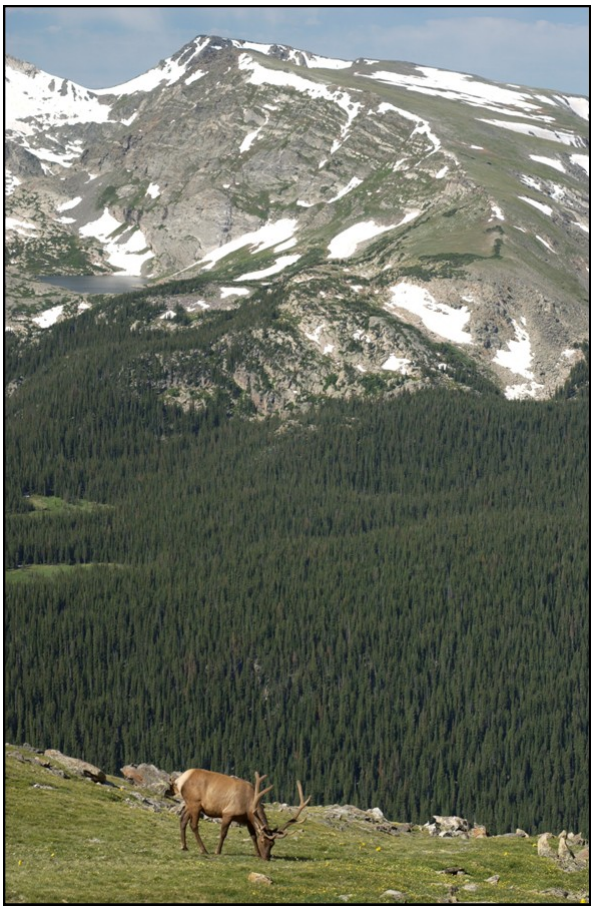


Elk graze on Trail Ridge with the Continental Divide in the background, Rocky Mountain National Park

Forest scientists and managers use the concept of "historical range of variability" to estimate the range of ecological conditions and processes that occurred in the past. This range of variability indicates a set of boundaries between which native biodiversity has been able to persist. For example, a lodgepole pine forest that burns in large crown fires on average between every 100 to 300 years remains within its historical range of variability (or HRV) , because fire suppression has only been in effect for the last ~100 years. A lower elevation ponderosa pine forest that has that kind fire frequency would be considered outside of HRV because those types of forests have evolved with more frequent surface fires. Thinking in terms of sets of dynamic boundaries helps us understand the extremes in climate, fire occurrence and other factors that forests have evolved with and what we can do to restore forests.

In the case of lodgepole pine these concepts help us understand what we can do to effectively decrease fire damage to our communities and infrastructures while allowing the forest to continue on its ecological trajectory. We are now increasingly using a similar concept to estimate the future sets of dynamic boundaries within which ecosystems, ecological processes and conditions may operate: "future range of variability" or FRV (Binkley and Duncan, 2009).

This document was published by the Colorado Forest Restoration Institute (CFRI) to coincide with the conference it is hosting in Steamboat Springs in April 2010 titled "Beyond the Bugs: Future Ranges of Variability in Forest Landscapes and Communities". At this conference the ecological sets of boundaries but also future social and economic conditions will be explored. In this document CFRI, with the help of a number of scientists, aims to address some main points regarding the ecological factors related to future range of variability.

While some questions are still unanswered, a number of scientific studies are in progress to address others. This document is framed around several of the major questions with a few new answers based on current research. This is not meant to be a complete review of these issues but rather a brief summary for a broad audience about where we are in answering some of the questions about the outbreak at this point in time (spring of 2010) and the future of our forests in the central Rocky Mountains. There are other helpful documents that discuss related subjects and we include a few references at the end of this summary for more in-depth discussion of these issues.

There is usually a certain amount of uncertainty in science, as in life, and the more data collected that indicates similar results, the more certainty can be obtained. Although scientists are finding increasing amounts of evidence to support some theories, there is still a certain amount of uncertainty when predicting the future range of variability in lodgepole pine ecosystems. This uncertainty makes place-based efforts that utilize collaborative learning, monitoring and adaptive management all the more essential.

This document itself was the result of collaboration and Colorado Forest Restoration Institute thanks all the authors and reviewers for their contributions to this effort, in particular the lead author Peter Brown.

We hope this document will help the reader to gain further insight into the resilience and opportunities that are inherent in the future range of possibilities of lodgepole pine ecosystems.

Sincerely,

Jessica Clement, Ph.D.
Colorado Forest Restoration Institute
31 March 2010

Aspen forest, Colorado State Forest Service

Question #1: Can anything be done to stop the MPB outbreak?

The short answer to this question is "no". At the very broad scale across Colorado and the central Rockies there are no control measures that forest managers can employ to stop the spread of the beetles. The outbreak will only stop when the beetles run out of suitable habitat or if the overwintering larvae are killed by a consecutive number of very cold days.

However, there is a lot of research focused on control of bark beetles in local areas, for example around homes, campgrounds, and ski areas. These control measures include insecticide sprays or injections into trees, various organic compounds including using the beetles' pheromones, and even some promising research using the beetles' sounds to cause them to change their behavior or abandon trees before laying their eggs. Several of these measures have proven to be very effective on individual trees or in small stands of trees, although most of these measures, especially the insecticides, have to be applied before the beetles are present. Once a tree has been hit, the next best control measure is to remove the tree before the adults emerge from the larval stage and fly to the next tree.

Question #2: Will lodgepole pine forests come back after the beetles have left?

First, it is important to recognize that not all forests affected by beetles are the same. In Colorado, "lodgepole pine forests" range from pure stands where lodgepole pine is the only tree species present, subalpine forests where lodgepole is mixed with Engelmann spruce and fir, mixed-conifer forests with lodgepole pine, blue spruce, fir, Douglas-fir, and often ponderosa pine growing in various combinations, and lodgepole-aspen forests where aspen is co-dominant with lodgepole. In the mixed stands, even with a lot of dead lodgepole pine, the other species will still be there after the outbreak has passed. Only pines (lodgepole, ponderosa, limber, and bristlecone pines in Colorado) are hosts for MPB. Piñon, another pine species found in Colorado, is not affected by MPB but has succumbed to piñon ips, another bark beetle in the southern part of the state.

Colorado State Forest, Colorado State Forest Service

A recent Colorado State University study from the Department of Forest, Rangeland, and Watershed Stewardship (in review) in Rocky Mountain National Park found that in forests where lodgepole pine is mixed with other species, minor increases in fir, spruce, and aspen have occurred. The study also found that even in pure lodgepole pine stands there are numerous surviving seedlings and saplings despite widespread mortality of the dominant overstory trees. The beetles prefer larger trees, leaving many young trees untouched. These young trees will eventually grow to become the future forest, especially now that the canopy has been opened up by the beetles. Thus, these areas will remain as forests - and in most areas they'll remain lodgepole pine forests - for the

Lodgepole pine seedlings, Colorado State Forest Service

foreseeable future. It will just take a while for the surviving lodgepole pines to grow as large as they were before the outbreak.

In studies conducted on managed forest land, researchers from the US Forest Service, Rocky Mountain Research Station compared how stands regenerating after the current pine beetle outbreak may differ from historic, pre-outbreak stand development. They used historic (pre-outbreak) and recent (outbreak) data to quantify seedling densities in unmanaged stands and in harvested areas. In contrast to other parts of North America where tree seedlings have failed to successfully regenerate beneath dead pine overstory, lodgepole pine and subalpine fir both become established beneath untreated beetle-killed stands in central Colorado. New pine seedlings were also found to be abundant both throughout areas that were salvage-logged due to bark beetle attack and those harvested during the pre-outbreak period. This research provides evidence that tree regeneration will be at least as high after extensive mountain pine beetle-caused mortality as under relatively healthy, pre-outbreak conditions, but that species composition of stands regenerating after this outbreak may differ between treated and untreated stands.

There are still questions about the future of lodgepole pine forests generally. Some forests may not have enough surviving seed trees to provide enough seeds for a future forest. Also, in some areas smaller trees - in addition to the dominant overstory trees - are being killed and this may limit the regenerative capacity for the forest to recover after the outbreak. Thus, more research is needed to address this question across broader areas of Colorado where the beetles have had significant impacts.

Nevertheless, at this point there is general agreement among researchers and managers that few stands hit by the beetles have had 100% mortality of the lodgepole pine, and that almost all locations have enough surviving trees to make up the future forests.

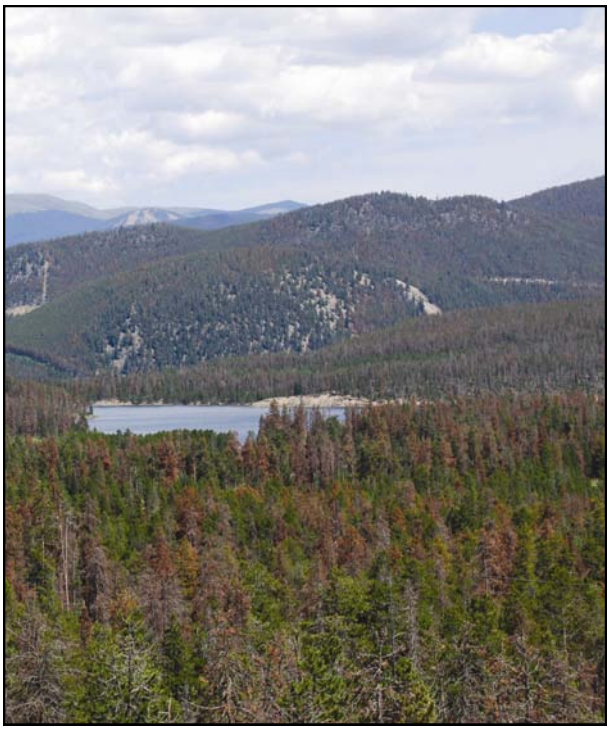
Question #3: Outbreaks have happened before, so why is this one so unusual?

MPB is a natural disturbance in pine forests of the central Rockies. Evidence of MPB has been found in lake sediments going back several thousand years, and it is likely that the links between MPB and pine forests goes back a lot further than that. MPB is a native insect and has co-evolved with its pine host tree species and, as a result, these trees have developed good self-defense mechanisms against MPB attacks. Trees produce resins and other compounds to "pitch-out" the adult beetles

Colorado State Forest Service

before they are able to lay their eggs in the tree's phloem. The phloem is what the beetle is after; this is the area just under the bark where sugars produced by photosynthesis in the leaves travel down the stem to produce new stemwood and roots. The larvae "mine" the phloem around the stem, and if enough of them are present they may eventually completely girdle and kill the tree. Another means MPB can kill a tree is by introducing blue-stain fungus into the tree's sapwood, which starves the tree of water and nutrients.

It is also important to distinguish between "endemic" levels of MPB activity, in which individual trees or small patches of trees are killed, versus "outbreak" (also called epidemic) levels in which large numbers of trees across large areas are killed. In contrast to endemic levels, during outbreaks beetle populations soar and can overwhelm the trees' defenses through mass attacks, leading to both increased mortality of the trees they hit and more extensive areas of dead trees across a landscape.



Colorado State Forest Service

Dead lodgepole pine trees killed by infestation of the mountain pine beetle contrast with living lodgpole pine as well as other conifers and aspen trees on private land in the Old Park Subdivision near Gore Pass northwest of Kremmling, Colorado, Arapaho National Forest, June 9, 2007.

During the 20th century in Colorado (the period for which we have observations), foresters recorded both lots of endemic MPB activity as well as numerous fairly extensive outbreaks during which many trees were killed across large watersheds or mountain ranges. But we have no record of an outbreak on the scale we are experiencing now. In fact, many people suspect that the current outbreak may be more extensive and severe than any outbreak over at least the past few centuries. On the other hand, we do not have the type of historical evidence we need in order to know for sure how unusual the current outbreak is. Unfortunately, MPB outbreaks do not leave physical evidence (such as fire scars that provide a record of past forest fires) that would permit researchers to reconstruct the type of outbreak histories needed to definitively answer this question.

Another important fact to know about the current MPB outbreak is that it is not just happening in the central Rockies, nor is MPB the only issue. MPB is only one of many species of bark beetles that have been causing concern in western forests during the past 10 years or so. A recent outbreak of piñon ips - coupled with widespread and severe drought -

caused significant mortality of piñon trees in piñon and juniper woodlands over large areas of the Southwest, including southwestern Colorado. Also extensive outbreaks of spruce bark beetle have impacted spruce forests stretching from the San Juan Mountains in Colorado up to Alaska.

This brings up a major question of whether these outbreaks are related in some way. These major outbreaks - coupled also with large forest fires over the past few years - have many researchers and managers wondering if this is not the beginning of widespread transitions in ecosystems due to global climate changes. Although it is difficult to show a direct cause and effect between the two, changes in drought patterns, increased temperatures, increased growing season lengths, earlier snowmelts, longer fire seasons, and other interactive climatic and ecosystem changes have occurred or are predicted to occur as a result of global climate change. In fact many researchers believe there is strong evidence that changes occurring in our forests today are the result of broader changes in climate patterns. If this is the case, recognition of these climate-driven changes is important both for the future management of our forests and to increase acceptance that some of our forests may be forever changed from what they have been in recent memory.

Question #4: What is the effect of beetle-killed trees on the risk and severity of fire?

First, it is important to recognize a difference between fire risk and fire severity. Fire risk is the chance that a fire will start. Fire severity is the effect of fire on plant communities, usually measured as the amount of trees removed. Fire - like bark beetles - has always been an ecological factor in lodgepole pine forests. Probably most if not all lodgepole pine forests in Colorado established after past, severe stand -replacing fires. This means that there is always some risk that a lodgepole pine forest will burn in a crown fire. So it is wise to take measures to protect communities and infrastructure from fire regardless of whether MPB is a factor or not. Generally, it takes the right combination of the proper weather conditions - very dry, low humidity, hot, and typically a strong wind, plus an ignition either from humans or lightning - for a crown fire to start and spread. These conditions will still need to exist even with the addition of MPB-killed trees.

Lodgepole pine cone, Colorado State Forest Service

Furthermore, fires in lodgepole pine forests always have been very severe, with most of the forest killed by burning of the tree crowns. In fact, lodgepole pine trees have evolved a unique ability to re-colonize a site after a severe fire. Most lodgepole pine trees throughout the Rockies have serotinous cones, in which the seeds are stored in resin-sealed cones that actually require the heat of a fire or intense sunlight to open. Lodgepole pine trees are also very shade-intolerant, meaning that they prefer open forest conditions to germinate and grow. Both of these factors come together because lodgepole pine forests typically burn during

infrequent crown fires, once about every 100 to 300 years, during which most or all of the forest is killed. After the existing trees are dead, the cones open and release seed into an environment that is ideal for their germination and rapid growth. The end result is that a few decades after a fire a new forest is established.

Lodgepole pine seedlings, United States Forest Service

Given that fires in lodgepole have always tended to be severe, the question is whether the risk of a future fire has increased because of the presence of the MPB-killed trees? As in much of ecology, the answer to this question is, "it depends", in this case on the time since the trees were killed. Just after the tree dies, the needles dry out and turn red. During this "red stage", fire may indeed burn more easily through the tree crowns. However, this stage is very short-lived; within 2 to 3 years the red needles fall off. If there are no ignitions and weather conditions are not conducive to maintaining a fire, this stage will probably pass uneventfully for most MPB-affected forests. Once the needles have fallen, fire is much less likely to spread through the bare canopies. Crown fire risk is therefore actually reduced for some years during this "grey stage" due to the reduction of canopy fuels, and the fact that it's hard to ignite wood (twigs, branches and stems) on standing dead trees once the smaller and more flammable needle "kindling" is gone.

However, once the dead trees start to fall in coming years, there is some question as to whether the accumulation of large woody stems on the forest floor may contribute to intense surface fires (rather than canopy fires) if an ignition occurs. There is concern that such fires may damage soils and emerging seedlings, and will increase the risk of erosion and impacts to watersheds. However, because dry, windy weather will still be required for fire to spread, the chance of a fire occurring may not be all that much greater than before the outbreak. Whether a severe surface fire will cause ecological damage, should it occur, is an area that needs more research. And all these conclusions depend on whether or not we enter a new period of dryer and hotter climate, in which case fire may be more likely to occur regardless of any difference that the MPB-killed trees make to fire risk.

Ponderosa pine forest, Colorado State Forest Service

Question #5: Will the MPB outbreak move from lodgepole pine forests into ponderosa pine forests?

In addition to lodgepole pine, several other species of pine in Colorado are potential hosts for MPB, including ponderosa pine, white bark pine, limber pine, and Rocky Mountain bristlecone pine. Current research suggests MPB may indeed be starting to move into these other species and into areas where it has not been a problem before now.

Ponderosa pine cone, Colorado State Forest Service

A recent survey conducted during the summer of 2009 in mixed lodgepole pine/ponderosa pine stands extending from the Wyoming border to Gilpin County in the northern Front Range found as much as 50% mortality in the ponderosa pine in addition to the lodgepole pine. The levels of mortality varied widely, with the greatest mortality in stands north of Estes Park and the Larimer County line. However, the MPB is expected to move even further south and into stands that have not seen the outbreak yet. Losses of ponderosa pine are most severe in areas with large populations of MPB already present in denser lodgepole pine forests, which then disperse into the adjacent ponderosa pine forests. Loss of limber pine and bristlecone pine is also starting to increase in areas where these two species occur. Currently, mortality is again greatest in stands closest to existing MPB-affected lodgepole pine forests. Thus, it appears likely that the outbreak will continue to expand into new species and new areas for at least the near future.

Question #6: Can we "beetle-proof" future forests?

It is logical to wonder whether fire suppression and/or the lack of forest treatments have increased the "homogeneity" of our forests, leading to continuous landscapes of suitable MPB habitat with even-aged lodgepole pine forests. However, as mentioned above, fire intervals in lodgepole pine forest range on average between 100 to 300 years, and both fire establishment and MPB outbreaks are far more driven by weather conditions than immediate human activity or the lack thereof.

Colorado State Forest Service

Thus, treating entire landscapes in order to "beetle-proof" them will be difficult, costly and may cause unforeseen and possible undesirable ecological consequences. Despite the best science on how stand structure impacts MPB, we will never be able to create completely "beetle-proof" our forests.
However, at smaller scales there may be

The Mummy Range from Moraine Park, Rocky Mountain National Park

chances to at least decrease future beetle impacts. This depends mainly on the forest. One recent Arizona study found that ponderosa pine stands with higher tree density had heavier MPB mortality rates. Other studies have also agreed that thinning can reduce MPB population levels in ponderosa pine forests.

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In lodgepole pine forests the options are more complex. In contrast to many ponderosa pine forests that historically contained more open, often "park-like" stands, lodgepole pine forests have always tended to naturally be more "closed canopy". Although there is some evidence that while on stand scales, silvicultural thinning in lodgepole pine can reduce MPB-caused mortality, on large scales thinning appears more likely to create unnatural stand conditions and trees that are left may be lost to blow-down because of lodgepole pine's typically shallow root system. One approach to reducing future impacts of beetle outbreaks is to create - through timber harvests and prescribed fires – greater diversity in landscape forest conditions that will reduce the suitable MPB habitat. However, this is a long-term approach to the problem. The appropriate time to treat stands will be after the current epidemic has run its course and MPB populations return to pre-epidemic levels.

Furthermore, although we know a lot about the stand-level conditions and treatments that can make forests less susceptible to endemic levels of MPB attacks, we still lack knowledge of how to apply those treatments across landscapes and what impacts they may have on MPB outbreaks and other ecosystem conditions.

Question #7: What does the MPB outbreak in lodgepole pine ecosystems mean for wildlife?

First, the main points:

1) Wildlife populations are expected to change in the short- and long-term with the response of each species changing over time as forests recover from MPB epidemic. Some will respond positively and some will respond negatively.

2) The consequences will be dramatic for some wildlife species with significant changes in their populations in first 3 to 7 years. However, we do not expect any unacceptable catastrophes to animal populations.

3) Wildlife in this region have experienced dramatic forest changes in the past, so the ability of species to move and respond to forest disturbance is not being tested for the first time.

Rocky Mountain Elk, Colorado State Forest Service

With an understanding of species habitat relationships, biologists can predict, with reasonable confidence, the outcome for many species in the short-term. Because of the strong tie between wildlife and vegetation we can be certain that species abundance and distribution will change as a result of the epidemic and as forests recover.

Wildlife species' responses to MPB will be **very species-specific**. Some species will respond with increasing populations, while others will decline (a perfect contrast is the difference between woodpeckers and pine squirrels, see below). These responses will also change over time, particularly in the short-term immediately following infestation and tree death but also as response to forest recovery in the mid and long term.

Looking beyond the short-term, it is important to remember that these are dynamic systems – 10, 20, and 50 years from now the birds, mammals, and insects will be quite different than those this past year. We know forests in Rocky Mountains are adapted to severe disturbance and that forests will recover. Although future forests will not be the same as past they will be reasonably similar.

The dramatic change in forest from MPB is unlikely to result in an 'unacceptable' catastrophic, region-wide decline in any vertebrate species. There are no wildlife species that are dependent solely on lodgepole pine. But, there are many species that find quality habitat in lodgepole pine.

Hairy Woodpecker, Colorado State Forest Service

The Regional Forester has a list of priority species classified as 'Sensitive Species' which include:

American marten, pygmy shrew, northern goshawk, boreal owl, olive-sided flycatcher, American three-toed woodpecker, black-backed woodpecker.

Table. 1. How might populations of these species change? As trees die, will a majority of species decline? To give an idea of possible projection for the first 5 years following mortality, we think there will species will typically respond as follows:

Wildlife Population Projections for the first Five Years after MPB Outbreak	
Increase	**Decrease**
American three-toed woodpecker	Pine Squirrel
Downy woodpecker	Red-back vole
Hairy woodpecker	Northern goshawk
Northern Flicker	Boreal Owl
Red-breasted nuthatch	Snowshoe hare
Stellar's Jay	Brown Creeper

Other important species to consider:

Snowshoe hare, pine squirrel, Rocky Mountain elk, hairy woodpecker, northern flicker, red-backed vole, mountain bluebird, red-breasted nuthatch.

Even in the short term, wildlife species' responses won't be completely predictable and we can expect some interesting species interactions. To give a few examples, here are some possible scenarios for four lodgepole associated wildlife species:

Red Squirrel, Colorado State Forest Service

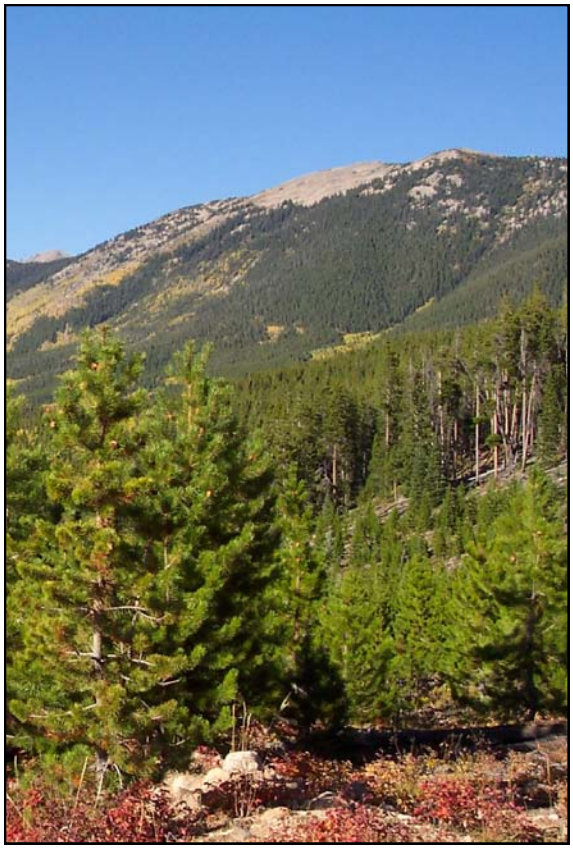
Pine squirrels will experience a dramatic response to bark beetle.

- They feed on a variety of foods: mushrooms, fruit, even bird eggs and young birds but rely on seeds from pine cones for winter survival.
- Have pine cone middens and smaller caches as hedge against variable cone crop.
- Biologists familiar w/ squirrels suggest that stored cones may provide up to 3 winters of food for squirrels leading to a potential lag between lodgepole mortality and squirrel mortality.
- Within a decade, squirrels will likely be absent from stands - formerly pure mature lodgepole.

The dynamics of re-colonization of forests by pine squirrels and identifying which forests act as refugia for squirrels will represent one of the neat drama's we'll observe over the next 30-40 years.

American three-toed woodpecker: (similar expectations for other woodpeckers)

- Populations will increase rapidly in response to abundant food supply
- Remain super abundant for about 5 years while pine beetles are present in the forests
- Drop in abundance very rapidly to levels BELOW the pre-epidemic abundance.
- Will be virtually absent in areas formerly dominated by lodgepole pine during the next 70 years then gradually increase in abundance. In areas of mixed spruce-fir/ lodgepole pine the species will increase in abundance during the epidemic and then decline to pre-epidemic levels more gradually.



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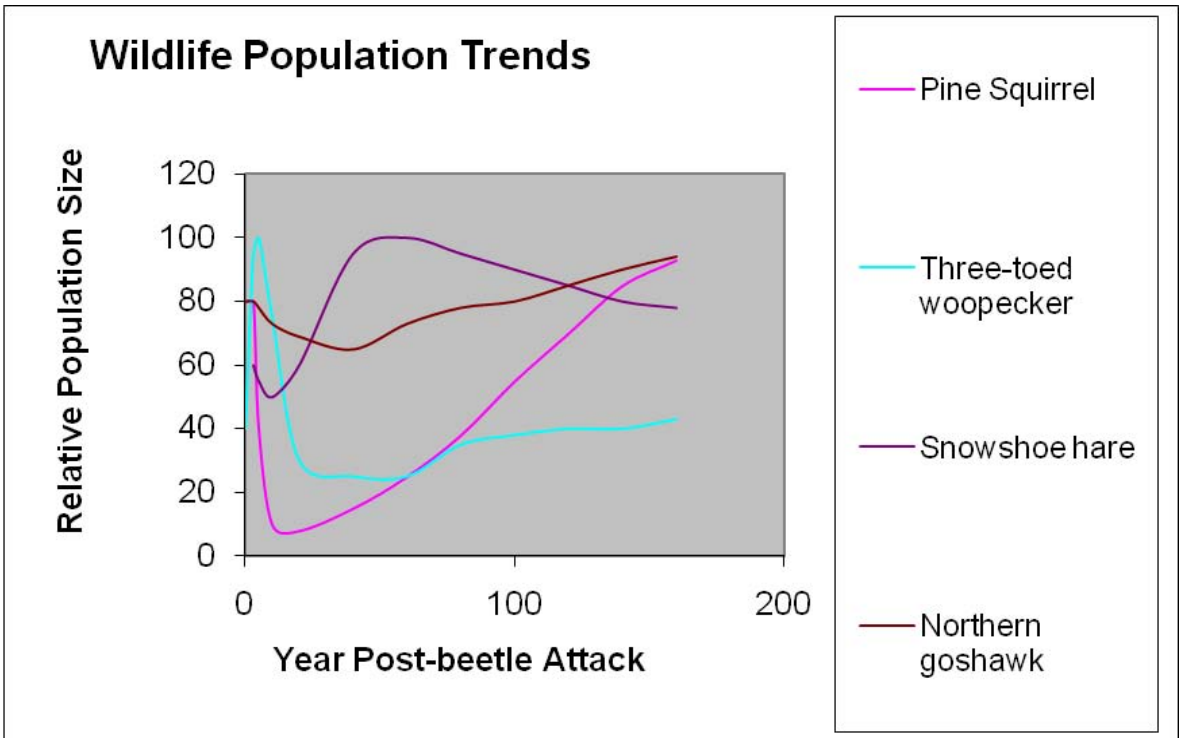


Figure 1. Wildlife Population Trends After MPB. By Greg Hayward, USFS and Robert Skorkowsky, USFS

Snowshoe hare (is the primary prey species for the Canada lynx and other predators):

- Generally expect a gradual decline in areas dominated by older lodgepole
- Remain at low numbers for next 10-15 years.
- Rapid increase during the period when regenerating lodgepole is dense and above the snow level.
- Will remain high for 20 years or more, then decline again as foliage moves above reach, till complex forest structure develops when hare will again increase.

Snowshoe Hare, Colorado State Forest Service

Northern Goshawk (eats all of the species mentioned above).

The northern goshawk has a strong association with lodgepole pine forests in the Rocky Mountain region but is found in a variety of forest types.

This highly territorial raptor, will remain within traditional nesting and foraging territories until stands begin to fall apart and prey species populations decline (the increase in woodpeckers will offset the decline in pine squirrels in the short-term).

As prey populations decline and nesting stands begin to fall apart, this species will redistribute itself to other live forest types with higher prey densities.

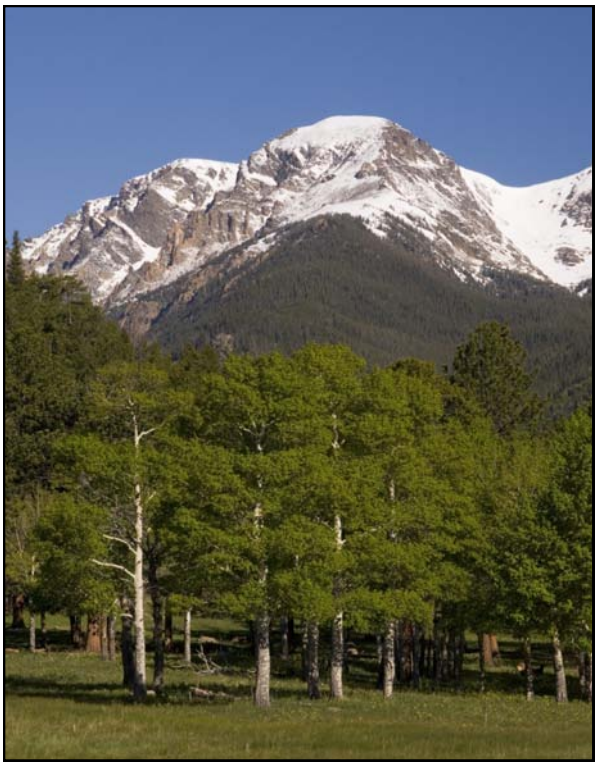
Elk: (important to many recreationists, wildlife agencies and source of income for rural communities): We may see a positive response due to more forage and depending on the site (over short and mid-term) cover. So there may be an increase in numbers which is a management problem in portions of the state.

Rocky Mountain Elk, Dave Leatherman

Summary

Seen from an ecological perspective, we can say with some certainty that the current outbreak is much larger in extent than anything seen since European settlement, but that the presence of MPB and MPB-killed trees in our forests is part of a natural process that has been going on for thousands of years. We can also say with certainty that lodgepole pine forests will not disappear from Colorado or Wyoming. Lodgepole pine forests, other Colorado forests and the wildlife species we treasure will still be there for our children and grandchildren in the future. But right now, seen from the social, economic, and aesthetic perspectives, the outbreak may be viewed as a major change to our forests. No one likes to see hillsides of dead and dying trees.

So what is needed is some balance to these perspectives. One way to do that is by taking the long view. When looking at the hillside of dead trees in back of your house or on your drive home from a weekend skiing, remember that this is natural disturbance agent that is changing the forest. Forests are dynamic systems that are constantly changing. Turnover of the forest has happened before - either from beetles or fire – and the forest will recover. We need to learn as much as we can from how and why this outbreak occurred and apply these lessons to future management of the forests, for the benefit of forest landscapes and communities.



Mount Chapin from Horseshoe Park, Rocky Mountain National Park

Further Readings

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Cover photo: Longs Peak and Bear Lake with fall aspen, Rocky Mountain National Park, Colorado

Back cover photo: Mount Sneffles area

Conference Notes

Conference Notes

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