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Research, part of a Special Feature on Historical and Future Ranges of Variability

Range of Variability in Southern Coastal Plain Forests: Its Historical, Contemporary, and Future Role in Sustaining Biodiversity

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ABSTRACT. Historical range of variation (HRV) has been used as a conceptual tool to determine appropriate management actions to sustain or restore diversity of ecological systems. This concept has come into question for both biological and social considerations, and the southeastern United States is a good model system to test its utility. Southeastern Coastal Plain upland pine savannas and woodlands and their associated wetlands are among the most diverse communities in temperate North America, having both high levels of species richness and large numbers of endemic flora and fauna. However, this diversity is intimately linked with disturbance regimes. Maintaining frequent fire, varied in season based on changing management objectives through time, is the most important management tool for sustaining biodiversity. Moreover, the landscape has been molded by a long history of intense land use that has altered both the biological and the social landscape in which management occurs, and threatens the native diversity. Management must anticipate likely trends and adopt strategies that provide flexibility for managers to deal with the future, both socially and ecologically. In the Southeast, the most dominant trend is associated with urbanization and forest fragmentation, which results from urban sprawl. This issue joins others—fire and smoke, logging, access, in-holdings, and the uncertainty of scientific models, for example—as matters of major concern to the public. Ultimately, it is the public that eventually grants or withholds social permission to manage. We explore, here, the potential and the limitations for how history can inform future management. Rather than being used as a specific management tool, we find that one purpose for which HRV may be well suited is serving as a broad communication framework to help diverse publics understand the concept of landscape dynamics. This approach would provide the fundamental background material for stakeholders to understand how ecological conditions and social acceptability interact through time to mold and constrain future possible ranges of variability.

Key Words: *disturbances; fire regimes; historical, social, and future ranges of variability; legacies; rareness; social acceptability; species richness*

INTRODUCTION

Southeastern Coastal Plain pine savannas and woodlands and their associated wetlands are among the most diverse communities in temperate North America, having both high levels of species richness and large numbers of endemic flora and fauna (Walker and Peet 1984, Hardin and White 1989, Peet and Allard 1993). Species richness of the flora is notable at multiple scales: as many as 50 plant species can occur in a single square meter, and more than 1000 species can be found over a few thousand hectares (Peet and Allard 1993, Drew et al. 1998, Kirkman et al. 2001). In fact, nearly one-quarter of all vascular plant species found in the USA and Canada occur in the Southeastern Coastal Plain landscapes (Clewell 1986, Stein et al. 2000). This high level of diversity is only found in sites that have been frequently burned, where the original understory plant community has not been disturbed belowground (Kirkman et al. 2004, Kirkman and Mitchell 2006). Altered disturbance regimes and land-use practices have extirpated this system from more than 95% of the areas where it was found before European settlement. The great diversity of the system, the threats to sustaining the system, and the intimacy with which disturbance is connected to sustenance of diversity has increased interest in assessing how variation in disturbance itself, and the variation created by disturbances, might

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illuminate management options to sustain those systems that remain, as well as restore others that have been degraded or lost.

It should be noted that our arguments are founded on the strong belief that management for sustaining biodiversity is most important on lands that are most diverse. This is in part because it is cheaper to sustain than restore, but also because management goals for sustaining biodiversity are more likely to be in place on lands that are still biologically complex. Thus, although much of the southeast is "pines in lines," our attention is on those areas retaining their native diversity as the sources of greatest continuing diversity. Furthermore, we believe the past is no longer prelude; globalization is likely to change the landscape of land use as pulp mills move to other places in the world, and pulp stumpage declines. This appears inevitable in the southeast, and thus the research that might anticipate outcomes of such change will increase in importance.

Managing to restore or sustain native biodiversity is frequently founded on the historic range of variation concept (Schulte et al. 2006). This construct is founded on the assumption that ecosystems evolved under a disturbance regime that, with variation in site and climate, bounded variation. If managed disturbances did not exceed those boundaries, the native biota would be adapted to sustain their populations. However, as with globalization and economic patterns, the past is not a good indication of future performance in climate. Moreover, the magnitude of variation varies widely depending on how far in the past one wishes to peer (Jackson 2009). These issues, as well as others, suggest that understanding how variation in management might be used to sustain biodiversity may need considerably more information than has been suggested by the historical range-of-variability concept and its use.

Traditionally, ecological and social assessments have been designed and executed separately, with little or no acknowledgement that each is crucial to weaving a complete tapestry of a region's biodiversity status, potential, and challenges. The historical division between scientists and non-scientists, the allegedly rational and the irrational, and decisions made in democratic and technocratic settings, all contribute to our propensity to view ecological and sociological information separately (Priest 1995, Pouyat 1999, Fischer 2000, Rykiel 2001, Yosie 2001, Duncan 2006). However, in many senses, ecological and social contexts are codependent and even co-created—unless we ignore human beings and their daily pursuits. How people think about and treat their ecosystems is inextricably connected. Social acceptability of landscape conditions and management prescriptions has long been recognized (e.g., Firey 1960, Clawson 1984), but only more recently have they been widely acknowledged as a central component of a science-based policy development approach (e.g., Stankey and Shindler 2006).

In this manuscript, we integrate social and ecological findings—not a trivial task—and thus investigate important relationships between the state of ecological understanding of a region, the state of a region's biodiversity, and the state of the region's social understanding of how it might be managed for biodiversity conservation into the future. First, we defined concepts of variation, reviewing the literature that speaks to variation in the Southeastern Coastal Plain region and its connection to the high levels of diversity found therein, and lastly, we conducted focus groups with those involved in land management to assess how they understand and use variation in management when goals include sustaining biodiversity.

DEFINING VARIABLITY

This project assessment relies on a unified concept of range of variability delineated in separate synthesis papers (S. L. Duncan, B. McComb, and K. N. Johnson, unpublished manuscript; B. McComb and S. L. Duncan, unpublished manuscript). Those authors rely on established concepts of historical range of variability (HRV), and have developed the concept of the social range of variability (SRV) to help explain the interaction of social and ecological assessments, in particular their interaction to create future ranges of variability (FRV). They define each as follows:

Historical Range of Variability (HRV): the estimated range of some ecological condition or process that occurred in the past. This is often expressed as a probability distribution of likely states. Historically, this range of variability denotes a dynamic set of boundaries between which most native biodiversity variables have persisted—with fluctuations—through time and across space.

Social Range of Variability (SRV): The range of an ecological condition that society finds acceptable at a given time. In the work of Duncan et al. (2009),

this is expressed as a distribution of public acceptability.

Future Range of Variability (FRV): The estimated range of some ecological condition or process that may occur in the future—a dynamic set of boundaries on some condition or process that may occur in the future. In these as-yet unpublished manuscripts by S. L. Duncan and colleagues and B. McComb and S. L. Duncan, this is expressed as a probability distribution of likely states.

METHODS

This study centered on the research question: how do future trends affect the usefulness of the HRV concept? We took a two-pronged approach, embracing both ecological and sociological precepts of inquiry. First, a detailed literature review of how both the social and ecological history of the area under study was developed as a complement to ongoing research at the Jones Ecological Research Center. This appears immediately below. At the Jones Center, ecological studies are focused on the past and likely future of the native longleaf pine (*Pinus palustris* Mill.) landscape, and the highly complex biodiversity associated with it. A review of the value of HRV was, therefore, a natural progression of thinking at the site.

Second, the Jones Center hosted a 2-day workshop to bring together researchers and practitioners of many kinds to consider the socioeconomic implications of using HRV as a management tool. Following a number of research presentations on the HRV concept, its historical context, and the regional ecology, we designed the focus-group segment of the workshop to allow full and unfettered responses from scientists and non-scientists alike, addressing the usefulness of the HRV concept given likely futures. Specific additional questions addressing HRV, SRV, and FRV and alternative strategies for conserving biodiversity included: How do social factors (e.g., land use, development) affect the ranges of variability we can use when managing for biodiversity? How will biophysical factors (e.g., climate change, invasives) influence the way we use ranges of variability to manage biodiversity? What future strategies incorporating both social and biophysical ranges might be most successful in conserving biodiversity?

The data from the focus groups, in the form of transcribed text, were analyzed by coding text for dominant ideas and themes relating to the central research question (e.g., Morgan 1997). This involved clustering like terms used by participants (in vivo coding), linking similar references and concepts, then testing across the two focus groups for consistency. This process allowed us to identify key themes of importance to both groups, then crosscheck for supporting data (text or excerpts) that best expressed the core values of the theme.

The 15 workshop attendees included managers from public and private lands, NGO representatives, fire and ecosystem researchers, and consultants to private landowners. Although this number of participants appears small, the make-up of the group was purposefully designed to cover multiple interacting categories of interested and attentive members of the sectors actively considering modern forestry trends and biodiversity issues in the Georgia context. There was, as expected, considerable disagreement among attendees on details, which reassured researchers that we had captured a span of interests, and allowed us more effectively to identify those areas that did emerge as broad themes.

LITERATURE REVIEW

Disturbance and the Pre-European Settlement Forests

The coastal plain of the southeastern USA was described by early botanists as being dominated by longleaf pine uplands that were composed of open-canopy longleaf pine woodlands variable in age, with even-aged cohorts regenerating in the larger openings, and with a diverse understory rich in species (Bartram 1791, Schwarz 1907). The open, two-layer structure of woodlands and savanna are only sustained in the presence of frequent disturbance. Disturbance-sensitive species invade rapidly if the fire return interval is insufficient, closing the canopy and competitively excluding the biologically rich understory. Thus, longleaf pine has been estimated to burn every 1–10 years (see fire history). This frequent fire disturbance interacts with other disturbances, particularly the frequent hurricane and tropical activity experienced in this region over the millennia (Myers and van Lear 1998) to structure these ecosystems.

Discerning the extent and frequency of hurricanes in the pre-European settlement landscape of the southeastern USA, has been difficult until recently

(Myers and van Lear 1998, Miller et al. 2006). Nonetheless, we know they were frequent and occasionally severe. This frequency and severity are thought to alter the structure of these systems and interact with other disturbances, most notably fire to create the diverse landscape of the Southeastern Coastal Plain woodlands (Myers and van Lear 1998).

Longleaf pine woodlands may also be more able to withstand hurricane-force gales than other southern pine species due to structures found within the tree and those associated with structure of the ecosystem. Older stands of longleaf pine (those that the early botanists described as the dominant forest) have large amounts of heartwood that is very resistant to decay and breakage (Wahlenberg 1946, Gresham et al. 1991). The heartwood of pine may be one factor that decreases sensitivity to blowdown. However, the structure of the longleaf forests and pre-European landscape may also be inherently more wind firm than forests we most commonly see today on the landscape. These forests were vast in extent, occupying the uplands between cane-breaks and large river systems; thus, little edge was encountered and that which existed was a relatively soft edge. This is in sharp contrast with today's fragmented forests that are closed canopy, even aged, with sharp edges that provide an almost "sail-like" catch for hurricane-force winds.

Hurricanes and fire likely interacted in determining structure of pre-European settlement forest structure and sustaining these diverse woodlands and savannas. For instance, after an intense hurricane, forest fuel loads are increased. Any increase in mortality that was associated with greater fire severity associated with elevated post-hurricane fuel loads would result in additional death of some mature trees, and increase the opportunity for regeneration of new cohorts of longleaf, thus resulting in pulses of regeneration. This may be the cause of the bi-modal and irregular diameter distributions often seen in the remnant old-growth longleaf pine systems (Mitchell et al. 2007). The stochastic nature of these storms would create variable density from very open savannas to dense woodlands depending on the time since hurricane disturbance. Very open old-growth forests may, after time, fill in with regeneration and, as the young cohort replaces older trees in the canopy, the stand would move to a more dense structure over time until the next hurricane opens the forest up again. Thus, an old-growth forest may represent a position along a disturbance continuum rather than only representing a single end.

Disturbances, most notably frequent fire and infrequent hurricanes, structure these forests such that extremely high levels of biodiversity can be achieved (Platt et al. 1988, Kirkman et al. 2001). The open-canopy nature allows sunlight to support the grass-dominated, species-rich ground strata. Frequent fire maintains plants in a small stature such that many species can be packed in small spaces, and once established, plants are not overtaken and competitively displaced by competitors even if they establish outside of their ecological optimum (Kirkman and Mitchell 2006).

History of Land Use of the Southeastern U.S.

The paleoecological record suggests that longleaf pine woodlands of the southeast began to appear as the retreat of the Wisconsin glacial period began, and is coincident with evidence of the first people to populate this area some 10 000–12 000 years ago. Thus, longleaf has a long history of human intervention and climate change! Although the population size and impact of indigenous people are under debate, their effect on longleaf forests was potentially large due to their use of fire (see "History of Fire in the Coastal Plain").

European settlement, however, profoundly influenced the landscape. First and foremost, settlers cleared the forest to make way for agriculture. Agricultural clearing increased as the South moved into the Plantation Antebellum Period. More than 90% of some states went under the plow, mostly for cotton production. The rise of pests, most notably the boll weevil (*Anthonomus grandis*), and the exhaustion of soils from poor practices resulted in large-scale abandonment and old-field succession, mostly to loblolly pine (*Pinus taeda*), closed-canopy forests. These forests lacked much of the diversity of the longleaf system they replaced (van Leer et al. 2005, Mitchell et al. 2007).

In addition to agriculture, these forests were exploited for timber and chemicals. Clearing of forests was first done in the vicinity of major waterways, but the advent of the steam engine in the mid to late 19th century expanded the reach of loggers. Logging longleaf peaked as early as 1909, and not only had the old-growth forest been largely extirpated by mid 1920s, but only a small portion

of the original forest developed into second-growth longleaf because of the lack of longleaf regeneration (McGuire et al. 2001). Similarly, the extent of turpentining increased the exploitation of the woods as rails increased the ease of transport. Both the clearing of the forest and turpentining rapidly depleted the primary forest of the Southeast. This land-use history had devastating consequences for the biologically rich primary forest. However, diversity was not only influenced by use of land, but the management of fire.

History of Fire in the Coastal Plain

Longleaf pine grasslands appeared as the dominant vegetation type of the Southeastern Coastal Plain after the retreat of the Wisconsin glacial period, when massive climate change was occurring. Simultaneously, the Southeast was becoming populated by indigenous people known for their use of fire (van Lear et al. 2005). Climate, through lightning and drought, is thought to have played a particularly important role in sustaining pre-European settlement fires (Komarek 1974), although deliberate burning by Native Americans influenced the landscape that the first European settlers found and that the early botanical records reveal (Carroll et al. 2002).

These populations used fire as their primary tool of landscape management. They burned to reduce fuels and wildfire risk, enhance habitat and hunting of wildlife, foster plants that aided in hunting and gathering (berry- and nut-producing plants and enhanced forage), protect themselves from both enemies and predators, and improve health and quality of life by reducing biting insects such as ticks, fleas, and other pests. Although lightning fires were most common during the growing season (Bonnichsen et al. 1987, Pyne et al. 1996), Native Americans burned at all times of the year (Pyne 1997). These two ignition sources ensured that fire occurred frequently during a variety of seasons, and maintained a shifting mosaic of prairies, savannas, and woodlands in the upland promoting rich, fire-dependant, and floristic communities while allowing more fire-sensitive species, such as hardwoods, to develop in bottoms and in fire shadows (Landers et al. 1995).

When disease decimated "New World" populations, there was also a decline in burning, both in frequency and extent (van Lear et al. 2005), resulting in prairies and open savannas gradually succeeding to more dense mixed hardwood–pine forests over extensive areas of the Southeast (Rostlund 1957).

European settlers and their African slaves gradually replaced indigenous American populations. European settlement of the area was largely from the region of western England, Scotland, and Ireland, where burning and open-range herding was customary (Johnson and Hale 2002). These settlers burned frequently, often annually, to achieve many of the goals of Native Americans, and to provide forage for cattle that grazed throughout these forests (Pyne 1997). Use of fire became deeply ingrained in the rural population of the Southeastern U.S during the late 1800s and early 1900s.

However, in the early decades of the 20th century, fire suppression in the forest became the official national policy of forest management (e.g., U.S. Forest Service). Within this climate of fire suppression, Herbert Stoddard (1931) published his classic book on the management of bobwhite quail (*Colinus virginianus*) and identified the lack of fire as the fundamental reason for the decline in quail populations that many hunting properties had seen after following the advice of resource professionals and suppressing fire on their hunting plantations. During the last half of the 20th century, quail-hunting plantations, with their traditions rooted in frequent burning remain one of the most important sources in the Southeast for the sustaining longleaf pine ecosystems and the biodiversity found therein (Drew et al. 1998).

Although resisted in some corners of the Southeast, fire-suppression policies in much of the region replaced frequent, non-lethal understory burns that characterized the fire regime before the 1900s. When fire occurred, it often was more severe because of the build-up of fuels and often resulted in considerable pine mortality (Brown 2000). In addition to mortality of pines, invasion of areas by fire-sensitive, woody plants resulted in declines in plant diversity, and changes in the forest structure that led to loss of habitat for many of the fauna species characteristic of this ecosystem. Although the Southeast leads the nation with frequent prescribed burning applied to about 3.2 million ha, legacies that resulted from some period of fire suppression are found in many, if not most, stands in the Southeast (Outcalt and Sheffield 1996).

Within this historical context, variation in fire regime must be viewed as vital to sustaining biodiversity of the Southeast. Fire frequency is indisputably the most important feature of a fire regime that sustains the high diversity of Coastal Plain ecosystems (Glitzenstein et al. 2003, van Lear et al. 2005, Kirkman and Mitchell 2006). Floral diversity has been shown to decline in these ecosystems if fire return intervals exceed as few as 3 years (Glitzenstein et al. 2003, Kirkman et. al. 2004).

Today's landscape holds relics of the rich longleaf pine ecosystem. Understanding, in general, how disturbances have been applied to these remnant systems gives some insight into future management that might conserve or restore native diversity. Most of these areas were frequently burned for decades, often annually, outside the lightning season, at least since European settlement, if not before by indigenous people. This suggests that burning outside of the lightning season can sustain biodiversity for many years.

Social findings argue that a compelling and immediate challenge is to provide enough understanding of the vital relationship between frequent fire and biodiversity to dilute the resistance to smoke-induced, air-quality problems. This understanding may then be leveraged to retain the social license that has allowed prescribed burning throughout this region. Resistance to buning is increasing in relation to development across the region by people who have moved to the region and who are unaccustomed to the use of fire as a land-management tool. It is further exacerbated by air-quality restrictions near urban areas.

Recent Human Influences on Southeast Forests

Modern forest management has also played a strong role in the extirpation of longleaf pine from much of the landscape. In the post-World War II era, the development of the pulp technology that allowed for loblolly and slash pine (*Pinus elliottii*) to be used widely for pulp changed the dominance of southern pines from older, multi-aged native stands of longleaf pine to young, even-aged plantations of loblolly and slash (Earley 2004). This development, combined with forest science that gave foresters the tools to manipulate genetics, improved the quality of seedlings, and development of silvicultural practices that accelerated the rapid production of fiber from pine lands. The rapid growth of these two pines, compared with slow early growth of longleaf, and combined with a utilitarian, timber-dominated sense of forest value, resulted in a monolithic view of silviculture (even-aged optimization of internal rate of return) with little regard for the impacts on the diversity of ecosystems. Between 1930–1945, more than 2 billion slash and loblolly pine trees were planted under the Soil Bank Program. Forest acreage increased by more than 7 million acres in southern states from the Depression to mid 1960s, but longleaf forests declined by more than 5 million. This trend of intensive forest management for young, even-aged rotations so completely dominated the wood basket of the Southeast that a Forest Service administrator spoke of longleaf as being a dead species, one with no future in southern pine forests (Earley 2004).

The pulse of longleaf pine and biodiversity concerns in southern forestry were first faintly revived in the mid 1970s–1980s, in part by the National Forest Management Act, but were resurrected by the Endangered Species Act, and the red cockaded woodpecker (*Picoides borealis*). This major change in how forests are viewed and the emphasis on management for biodiversity started then and increases in strength and depth today. Forest science in the Southeast now is moving away from a nearly exclusive attention to production forestry, to a wider view of forest management that produces timber while sustaining native biodiversity in an ecosystem context (Mitchell et al. 2007). This has come at the beginning of globalization and the decline in pulp markets throughout the Southeast. Precisely how forest management will develop in the face of increasing global pressures affecting the market in the Southeast is difficult to predict. However, another disturbing trend for forest management in the region that is easier to understand is urbanization. The South is becoming more urban!

Much of the Southeast, particularly those sites close to the coast, are being transformed from rural to urban. From 1945 to the mid 1990s, the amount of land dedicated to urban uses tripled (Wear 2002). Projected losses of forest land (1992–2020) are in the most urbanizing centers of the Southeast, but particularly the Atlantic and Gulf Coast region. This decrease in forest land greatly affects management. Wear et al. (1999) showed that timber management and population density in the Southeast were significantly and inversely related. Urbanization influences management of fire by increasing the

density of smoke-sensitive sites, decreasing the population's tolerance for smoke, and increasing pollution from other urban sources (Mitchell et al. 2007). Costs of management tend to increase as population increases, both due to land prices and regulation, in ways that influence not only timber management, but management for conservation of diversity.

Silviculture that Sustains

Any management activity in the coastal plain of the Southeast that is geared toward improving the conservation of biodiversity will first and foremost incorporate prescribed-burning considerations into silviculture (Mitchell et al. 2007). Any forest management practice that compromises frequent fire also will lower biodiversity (Leach and Givnish 1996, Liu et al. 2005). Silvicultural activities affect fire management by altering the distribution, type, and amount of fuels (Mitchell et al. 2007). The high fire frequency and low fire intensity necessary to sustain the longleaf pine plant community requires that fuels be continuously distributed in time and space. As pine needles represent more than one-half of the available fuels for maintaining fire (Ottmar et al. 2003), silviculture necessarily impacts fire through its influences on the variation in fine fuel production by affecting tree crown distribution. Longleaf pine needles provide ideal fine litter for frequent fire because of their high resin content (Fonda 2001) and structure (Hendricks et al. 2002). Bunchgrass crowns act as perches for fallen needles, creating a well-ventilated fuel bed that dries easily (Myers 1990). This synergy among fine fuels, i.e., grasses and needles, is the salient feature of this system that allows for the very frequent fire regimes required to sustain the high levels of biodiversity characteristic of these systems. Thus, any silvicultural system that is oriented toward goals of sustaining native biodiversity and timber management must consider the nexus between management impacts on forest dynamics and the ability to sustain fire over space and time.

Although overstory pine disturbance and mortality directly influence the production and distribution of pine needles and, thus, fire, they can also influence fire behavior indirectly through canopy impacts on resources and microclimate, and their influence on forest dynamics. Open-canopy forests tend to vary such that light levels typically are greater than 30% of full sunlight and rarely more than 80%–90% (Battaglia et al. 2003, Pecot et al. 2005). This variation in light is sufficient to sustain a vigorous and diverse understory (Kirkman et al. 2001), and fuels that support frequent fire. However, if disturbance, particularly due to harvesting groups of trees, results in large clearings, then oaks (*Quercus* spp.) and other woody plants that were kept small in stature by competition and fire are often released (Jack et al. 2006, Pecot et al. 2005). This can result in greater production of less flammable litter that can burn with lower intensity (Williamson and Black 1981). In addition, the woody plants that are released often shade the understory grasses, reducing or eliminating their contributions to fine fuels (McGuire et al. 2001). The reduction in fine fuels from pines and grasses and the increase in fuels from hardwoods can interact, making it more difficult for fire to spread continuously into openings and provide feedbacks that encourage the domination of openings by fire-sensitive woody species. If gaps are cut so they expose hard edges, wind eddies can further exacerbate difficulties in burning openings.

In summary, the literature provides considerable guidance with respect to how variation in disturbance is related to sustaining biodiversity and how that variation could be used to manage and monitor management impacts on future forest trajectories. We recognize that the literature does not yet offer specific guidance on how managers and other stakeholders perceive variation, and how variation might be managed, nor how current understanding of scholars connects with on-the-ground land-management views. Therefore, we developed our own data by means of the workshop and focus groups and analyzed the results to produce the findings below.

RESULTS

The Use of HRV/FRV—a Social Assessment

Analysis of focus-group data identified three key themes: (1) HRV is not deemed to be a primary guide for land managers; (2) past management and land-use patterns (history) affect thinking about management at least as much as natural ranges of variability; and (3) social acceptability (Stankey and Shindler 2006) trumps all considerations in management planning.

Acceptance of HRV

Historical range of variability is neither wholly embraced nor wholly rejected, but is one among a suite of approaches used for framing management strategies. The idea of specific reference points in the past toward which we ought to return in an ecological sense is, however, generally discarded. In general, the uncertainty of future conditions is perceived to undermine the value of predicting future landscape responses based on past conditions that are unlikely ever to return.

Likewise, when the question was raised whether HRV might help construct an "objective ecological yardstick," it was strongly resisted: the notion of metrics for historical ranges, particularly measures of central tendency, is perceived to be arbitrarily constraining:

> *You have to wonder, is it a kind of Cartesian habit, developing these yardsticks....doesn't it become somewhat of a fool's errand in a direction that's a big distraction, and is it more important as we proceed towards the future, to think about mechanistic things such as structure and function, and think about them over time....so shouldn't we continue to adapt in the future and not get so fixed on particular outcomes?*

Despite such challenges to its utility, HRV is indeed used—in a selective manner—to set sidebars and contexts for planning and management, with regular use of fire being the most obvious example. It is broadly considered, despite its limitations, to be a conservative approach to preserving future options, and a template for creating reservoirs, refugia, and buffers for biodiversity.

Answers vary on the specifics of its usefulness: HRV can guide understanding of the structure and function of which the landscape is capable, show managers some parameters for adaptability, and help them consider functionality over a large scale. Ultimately, what emerges from the different conceptions of its use is that "resilience" is perceived to be a more useful notion in setting management objectives:

> *....(this area) was hammered so hard during the cotton days, that what we have left is inherently resilient. There's not much you can do to enhance diversity, and there's not much more you can do to lower it, because it's already been through the wringer.*

And:

> *....despite those tremendous variations (in past climates and vegetation), our diversity is still high in the Southeast. What was it about the landscape that could recover from dramatic changes in carbon dioxide and all these other factors, and how can we inform ourselves from that in trying to construct our landscapes of today?*

The idea of "system persistence" was used to explain that, no matter what happens to a system, it does keep running, even if it runs differently or more slowly. Thus, the concepts of management adaptability and resilience merged in the idea of having to "manage with what's left." This suggests a more culturally devised range of variation than nature based, and drove the broad-ranging discussions of management philosophies.

Effects of history on management thinking

In management of southern forest lands, it appears that the overriding need for pragmatism interferes with the consistent use of a structured HRV framework:

> *You might have a chance to argue that some landscapes can be managed relatively close to the way they were 500 year ago, or whatever time frame, but not many places, because everything is so completely modified, so completely different that we're looking at novel management challenges.... We (now) manage systems that are completely and wholly dependent on our actions with respect to biodiversity.*

Across the board, managers of public and large and small private holdings articulated an approach that grew to a significant degree out of what was termed "anthropogenic variation": in other words, the management or mismanagement footprint of the humans who had come before, or history, as opposed to HRV. With such a fundamentally altered landscape, particularly as it continues to change very rapidly, management to conserve biodiversity becomes a matter of "playing with the cards we're dealt."

Even the use of fire, widely used as a management tool, is only a partial return to historical conditions, given that stand-replacing wildfires are "absolutely not" going to be allowed to run free under today's land-use conditions. At best, we can try looking as far back as possible at the extremes of variation, and from that, try to learn about cause-and-effect relationships. Applying value judgments to these relationships from specific management experience, most participants concurred, will be the best insurance against the effects of catastrophic, non-predictable disturbances.

Another viewpoint on this intersection of pragmatism and management by HRV is suggested by the notion that "....managers work at the stand scale; HRV works best at the landscape scale and tends to be merely heuristic at the stand scale." Multiple ownerships in a landscape such as Georgia's create mosaics of multiple objectives or experiments that carry their own inherent variability, which in turn generates what was termed a "managed range of variability." In this context, participants observed that creative management can find a variety of learning opportunities. The artistic, flexible nature of what is perceived as good management, as opposed to an engineering mode, was presented as a strong argument against the constraint of measuring toward a specific yardstick.

Even within their own purviews, managers from different ownerships recognize they will get a range of variation from local weather, fuels, and fire itself:

> *My opinion is if I use fire, and it's driven by objectives, I'm using variation, because different wildlife species and different vegetation give you windows to burn in, and within that I get variable seasons and I get variable fire.*

Fire will favor some species at some times, others at other times, and will of course not favor fire-intolerant species, "so it's not necessarily going to be a flat curve where every condition is equally represented." For example, industrial land managers are constrained by costs, shareholders' expectations, and the availability of affordable fiber.

Overarching any kind of management, regardless of ownership, is the humbling nature of truly large disturbances. Such disturbances can be selectively perceived as discouraging, in the sense that any management footprint can be wiped out by a single event, or enabling, in the sense that the opportunity for experimentation is quite open under a landscape already tested by significant change:

> *As distressing as it is when it happens, it presents a challenge and an opportunity to learn something, so we try to adapt with those things, see them as natural occurrences as they are....and see what nature does in response to these events.*

It is precisely the difficulty of walking away from such "damage" and waiting to see what nature does, that forces managers to run the ever-present gauntlet of public perceptions.

Central role of social acceptability

Georgia managers, planners, and researchers broadly recognize social acceptability as the prevailing constraint on forest management decisions relating to biodiversity conservation, trumping HRV and all other considerations over time across all ownerships. Humans and their needs and desires are seen to drive the speed of landscape change, management goals, and return on investment; hence the widespread concern over rapid development of rural and resource lands. However, it was noted that humans' skill in changing their environment, even when they were very thinly dispersed across the landscape, has always carried social and economic consequences.

Another social acceptability issue affecting use of HRV is property rights: in the U.S., unlike many other places, property rights are regarded as sacred (irrespective of the existing restrictions on all property owners), and asking for altruism is widely regarded as, on average, an enormously difficult proposal.

Underlying the social challenges to HRV as a management guide, according to many participants, is the problem that the general public lives comfortably with three closely related myths. The first is that there is such a thing as the balance of nature, where all living things exist in some kind of harmonious relationship. The second is that there is an historical Eden, a specific time when the landscape was in far better condition and health than it is today, and to which it is highly desirable to return. The implication is that today's landscapes are "bad." The location of this Utopian time in the past is unclear, and shifts around within any debate.

The third myth is that landscapes are static and relatively unchanging through time. This is particularly true of forests, where trees grow relatively slowly, and their life spans generally far outstrip those of the average human. The merging of these ideas forms a common worldview in which landscapes are not widely understood to be inherently dynamic.

Although public understanding is a specific challenge to guiding management by HRV, several participants understood that an HRV framework can be used to address such misperceptions. The need to educate the public about how landscapes work, how different today's land-use patterns and species are from those of the distant, or even the fairly recent past, and the changes from the day when the "village lived at the bottom of the watershed" and everyone agreed with the management objectives. The "villages" are now coalescing, the ecological patterns are highly altered, and the social constraints are vastly different.

Whatever the past relationship between people, landscapes, and the disturbances that formed them, future social ranges of acceptability were posed as drivers that now overwhelm the historical and ecological ranges of variability, the latter being merely "what's left" when social issues have played out. This distinction tends to be seen as a fairly new phenomenon.

Participants noted that shifting the levels of social acceptability into balance with understanding historical ranges of variation will necessarily involve education, both about past ranges, and about the potential nature of future trends. Better understanding at the ecosystem level, participants noted, would bring into focus the constancy of trade-offs in land management, thereby allowing managers to refine management targets, and be honest about what's doable and achievable under today's constraints. From that point, it may become possible to investigate and better comprehend future ranges of variability, both social and ecological.

DISCUSSION

Understanding how variation in the past differs from and interacts with the present landscape is critical to understanding how variation can be incorporated into management that sustains biodiversity; but it is in and of itself insufficient. Management must anticipate likely trends and adopt strategies that provide flexibility for managers to deal with the future. In the Southeast, the most dominant trend is associated with urbanization and forest fragmentation that results from urban sprawl (Wear and Gries 2002). The increase in population exerts several pressures on forest management that need to be addressed in the future. As cities grow and their air becomes more polluted, political forces to restrict emissions from burning increase due to the conspicuous nature of woods burning. Although restricting burning of woods has little influence on regional air quality due to the insignificant inputs of prescribed burning compared with those from vehicle emissions or energy production, it is more conspicuous and easier to regulate because of weaker lobbies (the pro-woods fire lobby is often weaker than the pro-petroleum or pro-energy lobby in the policy arena). In addition, although prescribed burning emissions can be regulated, emissions from prescribed burns are less harmful than those associated with wildfire emissions which, of course, are not regulated. Wildfires tend to occur in dry summer months during the most critical time for air quality, and burn with little opportunity to direct emissions away from populated areas.

Considerable work is needed to ensure that the social license for prescribed fire is sustained, and air quality will be a large part of that process, particularly as the South becomes more populated. Moreover, as people become less connected to the land, the culture of burning in the Southeast is slowly eroding; thus, many are unaware of the need and benefits of burning. In addition to the changes to the culture of burning, society as a whole is increasingly litigious, with prescribed fire susceptible to this social contagion. As a response to all these pressures on fire, and fire's critical role in sustaining the biodiversity of the Southeast, state fire councils have developed with objectives to reduce institutional regulatory and liability constraints on burning, and to increase public awareness of the importance of burning for conservation of our natural resources (The Nature Conservancy et al. 2003).

Other issues of concern to the public who eventually grant or withhold social permission to manage, include: logging, access to recreational playgrounds for motorized vehicles and hunting, sprawl and parcelization of landscapes, the associated rising land prices, the wildland–urban interface, and the presence of numerous in-holdings in larger tracts

that might have different management objectives. A closely related additional factor is the uncertainty of model-based projections about future trends. Science may be accustomed to working with uncertainty, but people prefer certainty, especially if they are being asked to change.

In addition to social changes across the landscape, managers need to account for future trends in the physical environment and biological context where management occurs. Climate change is a trend that will continue to challenge forest management in the Southeast. Predicted increased warming is likely to increase variability of weather, thus increasing the likelihood for increased frequency of extreme events, including droughts and tropical storm intensity. As longleaf pine is capable of sustaining itself across a wide ecological amplitude, from extremely xeric sandhills to the edge of wetlands it is particularly suited to managing for native diversity characteristic of past eras, yet resilient to vagaries of future environments. The open-canopy structure, variation in age and size class, and lack of strong edges all make longleaf pine woodlands more resistant and resilient to these large catastrophic disturbances.

Invasion of exotics is another trend that threatens the Southeast. Management using natural disturbances provides at least two features that mitigate, but do not eliminate threats of exotic invaders. First, invasion by exotics is often aided by large-scale disturbances (Liebhold et al. 1995); thus, when legacies of forest communities are kept intact, stands tend to be less susceptible to invasion. Secondly, as this management maintains wider genetic diversity than planting genetically "improved" slash and longleaf, the risk from imported pests in the future may be lessened to a degree.

Social findings suggest that attention in the region is more focused on development as a prevailing threat than it is on climate change or invasion by exotic species. Although the latter two are generally listed among major disturbances, they do not at this time provoke the same level of anxiety as urbanization, thus contributing to the current gap between ecological and social assessments of biodiversity issues for the region.

As population density increases in the area, SRV—the social range of variability—emerges as a powerful force directly affecting management today, in particular questioning whether the HRV concept is useful. The influence of SRV is likely to strengthen as development in the region continues. Managers in the Southeast seem to comprehend the urgency of managing now for future variability—taking current conditions and developing what resiliency is possible—but they remain constricted by the severely limited public awareness of landscape dynamics and the many related management problems, from invasive to prescribed fire and smoke management, to the effect of fragmentation on forest dynamics, and beyond.

Many factors contribute to such lack of public awareness: time lags between developing theories of landscape dynamics by scientists and application of new techniques by managers; confusion about scientists' role in associated practices by managers (Rykiel 2001, Lach et al. 2003); cultural and structural barriers between scientists and non-scientists (Priest 1995, Pouyat 1999, Fischer 2000), and challenges in subsequent understanding by the concerned public (Mills and Clark 2001, Duncan 2006). The lack of understanding by the public is exacerbated by the lag time in seeing results of management actions. Recovery of longleaf ecosystems and the species reliant on them from current plantations of slash and loblolly pine can take decades (Kirkman et al. 2004). Another challenge is the outdated model of one-way communication between scientists and non-scientific audiences: social perceptions of ecological conditions in a region are gleaned from multiple sources, of which formal science is but one. The result is the considerable distance between where scientists perceive a region to be based on ecological assessment, and where a social assessment places it. These time lags and differing perceptions also contribute to the uncertainty between current and future ranges of variability.

Thus, it appears that where HRV is used as a management tool, it may have traveled largely through scientific channels, reaching only some managers, and very few publics. Many such scientific concepts are only transferable after negotiation of meanings between different parties of interest—the fact that the concepts are carefully defined in the scientific literature is irrelevant to most residents of any given region (Weber and Word 2001). Ideas such as biodiversity, ecosystem management, fire frequency, and variability, for example, mean many things to many people. Even the range of variability concept itself is not a simple

target—ongoing academic and management arguments about what constitutes "historical" will continue to muddy the HRV waters.

Ultimately, understanding how historical ranges in variation influenced the sustenance of biodiversity is both useful and problematic in informing future management. History shows that the biophysical realm has been highly dynamic through millennial time frames; more recently, ranges of social acceptability have proven just as dynamic. Thus, picking any particular time for a reference is arbitrary. In addition, ecological variation at any historical time and social variation before European settlement are understood only imprecisely; thus, defining the type and amount of variation to incorporate can only be coarsely achieved. Significant changes to the biota, the landscape, and the social context in which management occurs makes implementation of past scenarios less effective in practice, and in some cases actually undesirable.

However, the past does give us a better understanding of two key factors: (1) how some elements of biodiversity have changed, in large part due to increased intensity of land use and management since European settlement, and (2) how past disturbances sustained that diversity before today's ecological and social challenges began to dominate and mold present landscapes. These challenges—development, changing social preferences, climate change, and invasive species—promise to interact in complex ways not yet imagined, thus weakening yet further the connection between past and future ranges.

The constraints placed by SRV upon the use of ecological relationships to plan biodiversity conservation create an opportunity to evaluate options and ranges for future management, drawing from both ecological and social knowledge. Defining FRV for any given region, then, will become a "social negotiation" process, wherein ecological and social assessments can become mutually referential by combining ecological theory with a sociopolitically based reality check.

CONCLUSIONS

The past can inform management for biodiversity in several key ways, touching on both ecological and sociological aspects of the challenge. First and foremost, biodiversity of the coastal plain is inextricably linked to the presence of frequent fire on the landscape. Maintaining frequent fire, varied in season based on changing management objectives for fire through time, is the most important management tool for sustaining biodiversity (Hiers et al. 2000). Development and implementation of silvicultural approaches that sustain fuels necessary for frequent fire, but also maintain heterogeneity in stocking, size and age classes, and vigor including dead and dying trees, and that view forests with respect to maintaining legacies that provide continuity across harvests and throughout the landscape are critical for sustaining biodiversity (Lindenmayer et al. 2006). The Southeast is fortunate to have 50 years of such an approach applied to the Red Hills region of north Florida and southwest Georgia (Mitchell et al. 2006). Understanding the principles and adapting this type of silvicultural approach provide an example of how variation can be used to sustain the globally important, yet threatened, biodiversity of the region.

Additionally, one emerging purpose for which HRV may be well suited is serving as a broad communication framework rather than a specific management tool. Public land managers and private landowners from the region agreed that HRV provides a framework that could help diverse publics understand the concept of landscape dynamics in order to understand current management and its connection to future planning for biodiversity conservation. This approach would provide the fundamental background material for stakeholders to understand how ecological conditions and social acceptability interact to mold and constrain future ranges of variability.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol14/iss1/art17/responses/

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