A Prospectus on Restoring Late Successional Forest Structure to Eastside Pine Ecosystems Through Large-Scale, Interdisciplinary Research

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ABSTRACT. At two different locations in northeast California, an interdisciplinary team of scientists is initiating long-term studies to quantify the effects of forest manipulations intended to accelerate and/or enhance late-successional structure of eastside pine forest ecosystems. One study, at Blacks Mountain Experimental Forest, uses a split-plot, factorial, randomized block design. Twelve 100-ha. split plots provide for three replications of two levels of each of three treatments: (1) forest structural diversity—high (emphasizing late-successional attributes) versus low; (2) fire—reintroduction versus continued exclusion; and (3) grazing—continuation of grazing versus exclusion of livestock. Existing Research Natural Areas act as "qualitative" controls. The other study, in the Goosenest Adaptive Management Area, uses a fully randomized design to test different approaches to accelerate the development of late-successional pine forests. Twenty 40-ha study plots provide for five replications of three treatments: pine emphasis—accelerating to late-successional attributes, emphasizing pines, (1) with fire and, (2) without fire; (3) large tree emphasis—accelerating to late-successional attributes, emphasizing largest tree diameters regardless of species, without prescribed fire, and (4) no treatment controls. All disciplines involved (wildlife, entomology, soils, fire, vegetation, etc.) are evaluating the same treatments, with all observations referenced to a 100 m grid network, allowing for detection of important interactions and processes in this large scale research.

Introduction. The great coniferous forests of western North America have been dramatically altered in the past century. Extensive logging, long-term fire suppression, and variation in precipitation are the primary forces that have changed forest structure and processes. Among the consequences of such change are the decline of species restricted, or nearly so, to late-successional forests. A re-evaluation of forest ecosystem management on public lands has begun. The Record of Decision (ROD, 1994) made clear the need for scientifically sound and ecologically credible ecosystem management in the range of the Northern Spotted Owl (Strix occidentalis). The ROD was as much for the owl protection as it was a prospective of all other wildlife interacting in the ecosystems in its range. An ever-expanding literature centered on ecosystem management (e .g., Franklin 1993, Slocombe 1993, Grumbine 1994, Alpert 1995, Chapin et al. 1996, Sampson and Knopf 1996, Boyce and Haney 1997) identifies the need to understand forest ecosystems at scales and for processes not previously considered. Central to any notion of empirically based ecosystem management is identifying and understanding processes on large spatial and long temporal scales that are critical to ecosystem function and sustainability. Despite decades of research on issues that are still today very relevant to ecosystem management, there remains a general paucity of understanding of how ecosystems "work," and, in particular, how key species and processes interact at scales relevant to understanding whole ecosystems.

The extensive pine forests on the east side of the Cascade Range and Sierra Nevada mountains have been, perhaps, the most dramatically altered in appearance since the time of European settlement (Laudenslayer and Darr 1990, Covington and Moore 1994). In particular, fire suppression has greatly changed the structure and composition of these forests that historically had frequent fire. Logging and cattle grazing have also played major roles in altering these ecosystems. Variation in annual precipitation has likely played a role as well (Fritts and Gordon 1980).

Fire regimes occurred naturally in eastside pine forests at intervals as frequent as three to fifteen years (Skinner and Chang 1996, Alan Taylor pers. comm.). Pre-European settlement forests were characteristically very open and park-like in appearance (Laudenslayer and Darr 1990, Covington and Moore 1994). They were composed of small stands of relatively even-aged trees interspersed with patches of other even-aged forests of different ages. Trees could be very large (greater than 80 cm dbh). Vegetation under the pines was often perennial grasses with few shrubs. These were the late-successional forests of the recent past. Note that the "succession" focus is one more of habitat structural components than of a sequence of a species replacement sequence. Late successional eastside pine here is defined in the context of its large-tree, park-like appearance. Fire history is critical to both the appearance of the large trees (with their fire-trimmed trunks) and the absence of woody understory elements.

In contrast, the eastside pine forests (and other ponderosa and Jeffrey pine dominated forests) of the present, after more than a century of logging, several decades of fire suppression, and intensive cattle grazing, differ in structure and composition. Their ecological processes are likely radically different. The pines today are, for the most part, younger and smaller, white fir is much more prevalent, and shrubs of several species have largely replaced the grasses in the understory (citations as above). A major consequence of these changes is a higher fuel load, and so fires that escape suppression can be of very high intensity and can produce devastating consequences to both these forests and surrounding areas. These forests are considered "early successional" with smaller trees, a more diverse shrubby understorey, and the absence of a fire regime.

The present distribution of the "yellow pines", ponderosa pine Pinus ponderosa and Jeffrey pine P. jeffreyi, that dominate these stands, occupy vast tracts of land from Baja California to British Columbia, and extend from the Cascade-Sierra axis east to the Rocky Mountains and to the Black Hills. The pine forests of our particular interest, the so-called "Eastside Pine" forests (McDonald 1983) of California, are distributed at elevations from 4,000 to 6,500 feet east of the Sierra Nevada – Cascade Range crest in northeastern California. The summers are warm and dry and the winters are long and cold. Ponderosa pine and, at higher elevations, Jeffrey pine dominate these forests, with California white fir (Abies concolor var. lowiana), incense cedar (Calocedrus decurrens), Sierra lodgepole pine (Pinus contorta var. murrayana) as typical associates. Shrubs of several species (Arctostaphylos spp., Cercocarpus ledifolius, Chrysothamnus spp., Artemisia spp., and Purshia tridentata, primarily) are common.

Here, we introduce a prospectus of the study design for two separate sites of large-scale research intent on restoring, and evaluating responses to, forest structures in eastside pine forests. Two features of this research are worth emphasizing: first, the study design planning and the research have been and is being done by an interdisciplinary team. The team is composed primarily of researchers from the Pacific Southwest Research Station of the USDA Forest Service, and a few collaborators from non-governmental organizations and universities. We contrast our notion of an interdisciplinary team from that of a multi-disciplinary endeavor because the team has jointly designed these research projects and we have worked out the details of the treatments and replicates. We have focused the direction of our individual disciplines towards evaluating the main effects of the treatments (Oliver et al, in prep.). Second, the size of our plots is large enough to encompass and evaluate the response variables from each discipline including wildlife, particularly woodpeckers, songbirds, and small mammals. Plots are from 40-50 hectares in size, large enough to contain several home ranges or territories of taxa from these groups. These large plots have replicate treatments and controls, so we can attempt to understand the variation in response of these groups.

Our two study sites are at the Blacks Mountain Experimental Forest, Lassen National Forest, and at the Goosenest Adaptive Management Area, Klamath National Forest, in Northern California. The Blacks Mountain Experimental Forest (BMEF), northeast of Lassen Volcanic National Park, was established as a formal research area in 1934 with some research dating back to 1910. Logging over much of the forest has been restricted to various modest silvicultural prescriptions. Fire has been suppressed. The forest is remarkable, therefore, for the number of very large and old trees still present, albeit with the above-mentioned white fir invasion. The forest at BMEF has both ponderosa and Jeffrey pine, with white fir and incense-cedar also common.

The Goosenest Adaptive Management Area (GAMA) is north of BMEF, east of Mount Shasta, and near the town of Macdoel, California. It is a more typical of present-day eastside pine forest in that it was subject to intensive logging since the early decades of this century. Fire suppression dates from near that time as well. The forest today is one with small to medium sized trees and extensive invasion of white fir. Almost no trees remain standing from the turn of the century. Ponderosa pine and white fir are the main conifers; there are no Jeffrey pine present.

In 1991, the groundwork for the research and treatments at BMEF was begun. The implementation of treatments began in 1996 through the thinning of treatment plots. The thinning continues this year (1997) and will be completed by the end of 1998. The re-introduction of fire through prescribed burns commences this fall (1997). Planning for the research at GAMA began in 1995. Forest manipulations at GAMA will commence (and are planned to be finished by) 1998. Prescribed burns may begin there by the fall of 1998.

Methods.

The two projects outlined below involve virtually the same members of an interdisciplinary research team (see Acknowledgements). The research disciplines include wildlife, entomology, fire ecology, soils, silviculture, and other disciplines. The projects have a separate administrative and funding history, but both are related to the theme of restoring late-successional forest structure characteristics to the existing forests. All plots described below have permanent, uniquely numbered grid points at 100 m intervals, and so all measurements have been and will be referenced to this system. Neither project is designed to be a "before and after" research program. The comparisons between treatments, and between treatments and controls will establish the anticipated (and necessary) long-term aspect of our study design. The treatments outlined below reflect our efforts at the outset. We anticipate the need to "re-enter" our treatment plots for subsequent manipulation through time. It should be made clear that there is no single definition or prescription available, nor could there be, for historic eastside pine forest structure. The reasons are both practical and philosophical. The practical reason is that, unlike the wetter coastal coniferous forests, virtually no late-successional ("old-growth") pine remains in the West. We are studying a forest in the Ishi Wilderness of the Lassen National Forest a forest, the Beaver Creek Pinery, which has had no fire suppression and has not been logged. It is, however, on the west slope of the Sierra-Cascade region and is small (ca. 100 ha.). We have looked at historic photos from many areas, and have a sense of stand densities and fire histories of eastside pine (A. Taylor, pers. comm.). From this we know that forest stands generally were considerably less dense (more park-like) with less shrub cover than present, as discussed above. From a philosophical standpoint, we recognize that the continual influence of a changing climate, the diverse effects of local conditions, and other sources of variation all make identifying a single eastside pine forest structure an unrealistic target. Therefore, our treatments reflect a general understanding of forest structure (primarily tree composition, age-class structuring and spatial scaling) of eastside pine prior to European settlement, and our treatments reflect the current structure of the forest we are working with.

The Blacks Mountain Experimental Forest is basically a large-tree forest with a 80-year history of fire suppression. Our main goal here is to maintain and enhance the late-successional forest characteristics of this eastside pine forest. The main research design at BMEF is a randomized block design with split plots (Table 1, Figure 1). In each plot prescribed fire will be introduced into one half, and kept out of the other half. Blocking was required because of the differences in the proportion of white fir (an elevation and aspect effect) among plots. We do not have untreated controls per se. Four existing Research Natural Area Plots will act as "qualitative" controls: they were not randomly assigned and have had a separate silvicultural history.

At BMEF we are creating two forest structures through manipulation. One treatment is intended to recreate late-successional forest structure, the other treatment to strongly contrast the former. The "High Structural Diversity" treatment retains the presence of the many large, old trees (primarily ponderosa pine, Jeffrey pine, and incense-cedar) that remain from the pre-European settlement days. The abundant snags are retained. The manipulations in this treatment attempt to create multiple canopy layers with interspersed dense clumps of smaller trees. The treatment creates many small canopy gaps and forest floor openings. It is a treatment that not only thins to a park-like structure with large trees, but also mimics the horizontal variation of patches of age-classes that helped characterize forest structure of a century ago.

For contrast, the "Low Structural Diversity" treatments will thin to a single canopy layer with small trees well spaced with very few large trees. Snags remain standing, but their exposure above the remaining canopy will probably accelerate their decline. In contrast to the horizontal structuring of the first treatment, there will be few canopy gaps and forest floor openings. Details of the treatment prescriptions will be published elsewhere.

Six replicate split plots exist for each treatment. Plot sizes vary somewhat, but each half of a split plot averages 50 hectares. Prescribed fires will be established in half the area of a split plot, and the other half will continue with fire suppression. The periodicity and seasonal timing of prescribed fires will be judged through time. The first prescribed fires are to be conducted in the fall of 1997.

The "qualitative" controls, the four Research Natural Area plots (RNAs), will have no forest thinning prescriptions. These plots are not split plots as in the treatments, however two will be treated with prescribed fire. The RNAs average 50 ha. in size.

Half of the split plots in each treatment (three each) and all of the RNAs will have fencing to exclude cattle grazing. Plots with the exclusion of cattle grazing will be fenced after the harvest treatment, but before the burning treatment.

The Goosenest Adaptive Management Area site, in contrast to the BMEF site, is virtually devoid of large pines. The proportion of white firs present is also greater. At GAMA, the challenge and main effort is to come up with prescriptions that accelerate the development of late-successional forest from

Table 1. Comparison of experimental design at both "Eastside" Pine research sites.

Site	Blacks Mountain Experimental Forest; Lassen National Forest	Goosenest Adaptive Management Area; Klamath National Forest
Emphasis	Maintain and enhance late-successional eastside pine forest characteristics	Accelerate development of late-successional forest characteristics of eastside pine
History	Experimental Forest's research date to 1910; partial harvesting and fire suppression results in large tree forest with white fir invasion today	Extensive logging and fire exclusion history over past 80+ years has resulted in few, mostly small and medium sized pines, with extensive white fir invasion.
Treatments	High Diversity Treatment: Thins to maintain the presence of many large, old trees with abundant snags, multiple canopy layers with dense clumps of smaller trees, and many small canopy gaps and forest floor openings (separate treatments with and without fire). Low Diversity Treatment: Meant to sharply *contrast* above; very few large trees, few snags, a single canopy layer with trees well spaced and few large canopy gaps and forest floor openings (fire treatments as above)	Late-Successional Pine Emphasis: Accelerate to late successional structure by selecting for ponderosa pine through thinning (to 80% pine by basal area). Create openings (15% of plot) of 0.2 –1.2 ha. Increase the proportion of pine in this initial entry by regenerating the openings. Prescribed fire in half of plots. "Big-Tree" Emphasis: "Accept" white fir invasion, thin small to medium sized trees of all species. Maximize individual tree growth and minimize the number and size of forest openings. No prescribed fires in these plots.
Controls	The existing Research Natural Areas (RNAs) serve as "Qualitative" controls as they were not randomly assigned and have a separate silvicultural history.	True controls, randomly assigned; continue with fire suppression and no other treatments.
Replicates and Area	12 Plots as "Split-Plots", 6 of each treatment divided into prescribed fire and no fire splits. Splits are ca. 50 hectares each; 4 "Qualitative" controls (RNAs) average 50 hectares (2 with prescribed fire, 2 without).	20 Plots of exactly 40 hectares each; 10 Late Succession Pine (5 with prescribed fire, 5 without), 5 "Big Tree" Emphasis (no fire treatments), 5 Controls (no fire treatments).
Calendar	Forest manipulation began in 1996, will be finished in 1998. Prescribed burns begin in fall 1997	Forest manipulation planned for 1998. Prescribed burns planned for 1999.

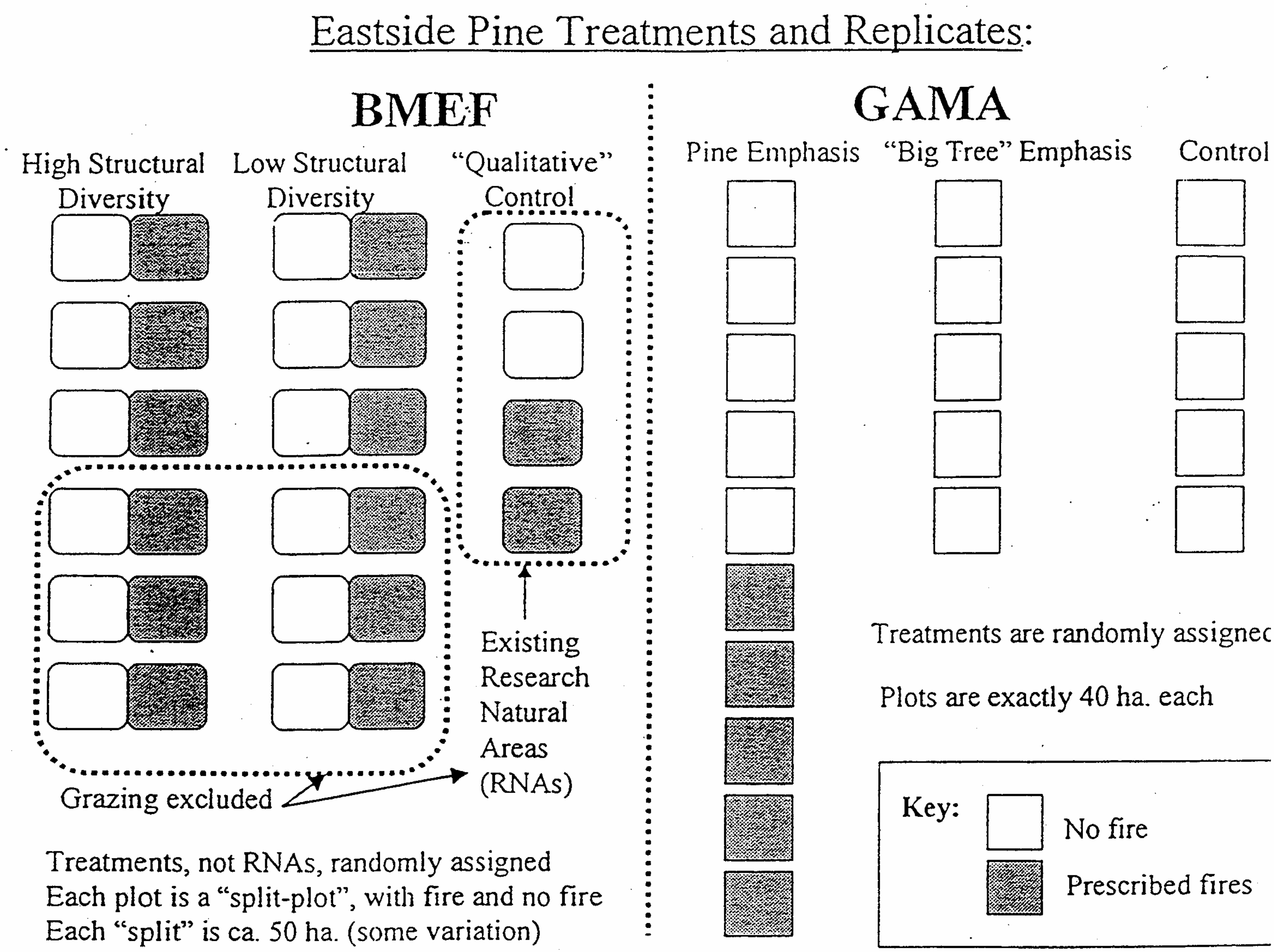

Figure 1. A schematic representation of the treatments and replicates involved at the Blacks Mountain Experimental Forest (BMEF) study site (Lassen National Forest) in comparison with the Goosenest Adaptive Management Area (GAMA) study site (Klamath National Forest) in Northern California.

existing young stands. Our two treatments reflect that interest (Table 1 and Figure 1). We have developed a fully randomized research design with three treatments and controls. Treatments and controls are replicated five times each. At GAMA, we have 20 plots of 40 ha. each. Most all plots are square. Each of the following treatments or controls was randomly assigned to the plots.

The "Late-Successional Pine Emphasis" treatment attempts to re-create forest structure and composition prior to European settlement. We are attempting to accelerate the development of large ponderosa pine trees in this treatment by attaining at least 80% composition of pine by basal area. We will attempt to do this with minimal differences in distribution of age classes between plots. As in the "High Structural Diversity" treatment at BMEF, we are attempting to instill representative horizontal diversity of age classes. Thus, we will create openings of 0.5 –1.2 ha. covering at least 15% of a given plot's area. These openings will be the sites of pine regeneration in the near future. Five of the "Late Successional Pine Emphasis" plots with have prescribed fires, five will continue fire suppression.

The final treatment we call "'Big Tree' Emphasis." In these plots, we in effect "accept" the consequence of white fir invasion and, instead of thinning for pine, we thin small to medium sized trees of all species. In this treatment, we are selecting for the larger trees of all species in an attempt to maximize individual tree growth. In these plots we are also minimizing the number and size of forest openings and no prescribed fires are anticipated. Attempting to prescribe fire in plots heavy with white fir would likely result in a conflagration that would leave few surviving white firs.

Control plots at GAMA will not be thinned or burned. In contrast to BMEF, GAMA controls were randomly assigned and so can be quantitatively compared with the three GAMA treatments ("Late Successional Pine Emphasis" with fire and without fire, and "Big Tree Emphasis."). Detailed methods of our treatment criteria and application will be published elsewhere.

Discussion.

Our large-scale, interdisciplinary research at Blacks Mountain Experimental Forest and at the Goosenest Adaptive Management Area afford us the ability to evaluate the consequences of manipulating eastside pine forests toward late successional structure (Figure 2). At BMEF, a large tree forest, we are thinning to enhance late successional characteristics and re-instill tree densities at levels similar to forests of a century past. Contrasting treatments at BMEF effectively reverse the successional stage to one much younger. At GAMA, we are attempting, through two separate treatments, to accelerate late successional characteristics in young forests, one selecting for ponderosa pine, the other simply for the largest existing trees. At BMEF and GAMA, we are evaluating the re-introduction of fire and contrasting its effects to the continued regime of no fire. At both sites, we have replicate plots to account for much of the variation in response that may otherwise mask the normative signal.
As our research on these treatments is interdisciplinary, we have created the opportunity to evaluate the response to these various treatments across many

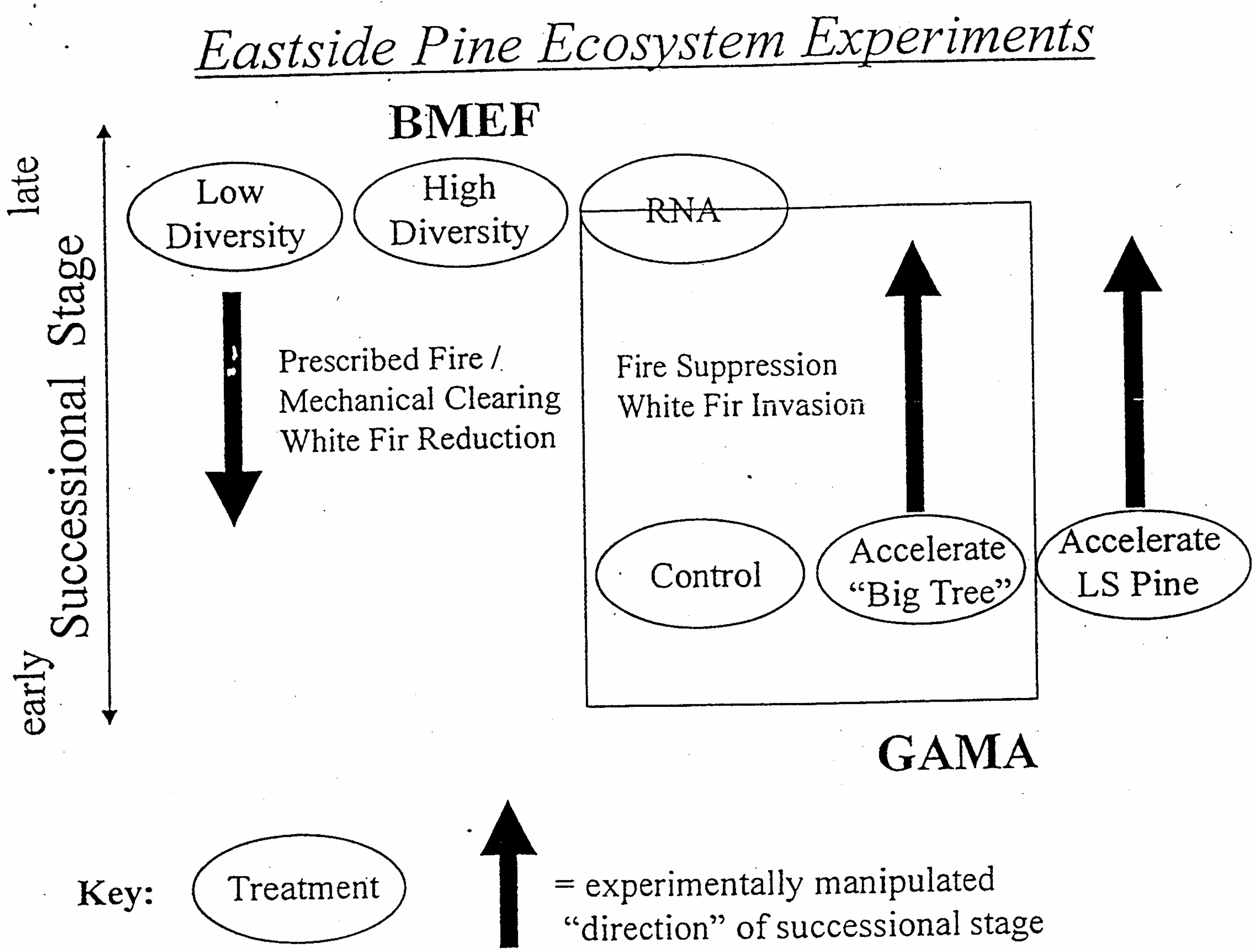

Figure 2. A schematic representation of how our treatments at Blacks Mountain Experimental Forest (BMEF) and the Goosenest Adaptive Management Area (GAMA) are attempting to manipulate forests with respect to successional stage. Succession in East Side pine forests refers more to condition than to composition, as early and late stages involve a similar vegetative community with structure and processes that differ along the early – late successional continuum. See text for details.

disciplines. Our ability to detect important interactions (e.g., woodpeckers – forest insect pests, soil processes and fire regime, small mammal response to prescribed fire) is greatly enhanced by the research design, and the we have the ability to reference phenomena on finer scales owing to the grids in the plots. Many fruitful avenues of research in our "templates" at BMEF and GAMA are possible. As our research is intended for long-term study, and not constrained to pre- and post-treatment analysis, we have created the possibility for new collaborations and new avenues of research for the future. There are several important forest-related disciplines absent from our team (e.g., studies of soil micro-organisms, soil arthropods, non-woody vegetation, herpetology, and others), and we are eager to expand our research enterprises.

As three of us on the interdisciplinary team members are involved in the study of wildlife (Zack, Laudenslayer, and George), we wish to add some notes and perspective for our approach to the understanding of woodpecker, songbird, and small mammal response to these treatments. Prior to the evaluation of treatment response, we are developing a series of predictions on how the main bird and mammal species will respond. By establishing such a priori predictions for the diverse wildlife community, we are using a hypothesis driven approach. The hope is less to be "right" concerning our suites of predictions, but rather to judge how impressions gleaned from the primary literature and our own experience either do or don't provide us with a basis for understanding this wildlife community in this forest ecosystem. A sample of our developing predictions is in Table 2 for some species' possible responses to the contrasting treatments at BMEF. It is clear that the "High Structural Diversity" treatment at BMEF is not expected to enhance wildlife diversity. On the contrary, the more simplified habitat structure of late successional forests and their more park-like appearance will likely reduce the number of many bird and mammal species.

We have established point count censuses of all bird species on all plots at BMEF and GAMA. We have also begun "spot mapping" territories of common species on a subset of plots at both sites. For the small mammals, we are engaged in a capture –recapture regime on sample plots of each treatment type. These data afford us a view of the numerical response of species to the treatments. By closely evaluating how certain species use microhabitats when foraging and for birds, in nest site choices, we are obtaining data on how they respond in a functional way to the treatments. Here, we refer to a functional response in the context of forest structural attributes like nearby tree density, crown cover, coarse woody debris, and snag condition.

Larger species like the Northern Spotted Owl, Northern Goshawk (Accipiter gentilis), and mammalian carnivores (e.g., Marten Martes americana and Fisher M. pennanti) appear to have declined dramatically with the decline of late successional forests in the West. It is not possible to establish replicated treatments of land on a scale relevant to these animals with such immense home ranges. It is possible, however, to evaluate the prey base of these taxa, in response to our treatments to help infer the responses of these species.

Table 2. Sample predictions for various bird and mammal species of their response to treatments. The exampl here is for the contrasting treatments at the Blacks Mountain Experimental Forest (see Table 1). Placing specie in ecological guilds assists in developing a hierarchical view of the response. The response predictions are qualitative and comparative, with ++ indicating a great increase, + an increase, 0 no change, - a reduction, and - - a great reduction. The diversity of predicted responses clearly indicate that the experimental treatments are not intended to increase wildlife diversity.

Guild	Species.	Experimental High Diversity	Experimental Low Diversity
Bark Prober	Williamson's Sapsucker	++	--
Bark Prober	Pileated Woodpecker	++	--
Bark Gleaner	Mountain Chickadee	0	0
Bark Gleaner	Red-breasted Nuthatch	+	--
Leaf Gleaner	Yellow-rumped Warbler	-	++
Leaf Gleaner	Solitary Vireo	-	-
Terrestrial	Dark-eyed Junco	-	+
Terrestrial	Chipping Sparrow	++	+
Aerial Sally	Dusky Flycatcher	+	--
Small Mammal	Yellow Pine Chipmunk	+	++
Small Mammal	Shadow Chipmunk	-	--
Small Mammal	Golden-Mantled Ground Squirrel	0	+
Small Mammal	Flying Squirrel	++	--

Finally, we hope to understand how certain wildlife species, particularly woodpeckers (Picidae) interact with different forest structures and compositions. At BMEF, the woodpecker community is diverse (eight species) and unusually abundant (likely a reflection of the numerous large trees and snags). The woodpecker community seems to be an excellent assemblage for applying the "ecosystem engineer" concept (Jones et al. 1994); their actions clearly affect the availability of wildlife resources. We are attempting to understand how quickly they find bark beetle activity, how quickly woodpeckers modify dying trees into wildlife habitat through hole drilling, and how the different species utilize the mosaic of forest tree structures for foraging and nesting.

Conclusion.

At our two eastside pine study sites, we have developed a complementary research design for evaluating some ways for, and the effects of, attempting to recreate historic forest structure. We hope in so doing that we create the possibility of recreating historic processes and species interactions lost in a century of forest transformation. We feel that the large scale, replicated treatment design will serve as a model of future forest ecosystem management, and in so doing, assist in moving from the rhetoric of ecosystem management ideals to an empirically based understanding of this important field.

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THESE ABSTRACTS ARE FROM PAPERS INCLUDED IN A SPECIAL ISSUE OF FOREST ECOLOGY AND MANAGEMENT.

Ecosystem management decision support for federal forests in the United States: A review. H. M. Rauscher. USDA Forest Service Southern Research Station, Bent Creek Experimental Forest.

Ecosystem management has been adopted as the philosophical paradigm guiding management on many federal forests in the United States. The strategic goal of ecosystem management is to find a sensible middle ground between ensuring long-term protection of the environment while allowing an increasing population to use its natural resources for maintaining and improving human life. Ecosystem management has all the characteristics of "wicked" problems that are tricky, complex, and thorny. Ambiguities, conflicts, internal-inconsistencies, unknown but large costs, lack of organized approaches, institutional shock and confusion, lack of scientific understanding of management consequences, and turbulent, rapidly changing power centers all contribute to the wickedness of the ecosystem management paradigm. Given that ecosystem management, like human survival and welfare, is a wicked problem, how can we proceed to tame it? Managers need to use the same tools that people have always used for handling such problems-knowledge, organization, judicious simplification, and inspired leadership.

The generic theory of decision support development and application is well developed. Numerous specific ecosystem management decision support systems (EM-DSS) have been developed and are evolving in their capacities. There is no doubt that given a set of ecosystem management processes to support and adequate time and resources, effective EM-DSS can be developed. On the other hand, there is considerable doubt that sufficiently detailed, explicitly described and widely accepted processes for implementing ecosystem management can be crafted given the current institutional, educational, social and political climate. A socio-politcal climate in which everyone wants to reap the benefits and no one wants to pay the costs, incapacitates the federal forest management decision making process. Developing a workable ecosystem management process and the decision making tools to support it are probably some of the most complex and urgent challenges facing us today.

This paper offers a concise review of the state of the art of decision support systems related to implementing ecosystem management. A conceptual model of the context in which ecosystem management is expected to function is presented. Next, a candidate for an operational ecosystem management process is described and others are referenced. Finally, a generic ecosystem management decision support system is presented and many existing systems briefly described.

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