Restoring the Fire Continuum: Restoring Fire Integrity

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Abstract—Fire is a natural environmental parameter on which the diversity of life depends. In the United States we are now engaged in sorting all remaining lands not already transformed from nature into two distinct categories of conservation. First are the lands we are committed to protect: National forests, national parks, wildlife refuges, wilderness, and other public lands, and private preserves. Second are the working landscapes found in ranches, small farms, and their woodlands, and some commercial timberlands. From the perspective of the planet, the most significant corollary of climate change is this final conversion of "natural" lands, driven by the population explosion, and portending mass species extinctions in the next three decades. Restoring fire integrity to our public and private natural lands can be reduced to a choice between embracing fire or surrendering to the forces of extinction. Emerging evidence indicates that restoring fire—the creator of habitats and sustainer of the web of life for most terrestrial species, from microbes and arthropods to birds, plants, and animals, and the broad conditioning agent of soils, fuels, and habitats—is our only countermeasure to extinction of perhaps half or all terrestrial birds, plants, and animals. When the pendulum swings our way again, the concept of fire integrity will drive funding for natural lands and the future of fire ecology. Until that time our central mission as fire practitioners, fire ecologists, and managers of natural lands consists of novel holding actions that will perpetuate the web of life.

Keywords: climate change, extinction, fire integrity, fire dependent species, HRV

INTRODUCTION

The natural continuum of fire—from the most fire-sheltered ravine in a landscape to the most fire-exposed prairie, savanna, or grassy woodland—creates the myriad habitats for the terrestrial species of North America. As fire professionals, our core mission, values, and personal commitments center on restoring the beauty and diversity of the portion of the natural world that, through our actions during the extinction bottleneck of the next three decades, we will bequeath to all future generations.

There are three striking fire continua that determine much of species diversity in nature. First is the local landscape continuum from fire-exposed to fire-sheltered sites. From this perspective, landscape factors such as fire compartment size, fire filters, topography, and pathways for fire flow, control fire frequency—not Native Americans, not lightning. Both of the latter are only ignition sources, and except for certain hotspots, fire frequency depends on what the landscape does with fire once it is ignited. Second, we find ourselves at the pinnacle of the 430 million year coevolutionary continuum of all terrestrial species with fire. Third is the distribution of organisms on the fire frequency continuum. Put another way, all terrestrial species from microbes and insects to migratory birds, have fire relations. Those species such as Venus flytrap (*Dionaea muscipula*, a threatened species) that require fire at least every 3 years, occupy one extreme; those of habitats that never burn occupy the antipode (Frost 2000). One new target of research is to be able to describe the range occupied by each species on this long gradient of fire frequency. We know this only for a handful of rare species, but with further work it will be possible to map the range occupied by every

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species of plant or animal on this continuum. This aspect of fire dependence represents one implement for preventing extinction through use of prescribed fire.

We find ourselves participants in an unprecedented confluence of four changing paradigms of seismic proportions: Climate change, mass extinction, the population bomb, and the final planetary triage of lands, of which "nature"—the world of full species diversity and natural processes such as fire—is already the smallest.

"Climate change changes everything" is an oft-heard motif in the struggle against censorship of discourse on global warming. Climate change is just one symptom of overpopulation. We can see two ways to put climate change in ecological perspective: First, we have the socioeconomic perspective implicit in the statement above. From the anthropocentric viewpoint this is undeniable: Our culture—no matter the inevitable resistance and conflict—is destined for pervasive social change in all dimensions, including restructuring of our economic systems.

In contrast, from the perspective of a fire planet, climate change changes nothing in the fundamentals of fire ecology. A species that requires a 3- to 5-year fire interval today will still require that interval 50, 100, and 300 years into climate change, even though its range may change and frequency requirements change slightly with fuels. Failure to distinguish these two perspectives sets up a dangerous and self-defeating muddle in conservation: Seen from the first perspective, everything is off on new trajectories and the old ecology does not matter anymore (Botkin 1990; Schmitz 2016). But throwing out the baby with the bathwater is a consistent feature of paradigm change that follows the acceptance phase. From the perspective of nature, the basic processes that support species diversity, including fire, remain unchanged.

Further, as we shall see, there seems to be no supportable reason to expect that the anthric "New Ecology" and the natural ecology that evolved with fire for 430 million years, can coexist in the same landscapes. The outcome of our mission as fire ecologists depends on being clear about this dichotomy.

THE FIRST DOMAIN

The First Domain, the public and private lands that have been set aside primarily for the survival of nature, is the world of concern for fire ecology. This is the planetary reserve, the islands and archipelagoes of diversity, the intricate natural world from which we arose and whose ancient sustaining processes such as fire, predation, and herbivory we have simply not yet begun to understand. In the United States this legacy consists of the 14 percent of lands permanently committed to preservation of species diversity and natural beauty—our national parks, national wildlife refuges, wildernesses; portions of national forests and Bureau of Land Management (BLM) lands; all comparable State and local lands; and the lands of private conservation agencies. In this domain there are some 25,800 protected natural areas in the United States (World Database on Protected Areas 2015). In the United States the great triage is nearly complete; beyond a few additions, this is all we will ever have to work with. Because of the threat of mass extinction—epitomized in North America by fire dependent species—restoring fire integrity to these lands is just not optional: Nothing short of eventual full restoration of original fire frequency across these lands seems likely to provide survival for some 50 percent or more of all our native species of birds, plants, and animals, the more sensitive half of our biota, the diversity that is incompatible with human-transformed lands.

Conversely, we should be able to dispense with fire as a tool for restoration in the 86 percent of the land already appropriated for farms, ranches, grazing lands, timber plantations, and the completely transformed world of cities and the intensive agriculture and silvicultural lands that support them. These are the domain of the "New Ecology" (Botkin 1990; Schmitz 2016). As we will see from several lines of evidence in the following discussion, truly natural fire regimes, because of their obligate frequencies for species diversity, are largely incompatible with production lands.

Fire Dependent Species and Fire Integrity

Understanding this core world of conservation requires two new definitions; first is the concept of fire dependent species. By previous conceptions, never really defined, a fire dependent species was one possessing some evolutionary trick such as serotinous cones that open with the heat of a passing fire to shower seeds onto newly exposed mineral soil. Mechanistic fire dependence, however, is only the tiniest tip of the iceberg.

Fire Dependent Species

For a realistic definition, a fire dependent species is any species of plant, bird, or animal that will ultimately become rare or go extinct without fire. By this new criterion, since a large percentage of our flora, along with the arthropods, bird, and animal species that depend on plants for food and habitat, require regular fire to maintain open, sunny structure, something approaching half or more of all terrestrial species in the United States are threatened by fire exclusion. This is mass extinction in progress, almost unheeded and obscured in the smoke and conflict over climate change.

Fire is a broad conditioning agent. Understanding fire dependence hinges on recognizing the totality of the effects of natural fire as it moves through a landscape. This engenders a second new concept, fire integrity.

Fire Integrity

Fire integrity is defined as fire moving freely through a landscape, through the seasons and years, at its natural frequency; displaying its customary range of behaviors; constantly renewing vegetation; stabilizing soil chemistry; removing dead fuels; renewing the complex multidimensional mosaic of species' habitats and structure at all scales, thereby sustaining the full diversity of terrestrial species from soil microorganisms to arthropods, birds, plants, and animals as it has done for over 400 million years. Full fire integrity must also include its interactions with the dynamic equilibrium of predators and herbivores.

This may seem complex, but nature is complex; the central concept inherent in the 10 points in the preceding definition is that fire is a broad conditioning agent, interacting at so many levels that there is nothing—*no conceivable surrogate for fire*—that can perform these myriad functions but fire itself. Like it or not, we have no choice but to eventually restore fire habitats and fire frequency to the 14 percent of public and private natural lands that we have committed to the perpetuation of the natural world.

To date only a handful of studies have begun to approach the full multifactorial complexity of these interactions (Fuhlendorf and Engle 2001; Fuhlendorf et al. 2006, 2012). Restoration of fire integrity is a rich new field for research. It will require close and regular interactions between the three currently disparate fields of fire ecology, wildlife biology, and plant ecology. There are almost no well-designed multifactorial studies involving all three disciplines in the study of species diversity and species survival under the interactions of natural levels of predation, herbivory, and fire. Yet these are the very conditions underlying terrestrial species diversity and its long-term survival that is by default our responsibility and mission.

Text Box 1 lists some components of the condition of fire integrity that will underlie any success we hope to have in sustaining species diversity on committed natural lands in perpetuity.

Eight Converging Lines of Evidence for Pervasive Fire Dependence Among Species and Habitats

The pre-European United States was a frequent-fire landscape. Except for the roughly 25 percent of the contiguous lands of the United States that is desert or mountainous, the landscape had substantial areas supporting very frequent fire, with intervals between 1 and 14 years (Frost 1998; Guyette et al. 2012). These regions contained literally thousands of species dependent on those frequencies to maintain their thousands of habitats.

First Line of Evidence

In the first approximation map of pre-European fire frequencies of the United States, large areas of the south-central and southeastern United States were shown in the 1- to 3-year fire interval class (Frost 1998). As pointed out in the text, but often overlooked if one only glances at the map, this does not mean that the whole landscapes burned at the intervals shown in the polygons. For a polygon to receive the indicated frequency means that at least an estimated 10 percent of the area burned at that frequency. The intent was to point out the highest frequencies to be found in each region of the country and to begin to convey the idea that the pre-European United States was a frequent fire landscape. This theme was echoed, using an entirely different approach, in a map by Guyette et al. (2012)

Text Box 1.
The conditions and principles of fire integrity.

The concept of fire integrity recognizes that:

- Fire integrity is a condition of the landscape, not a fire regime.
- Fire integrity is measurable in terms of natural habitat structure and presence of sentinel plant species, those most sensitive to departure from natural fire frequency. These are specific for each site.
- Predation, perhaps half by Native Americans and half by animal predators, once protected vegetation diversity by maintaining a dynamic balance between predation and populations of master herbivores such as deer (*Odocoileus* spp.) and elk (*Cervus canadensis*) in a landscape with vegetation diversified and constantly reinvigorated by fire.
- Fire is a universal conditioning agent affecting soils, surface fuels, and vegetation structure, and underpins the thousand individual species habitats on each site, even as they shift in relation to climate change.
- Only fire can perform the thousand tasks—chemical, micro, and macro—that must be executed regularly in each natural area.
- There is no surrogate for fire: Nothing else comes even close.
- In Domain 1, fire, like rain, is an indispensable component of the environment and is not made irrelevant by climate change, by new trajectories of succession, or the "New Ecology."

based on the Arrhenius equation. The two maps largely agree in their broad-brush vision, but Guyette et al.'s map offers better detail.

These maps constitute the first of several converging lines of evidence that some 50 percent of all terrestrial species of birds, plants, and animals in the United States are, in the long run, dependent on fire for survival.

Second Line of Evidence

Figure 1 shows a 245-year fire exclusion chronosequence for nine 0.1-ha plots on similar silty loam soils in eastern North Carolina. The plot on the left, JO03, with 68 species, had been burned in recent years on a 3-year frequency in the Croatan National Forest, maintaining the estimated natural, pre-European fire frequency. The other plots, when sampled, had already suffered declining fire frequency through changes dating to 1772. All plots were documented, from species remnants, historical information, and their position in frequent fire landscapes, to have historically supported open, sunny longleaf pine (*Pinus palustris*) savanna with an herbaceous grass-forb understory. The red line represents fire dependent species such as wiregrass (*Aristida stricta* var. *beyrichiana*). The green line indicates fire-neutral species such as gallberry (*Ilex glabra*) that can be found in annually burned savannas as a tiny shrub 10 cm high, but also with trunks to 15 cm diameter on islands that never burned. The blue represents fire-refugia (fire intolerant) forest species. When sampled, the last two plots on the right, on a site occupied by longleaf pine when advertised for sale in 1772, were now shady, closed-canopy beech forest with white oak (*Quercus alba*) and tulip-poplar (*Liriodendron tulipifera*). In the same county there had been exploitation of longleaf pine for tar, pitch, and crude turpentine as early as 1622 (Frost 2000).

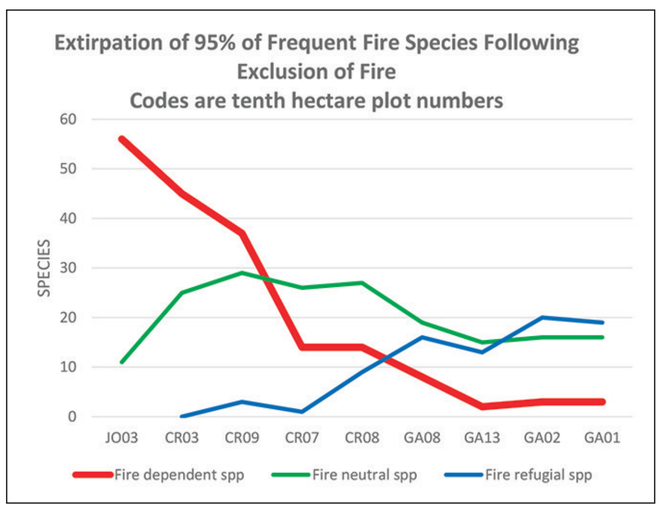

Figure 1—Number of species on plots in the southeastern Coastal Plain, North Carolina, following fire exclusion. The loss of 95 percent of fire dependent species in the southeastern Coastal Plain is a second line evidence for fire dependence and impending mass extinction. Codes identify 0.1-hectare plots.

Over the 37.6 million hectare former longleaf pine region, progressive fire deprivation has resulted in complete turnover from very frequent fire, open, sunny, species-rich communities to the uniformly dark, multistoried, species-poor forests and thickets that have taken over the eastern half of the country and many smaller areas elsewhere (Frost 2006; Nowacki and Abrams 2008). This is an ecological catastrophe the role of which in the impending sixth extinction is not yet appreciated.

Third Line of Evidence

This line of evidence lies in community response to extremely high fire frequency. In what they called the Most Frequent Fire Hypothesis, Glitzenstein et al. (2003) found that burning as frequently as fuels allowed produced the highest species richness in frequent fire longleaf pine communities. This positive fire community response to the *highest fire frequency possible* suggests that nearly annual (1–3 years) fire frequencies are natural in some landscapes and may be ancient, extending into the evolutionary past, far beyond the appearance of humankind in the western hemisphere.

Fourth Line of Evidence

This line presents itself in numerous studies and observations on pyroecology of individual species. The response of many endangered species indicates that fire deprivation underlies the increasing rarity of a previously unimagined large portion of our flora and fauna. For examples, see Venus flytrap in the Carolinas and in Florida the endangered Kissimmee grasshopper sparrow (*Ammodramus savannarum floridanus*), which rotates its nest sites into patches burned in the last year and a half, in a wet prairie landscape that experiences a 1- to 3-year fire regime driven today solely by lightning (Noss 2013).

In the Green Swamp of North Carolina a 30-year study found that the largest number of Venus flytraps per square meter occurred in plots burned annually. When mean fire frequency dropped to 2 and 3 years, numbers plunged; and when mean fire frequency dropped below 4 years, plots were overgrown with shrubs and flytraps disappeared (Frost 2000). This makes Venus flytrap the most fire dependent species known. This and its extreme evolutionary adaptions—the snap trap itself, with its triggering algorithm and its production of enzymes to digest insects for their nutrients—point again to landscapes with very frequent fire extending back millions of years.

Fifth Line of Evidence

Fire scar chronologies provide the fifth line of evidence. The existence of nearly annual fire in pre-European landscapes was first documented in Arizona from a fire scar chronology by Dieterich (1980) and more recently from Louisiana (Stambaugh et al. 2011), Florida (Huffman and Rother 2017), and other studies for a total of at least five States. At least five studies are in the southeastern United States, where a number of species dependent on this frequency have been documented.

Sixth Line of Evidence

Tracking the rate of slide of fire dependent species toward extinction is a new field and such evidence is needed to even begin to determine the percentage of species dependent on fire globally. Despite the necessity of such information for response to global extinction, this field is as yet virtually unfunded. Under the Global Strategy for Plant Conservation, Backman et al. (2018) reported current progress toward a global conservation assessment for all plants, assembled species status reports from available sources, and have assessed the status of up to 90,321 species to date. This represents 26 percent of known plant species. In the United States there is no government or private agency tasked with monitoring the overall condition of the flora and the rate of slide of all species toward extinction. The U.S. Fish and Wildlife Service responds when a single species is proposed for listing and States' Natural Heritage Programs maintain their lists of endangered and threatened species and periodically review rare species. There seems to be no place, however, where the rate of new listings over time is reported, much less any way to gauge the changing status of all species, be they plants or animals.

Seventh Line of Evidence

Similarly, there is no agency charged with monitoring the role of livestock in extinction of flora and fauna. Cattle (*Bos taurus*) can be expected to be a part of our civilization for hundreds of years. In the long run, however, because of their proclivity to dichotomizing native flora and fauna into "increasers" and "decreasers," livestock—at any commercially profitable level—are likely to be incompatible with as many as 50 percent of species native to North American grasslands.

For over a century, cattle and sheep (*Ovis aries*) ranchers have recognized that some plant species increase with grazing—these are the plants that livestock refuse to eat. They call these unpalatable, armed, or toxic species "increasers." Increasers are easier to document than decreasers because they increase. Changes in abundance of decreasers—the tasty, easily digestible, nutritious species—are easily overlooked unless they are among the dozen or so dominant forage grasses, shrubs, and showy native forbs found on a particular piece of range. In northern mixed grass prairie for example, species whose decease may raise alarm include cattle favorites such as bluebunch wheatgrass (*Pseudoroegnaria spicata*), western wheatgrass (*Pascopyrum smithii*), little bluestem (*Schizachyrium scoparium*), saltbush (*Atriplex* spp.), and purple prairie clover (*Dalea purpurea*) and standard range condition monitoring methods understandably are strongly slanted to these. Fleischner (1994) summarized the ecological costs of livestock grazing in western North America.

We can get some inkling of livestock potential for tipping the extinction scale by comparing what is known about decreasers and increasers. A few floras and plant guides across North America have begun to supply this vital information. The flora *Plants of the Black Hills* mentions palatability for 195 species, or 49 percent of the approximately 400 forbs covered in the book (Larson and Johnson 1999). Eighty-three plants or 43 percent of the 195 were considered to have some degree of palatability for cattle and 112 or 57 percent were unpalatable. So for the species for which something was known, a little less than half are negatively affected by livestock grazing and may have a long-term potential for elimination. We can infer a similar level of threat to native arthropods, birds, and animals native to the original fire-maintained North American grasslands.

Few studies of cattle grazing have taken into account that species diversity likely was maintained primarily by fire, not grazing. This is suggested by the large portion of the country—the lands west of the Continental Divide and east of the Mississippi River that had no bison (*Bison bison*) for some 9,000 years of the Holocene until the 1540 introduction of European diseases by the De Soto expedition through the Southeast and the simultaneous Coronado expedition from Mexico City to the vicinity of today's Kansas. Both explorations introduced plagues along the way, decimating Native American populations. Historical accounts of bison from these regions seem to date the expansion of bison range after diseases provided relief from hunting pressure. Prior to that event there was no cattle analog in large parts of North America, yet grasslands thrived. Despite the need for data for preventing extinction, no good multifactorial studies exist that have examined the relationships of species diversity of plants, birds, and animals under natural pre-European fire frequencies—almost universally much higher than for the last century—and the natural level of native grazers and browsers—almost universally much lower before settlement.

The unpopular, yet inescapable, conclusion for the web of life is that cattle will be a permanent part of working landscapes, as they are now, but, with portions of some agencies such as BLM excepted, livestock must eventually be excluded from most of the First Domain.

Eighth Line of Evidence

It is now possible to make fine-scale maps of pre-European fire frequency (Bailey et al. 2007; Frost et al. 2013; LANDFIRE 2018). This is another new field that should play an increasingly important role in restoring fire integrity to the First Domain.

While we are just beginning to glimpse the evolutionary world of natural fire regimes, it would be irresponsible to ignore the weight of emerging evidence summarized in the preceding discussion and the implications for species diversity. For most of the undocumented thousands of fire dependent species there is a fatal risk of not meeting their required fire frequency when planning the future of prescribed fire. Given our imperfect knowledge, the risk of omission—not burning often enough—far exceeds the risk of commission—too much fire in frequent fire ecosystems. Where these species occur on public lands and preserves, our highest obligation as land managers is to burn the most critical sites often enough to maintain full species diversity. Fire is our only practicable tool to employ against the current slide to mass extinction in North America.

HOLDING ACTIONS

If we recognize, in the current political situation, with its suppressed funding for all things natural, the impossibility in most cases of proceeding with full restoration of natural fire frequency over whole large "protected" land units, the most reasonable course should be to construct a clear plan of prescribed burn holding actions that will actualize our responsibility to ensure survival of full species diversity in each natural site we manage.

Abandon "Fire Rotations" in Favor of Ecologically Targeted Burning

Likely the most important holding action we can take is to adopt ecologically targeted burning. This is the opposite of broadcast burning or fire rotations. Heinselman (1973) coined the term "natural fire rotation" to obtain some handle on fire frequency in fire-suppressed northern landscapes, where even the natural fire intervals were longer than in most of the United States, and where ignitions were perceived as spatially random events—an invalid assumption for most landscapes other than perhaps boreal forest. It was defined further by Agee (1993) as the time needed to burn an area the size of the study area, while recognizing the critical point that some areas might burn twice or more and others not at all. This provided a rough measure that could be used to compare fire frequency between different areas, a tool that was useful with the limited data of the time. A quarter-century later we have much better fire history information (Frost 1998; Frost et al. 2013; Guyette et al. 2012) and can now make fine-scale maps of pre-European fire frequency (Frost et al. 2013).

The "fire rotations" concept has been misinterpreted in at least three ways, all of which set up situations for mismanagement and present severe threats to species diversity on public natural lands:

(a) Some users treat Heinselman's "fire rotation" as an indicator of natural fire frequency.

(b) Worse is the case discussed shortly where land managers try to burn all of a managed area one block at time and call that a fire rotation.

(c) Silviculturists sometimes use the term to refer to the cycle of burning on the arbitrary management units we set up according to roads, creeks, etc. for convenience. This might be a useful redefinition if we could drop the original, which has little application now that we have satellite imagery, geographic information systems (GIS), LANDFIRE, and new ways of getting at actual current fire footprints and historical fire frequency at fine scales.

Perhaps the best advice—since the term "fire rotation" seems to be popular in spite all of its misapplications—is to never use it in print unless it is made clear that we use it in the sense of case c.

Looking closely at case b, we can see how this most pernicious example is a clear threat to species diversity on public lands. In figure 2, the forest has the resources to burn 5,000 acres a year, so the year after the first unit is burned a second compartment is burned and so on until after 100 years all of the forest will have been burned and we will have completed one "fire rotation." Under this misinterpretation what we have done is set up a 100-year fire return interval and in the process, eliminated all of the fire dependent species and ruined the most important sites that once sustained the greatest species richness.

Ecologically targeted fire, in contrast, requires us to burn the three areas with the highest concentration of fire dependent species first, and do so as often as needed, before all else. If the three sites in the example require fire every 4 years we would burn one of them each year, and in the fourth year we have resources equivalent to burning 5,000 acres to spend elsewhere on fuel reduction, oak and hickory (*Carya* spp.) regeneration, and the like. We have to let the rest go. This seems a bitter choice but, given the current natural resources funding anomaly, we are presented

Burn compartments of hypothetical national forest of 500,000 acres

5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	**5,000**	**5,000**	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	**5,000**	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000

Figure 2—An illustration of the danger of one common misinterpretation of "fire rotation" in the eastern United States. Shown is a hypothetical 500,000-acre natural area such as a national forest, divided into 100 burn compartments. The three units in boldface represent naturally frequent fire sites with rare species and unique fire communities.

with no other option than to accept extinction of the ecologically most important species and communities. We may hope for and be prepared to use fire from lightning or other ignitions, but the core diversity—our legacy to future generations—must be preserved.

Agee (1993) distinguished two kinds of fire frequency, point frequency and area frequency. Noting that the term "point" is problematic because a single tree is rarely scarred by every passing fire, he expanded "point" to mean enough land to include enough trees to construct a composite fire scar chronology.

Site Fire Frequency

I would suggest that the most ecologically useful fire frequency be called site fire frequency, synonymous with natural fire compartment, which captures Agee's "big point." Site or fire compartment is defined as a unit of the landscape with no internal firebreaks and nearly continuous fine fuels, so that an ignition in one part would be likely to burn the whole unless there were a change in weather or fuel moisture.

Fire compartment size is the most important driver of fire frequency in most landscapes: The larger the compartment, the higher the fire frequency (Frost 1998). Further, by definition, boundaries of the fire compartment could be expected most often to correspond with boundaries of the fire footprint in landscapes with equable moisture. In many parts of the country—other than the drylands—streams, small swamps, and moist ravines divide the landscape into discernable natural fire compartments. Fire frequency, defined this way, is the most unambiguous term.

The Heinselman approach was a first attempt to provide a measure that could be used to compare fire frequency between different areas. Today, on many sites, we have 30 or more years of fire data, spatially mapped on GIS systems, as well as a growing repository of historical fire frequency in the national database represented in the International Multi-Proxy Database (IMPD) and in LANDFIRE as discussed in the lines of evidence earlier. Given that we now have far more data access—in the form of broad-brush maps (Frost 1998; Guyette et al. 2012), the IMPD, LANDFIRE, and fine-scale mapping (Frost et al. 2013), we may now focus on actual fire frequency—historical as well as modern.

It is time to honor Reed's (2006) call for abandoning the pernicious term "fire rotations" for good or to redefine it for use in case c above. Further, we should be careful with the generic term "fire cycle," always defining what we mean.

Plan to Burn the Most Ecologically Important Sites First

The best plans for prescriptive fire or fire use, where fire dependent species remain, would give such sites priority over any other uses of fire. Using the best available knowledge and with advice from regional fire, plant, and wildlife ecologists, we can choose the best historical and existing sites for active restoration and reintroduction of fire dependent grasses and forbs. While largely irrelevant for the vast working landscapes of farms, ranches, and commercial timberlands, restoring fire integrity to our protected natural lands is our only hope for avoiding loss of perhaps half of total species diversity in the United States in the impending mass extinction of the next few decades.

Poster Children

As a holding action, perhaps the most important step we can take as managers on every piece of public natural land or private preserve is to fully restore fire integrity to one or more of the sites with the highest historical fire frequency, or "exemplary sites." In most cases these would have been the sites with the highest diversity of birds, plants, and animals. With rare exceptions such sites will require reintroducing species extirpated by fire suppression and other past human disturbance and adjusting range boundaries for climate change. Reintroductions require assembling the best onsite knowledge plus expertise from regional ecologists and State heritage programs.

Such a site, made accessible to visitors, is like opening the index for a book, an index of what we are trying to achieve. Seeing is believing; be it a prairie, savanna, or forest with a grassy understory, frequent fire communities are always beautiful. Increasingly rare, an exemplary site creates a window on the natural world. Nothing is more likely to build public support for fire as a sustainer of the web of life.

The Pendulum

The pendulum of funding for conservation has gone through historical swings. Pressures from diverse sources are building and the present aberration will not last. Funding for natural resources and the environment, Budget Function 300, has declined from about 2.4 percent of the national budget in 1977 to less than half, about 1.21 percent today (CBO 2017), at the same time that environmental needs, unprecedented in the history of civilization, have risen. Many forces are building to bring funding back to rational levels. As with censorship of science and climate change, public awareness of the equivalent crisis, mass extinction, will emerge as more species vanish and the lid on media news about environmental crises lifts.

In surveys, some 70 percent of Americans consistently consider themselves conservationists. This includes groups ranging from hunter conservationists to People for the Ethical Treatment of Animals (PETA). In a recent survey of 5,550 adults, those who said that we need to increase the number of programs available for Americans to enjoy nature, the outdoors, and wildlife included respondents of whom 71 percent self-identified as conservatives and 81 percent as liberals. Measured by political affiliation, these represented 74 percent of Republicans and 81 percent of Democrats (Kellert 2017). Only 3.2 percent of all adults think these sorts of programs are overfunded. The disconnect between attitudes of the people and actions of government is striking.

In a second, encouraging, survey, younger adults are more likely (59 percent versus 35 percent of all Americans) to have taken some action to help stop the Federal government from reducing environmental protections or wildlife conservation (PGAV 2017). This survey among adults in the United States aged 18 or more, was weighted to ensure national representation across gender, region, education, income, and race or ethnicity. Both surveys suggest support for an impending swing of the funding pendulum and the future of conservation.

As the current political aberration plays out, a multitude of new careers in conservation are emerging and unrelenting land development and extinction pressure will require massive new funding in the next two decades. Our most promising action for now must lie in effective new holding actions, laying the groundwork and preparing to move when new funding appears.

CONCLUSIONS

Since the fate of perhaps half of plant species, as well as the animals that depend on them for food and habitat in the United States, requires returning fire to the First Domain, restoring fire integrity deserves to be a crucial conservation mission on a par with climate change.

History will little care nor long remember how many fires we fought or how many buildings we saved. What history will record is this era of holding actions, and the resolute and undaunted actions of those who advanced the field of fire ecology, from its very fundamentals to restoring windows on the natural world—places of beauty and species diversity, bringing the great sustaining process that is natural fire back to protected lands regardless of adversities. History will mark the turning point where we began to restore the natural processes of fire, along with its interactions with the dynamic balance of predation and herbivory, to the dedicated natural landscape. As all the remaining unprotected lands of the Earth are converted to human uses in this, the last generation of unmanaged nature, the magnitude of this gift of fire-maintained habitats with their thousands of species of birds, plants, and animals will resonate with all future generations.

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