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Forum

Of Grouse and Golden Eggs: Can Ecosystems Be Managed Within a Species-Based Regulatory Framework?

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Abstract

Declining greater sage-grouse populations are causing concern for the future of this species across the western United States. Major ecosystem issues, including exotic annual grass invasion and conifer encroachment, threaten vast acreages of sagebrush rangeland and are primary threats to sage-grouse. We discuss types of problems facing sage-grouse habitat and argue that complex ecosystem problems may be difficult to address under the Endangered Species Act as currently applied. Some problems, such as anthropogenic development, can be effectively regulated to produce a desired outcome. Other problems that are complex and involve disruption of ecosystem processes cannot be effectively regulated and require ongoing commitment to adaptive management. We believe that historical inertia of the regulatory paradigm is sufficient to skew management toward regulatory mechanisms, even though complex ecosystem problems impact large portions of the sage-grouse range. To overcome this situation, we suggest that the regulatory approach embodied in the Endangered Species Act be expanded to include promoting management trajectories needed to address complex ecosystem problems. This process should begin with state-and-transition models as the basis for a conceptual framework that outlines potential plant communities, their value as sage-grouse habitat, and their ecological status. Desired management trajectories are defined by maintenance of an ecologically resilient state that is of value as sage-grouse habitat, or movement from a less desired to a more desired state. Addressing complex ecosystem problems will involve shifting conservation roles. Under the regulatory approach, programmatic scales define regulatory policies, and local scales focus on implementing those policies. With complex ecosystem problems, programmatic scales empower local conservationists to make decisions necessary to adaptively manage problems. Putting ecosystem management on par with traditional regulatory actions honors obligations to provide regulatory protections while maintaining the capacity of the ecosystem to produce habitat and greatly expands the diversity of stakeholders willing to participate in sage-grouse conservation.

Key Words: Endangered Species Act, sagebrush, sage-grouse, state-and-transition

INTRODUCTION

In the tale of the goose that laid the golden egg, a farmer and his wife who are in possession of said goose, kill the goose based on their hypothesis that inside the goose would be found a great quantity of gold. Initial enthusiasm turned quickly to postmortem despair on finding the goose to be barren of internal wealth. The situation then went from hapless to hopeless with the dawning realization that, absent the goose, there would be no more golden eggs.

This fable may be an apt metaphor for some of the difficult conservation challenges facing today's society and natural resources professionals. Consider, for example, the issue of species-centric vs. ecosystem management. When populations of sensitive species decline, concern over their numbers often prompts species-centric actions on a variety of fronts, including policy, regulatory, and judicial actions (Mann and Plummer 1996). Meanwhile, public and private land managers struggle to maintain ecosystem processes and functions against a seemingly unending tide of destabilizing influences (Davies et al. 2011). This dichotomy between species-centric and ecosystem management is not academic but is instead consistent with contemporary challenges relating to the needs of a burgeoning list of sensitive species (i.e., golden eggs) vs. those of the larger ecosystem that produced these species (i.e., the goose). Unlike the farmer of the original story, most of the participants in this debate are ultimately driven by concern over the well-being of sensitive species and natural environments. Nevertheless, decisions have consequences, and the decisions regarding how we approach both species and ecosystem management have had and will continue to have significant bearing on conservation of our vast wealth of natural resources.

Those consequences are becoming increasingly evident as we approach a court-ordered 2015 deadline for a decision by the US Fish and Wildlife Service on whether to afford Endangered Species Act (ESA) protections to the greater sage-grouse (*Centrocercus urophasianus*). In the run-up to 2015, we have seen a wide diversity of management and policy initiatives unfolding across the western United States promoting sage-

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grouse habitat conservation (e.g., the Sage-Grouse Initiative, www.sagegrouseinitiative.com), preemptive management agreements in case the species is listed (e.g., Candidate Conservation Agreements with Assurances), and broad-scale state and federal planning and policy revisions to address threats to sage-grouse (e.g., the Bureau of Land Management [BLM] National Greater Sage-Grouse Planning Strategy). Ongoing sage-grouse habitat management programs have both individual and collective value, as will be discussed later in this article, but they are largely an outgrowth of concern over a potential listing of the species in accordance with ESA provisions. We argue that the current regulatory framework (i.e., the ESA) promotes a species-centric management approach and, importantly, fosters a disproportionate focus on the use of regulatory actions in management of sensitive species (Benson 2012). Missing from this equation has been a larger discussion of how to reconcile the notions of sage-grouse–specific regulatory concerns vs. those relating to ecosystem dysfunction and how we go about addressing and valuing complex ecosystem problems within the bounds of the ESA.

The above should not be taken to imply that there is a general lack of awareness of the ecosystem-based problems currently facing sage-grouse and other sagebrush obligate and facultative obligate wildlife species. Indeed, any number of topical papers and book chapters have characterized the current and future welfare of sage-grouse as being strongly driven by disruptions in ecosystem processes (Wisdom and Chambers 2009; Knick and Connelly 2011; Baruch-Mordo et al. 2013). However, this collective recognition is taking place under the umbrella of an overarching regulatory framework and has not translated into a sufficient emphasis on the complex ecosystem challenges currently facing sage-grouse. In fact, there seems to be an increasing expectation to view ecosystem issues through the lens of sage-grouse habitat requirements (e.g., the Habitat Assessment Framework; Stiver et al. 2010) and how these requirements might be used in a regulatory process (BLM 2013). We are concerned that a sage-grouse emphasis will encumber management of the complex ecosystem problems underlying the decline of the species and that a federal listing of sage-grouse would only exacerbate the gap between threats associated with complex ecosystem problems and the efficacy of policies to address those threats.

In this article, we seek to characterize the current management and regulatory challenges facing administration of sage-grouse habitat in light of two divergent problem sets: 1) problems that can be regulated and 2) ecosystem problems that cannot be regulated. Second, we develop suggestions for changes in the existing regulatory framework that would allow it to better address complex ecosystem problems within sage-grouse habitat. Within the manuscript, we provide contemporary examples of management efforts that address sage-grouse habitat issues arising as a result of complex ecosystem problems.

PROBLEMS AND PARADIGMS

Defining Habitat Management Problems

Boyd and Svejcar (2009) defined two classes of natural resource issues: "simple" issues, whose causative factors have little variation in space and time, and "complex" issues, with causative factors that vary over both space and time. Here we define two general types of problems relating to sage-grouse habitat management: 1) those that can be regulated and 2) those that cannot. "Regulatable problems" are those issues that can be directly addressed using interdictory or prohibitory-based administrative rule sets. Such problems are generally simple in nature and may or may not impair ecosystem function. These types of problems are often caused by humans (e.g., point-source pollution) and are often associated with species-specific impacts or impact groups of species with similar habitat requirements. Examples of regulatable problems include the decline of the American alligator (*Alligator mississippiensis*) due to inadequate harvest restrictions (Mann and Plummer 1996) and the impact of exotic foxes on Aleutian cackling goose (*Branta hutchinsii*) populations (US Fish and Wildlife Service [USFWS] 1990). Alternatively, "complex ecosystem problems" are those that cannot be effectively regulated, impair ecosystem function, and are always of a complex nature. Complex ecosystem problems generally impact habitat conditions for groups of species that may or may not have similar habitat requirements. The origins of these complex problems are often human caused, but the problem can persist in the absence of the original stimulus because the problem itself modifies ecosystem processes in ways that amplify persistence of the problem. For example, historical livestock overgrazing promoted exotic annual grass invasion, which can persist in the modern environment, with or without grazing, due in part to increased fire frequency associated with annual grass invasion and the negative effect of repeated fire on desired native plant species (Davies et al. 2009). Examples of complex ecosystem problems impacting individual species or groups of species include the effects of altered fire cycles on black-capped vireos (*Vireo atricapilla*; Grzybowski et al. 1994) and big sagebrush (Davies et al. 2011).

We believe it is important to differentiate "complex" ecosystem problems from "simple" ecosystem problems because the latter can often be regulated. Consider the effects of DDT on bald eagle (*Haliaeetus leucocephalus*) populations (Fig. 1; Grier 1982). We recognize that many elements of the use of DDT are associated with hierarchical effects that could culminate in complex ecosystem-level impacts. However, the basic problem facing piscivorous raptors was that reproductive output of these species was being compromised by consumption of DDT-laden fish stocks (Wiemeyer et al. 1984), and that is a problem that can be regulated. Thus, regulatory action to remove DDT from the ecosystem represented a simple, long-term solution to population declines in fish-eating raptors.

At the range-wide scale, greater sage-grouse are impacted by both regulatable and complex ecosystem problems (USFWS 2013). Regulatable problems have been reviewed in great detail by previous authors (e.g., see Connelly et al. 2004; Knick and Connelly 2011), and potential examples of such issues would include behavioral avoidance of energy development (Walker et al. 2007) and fence collision mortality (Stephens et al. 2012). Complex ecosystem problems impacting sage-grouse have likewise been detailed in previous literature (Knick and Connelly 2011), and two of the preeminent threats are expansion of conifers in high-elevation communities (Miller and Eddleman 2001; Miller et al. 2005) and exotic annual grass

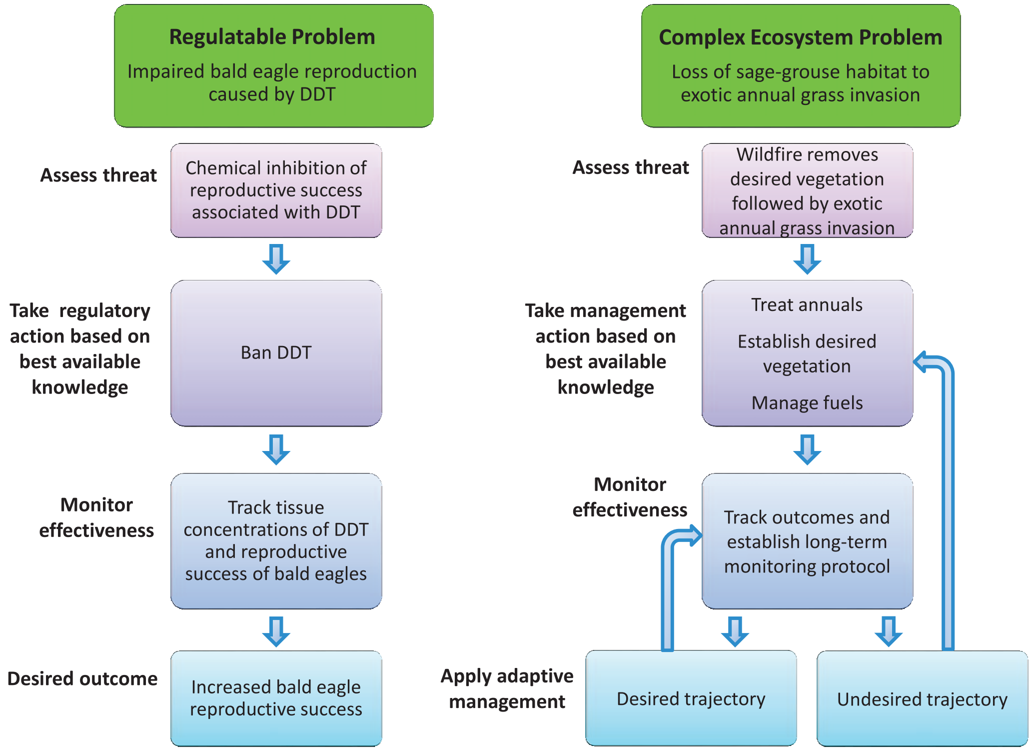

Figure 1. Declines in wildlife species may be precipitated by problems that can be regulated (left) or complex ecosystem problems that cannot be regulated. Regulatable problems have discrete end points as a function of regulatory actions. Complex ecosystem problems are temporally persistent and require continual inputs through time to maintain desired conditions.

invasion at lower elevations (Crawford et al. 2004; Davies et al. 2011), both of which contribute to habitat fragmentation and loss, which was one of the primary threats to sage-grouse identified in the 2010 USFWS Warranted but Precluded finding (USFWS 2010). The area covered by these two complex problems is enormous, and one or both of these issues have been identified as a "widespread" threat to 33 of the 39 major sage-grouse populations (USFWS 2013). Exotic annual grasses now dominate or have potential to impact plant communities on 28 000 000 ha of predominantly low-elevation western rangeland where their presence encourages frequent fire that negatively impacts desired native perennial species (Meinke et al. 2009). The expansion of these species has been characterized as the largest biological invasion in recent North American history (D'Antonio and Vitousek 1992; Chambers et al. 2007). Conifer expansion impacts approximately 19 000 000 ha of sagebrush rangeland in the western United States (Tausch et al. 1981; Johnson and Miller 2006; Miller et al. 2008). While these conifers are native, declining fire frequency in high-elevation habitats allows these fire-sensitive species to expand and replace native perennial grasses and shrubs, such as sagebrush (Fig. 2). The range of potential fire effects on sagebrush plant communities, dependent on elevation and site conditions, adds to the complexity of fire management in sage-grouse habitat.

Management Approaches and Ecological Realities

Approaches necessary to address regulatable and complex ecosystem problems are very different (Fig. 1). When problems can be regulated, threat assessment is followed by regulatory actions to address the identified threat. Monitoring can then be used to track the impact of regulatory actions on the identified threats. Assuming that the threat was correctly identified and that the regulatory actions are appropriate to the threat, regulatory actions should lead to desired outcomes. For complex ecosystem problems, best available knowledge is used to characterize and implement management actions necessary to address an identified threat. Measured outcomes are then used to gauge the effectiveness of treatments in addressing identified threats, and treatments may be modified depending on outcomes. Importantly, due to their persistent and complex nature, these problems are difficult to directly manage, and addressing threats to sensitive species does not lead to a temporally discrete and lasting desired outcome as depicted for regulatable problems (Fig. 1). Instead, addressing complex ecosystem problems involves an ongoing (i.e., long-term) commitment to adaptively using best available knowledge to affect ecosystem processes that in turn shape habitat conditions for sensitive species (Benson 2012).

Use of regulatory actions in wildlife conservation has been a critical and powerful component of wildlife conservation in the United States at local, regional, and national scales (Trefethen 1985; Mann and Plummer 1996). However, when declines in sensitive species are due to complex ecosystem problems, the regulatory and complex ecosystem problem approaches can be at odds. In such cases, what drives these approaches in different directions is often a divergence of temporal perspective. The regulatory paradigm seeks to and is often mandated to (by laws such as the ESA) identify and quell factors that negatively impact sensitive species in the here and now. In contrast, best

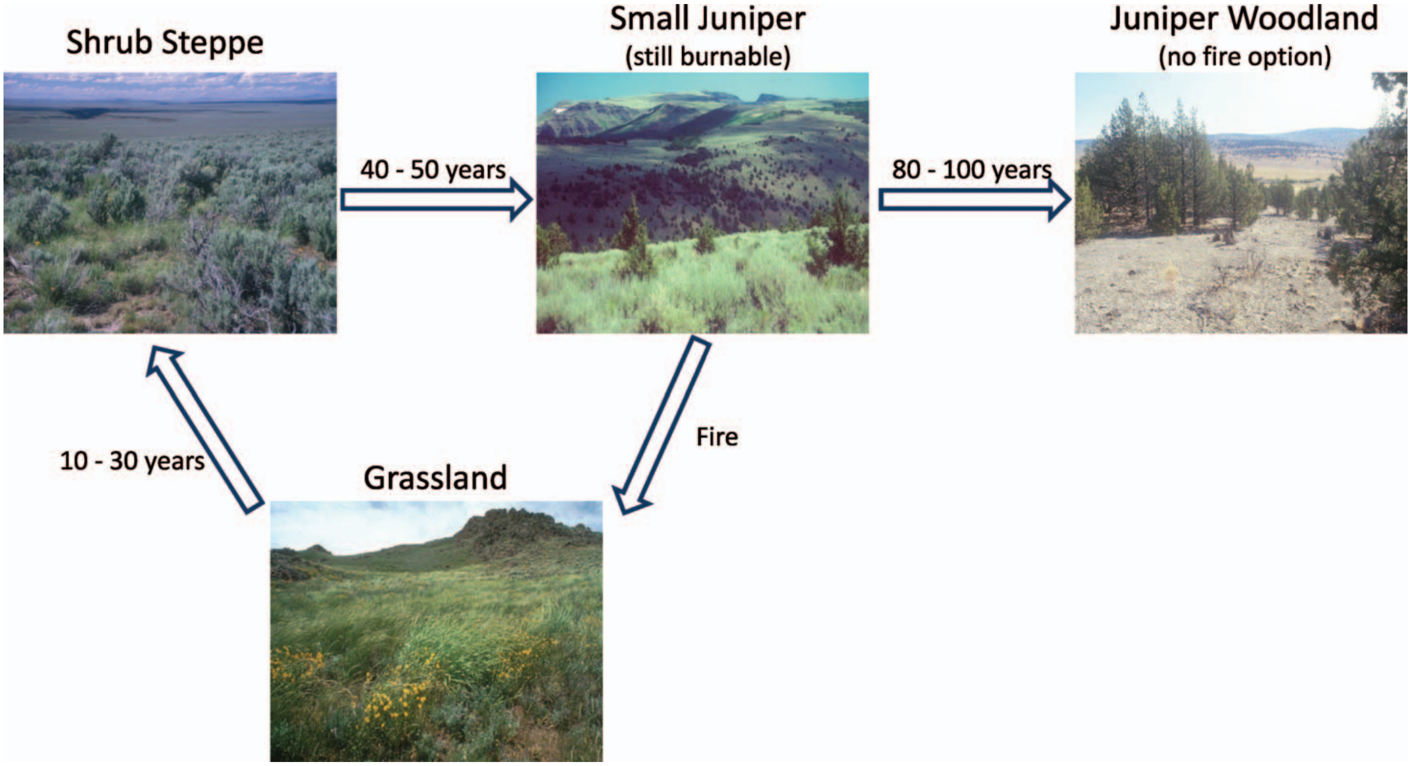

Figure 2. Model depicting plant community change over time following fire in a high-elevation sagebrush plant community with a cool and moist soil temperature and moisture regime. Adapted from Miller et al. (2005).

available knowledge under the complex ecosystem problem paradigm may suggest that improving the welfare of sensitive species can involve long-term investment in restoration of ecosystem processes (Scott et al. 2005), the benefit of which may be decades away.

A good example of this is this temporal dilemma is the relationship between conifers and fire on sagebrush Ecological Sites with a cool and moist soil temperature and moisture regime (Miller et al. 2013). As described above, declining fire frequency in these communities is associated with expansion of fire-sensitive conifer species and a loss of understory grasses and shrubs important to sage-grouse along with behavioral avoidance of these habitats by sage-grouse (Casazza et al. 2011). Expanding conifer populations have become a management imperative for both ecosystem restorationists and sage-grouse conservationists, but how the problem is viewed can have a large and important impact on how on-the-ground management unfolds. From an ecosystem management standpoint, the expansion of conifer populations is a logical consequence of the reduced presence of fire in the ecosystem. To better visualize this change, we refer to the work of Miller et al. (2005; Fig. 2). Using their work as a guideline, one might expect the progression from conifer arrival at a site to a "fully-stocked" juniper community to take approximately 100 yr in the absence of fire. Thus, viewing the situation as a complex ecosystem problem, the appropriate management trajectory would involve restoring the fire cycle in an effort to control expanding conifers. From a sage-grouse habitat standpoint, there will be a gradual decline in habitat quality over time as juniper expands in the absence of fire (Fig. 3a). However, with fire, sage-grouse habitat is essentially lost in the immediate aftermath of the fire due to an absence of sagebrush (Fig. 3b). Over time, sage-grouse habitat quality increases postfire with recovery of sagebrush but eventually declines again as conifers reinvade the site. Viewing this as a regulatable problem, the issue becomes twofold: 1) assuming we could regulate fire out of the system, sage-grouse habitat would be protected in the short term, but the ensuing lack of fire promotes conifer expansion (which negatively impacts sage-grouse habitat; Miller and Eddleman 2001), and 2) the most basic solution to the problem (i.e., restoring the fire cycle) temporarily destroys sage-grouse habitat (Connelly 2013). Thus, management trade-offs involve weighing short term costs vs. long-term benefits of fire (Fig. 3c). This conundrum can lead to divergent viewpoints of appropriate conservation measures, depending on whether the problem is viewed as being a regulatable or a complex ecosystem problem.

Overlooking the temporal aspects of ecological disturbances such as fire can promote and reinforce a regulatory-based species-centric focus in which disturbance effects are characterized as "good" or "bad." The net effect of this process is to hold ecosystem processes as subservient to the habitat requirements of a single species—a questionable notion at best that will limit both effective on-the-ground management of problems we do understand and iterative growth in our knowledge of problems we do not yet understand (Meretsky et al. 2000). Along the same lines, knowledge associated with complex ecosystem problems is not static but instead is inexorably tied both to the progress of science and to structured learning from past management efforts (Doremus 2007).

Consider the limitations of a regulatory approach in managing the complex ecosystem problem of exotic annual

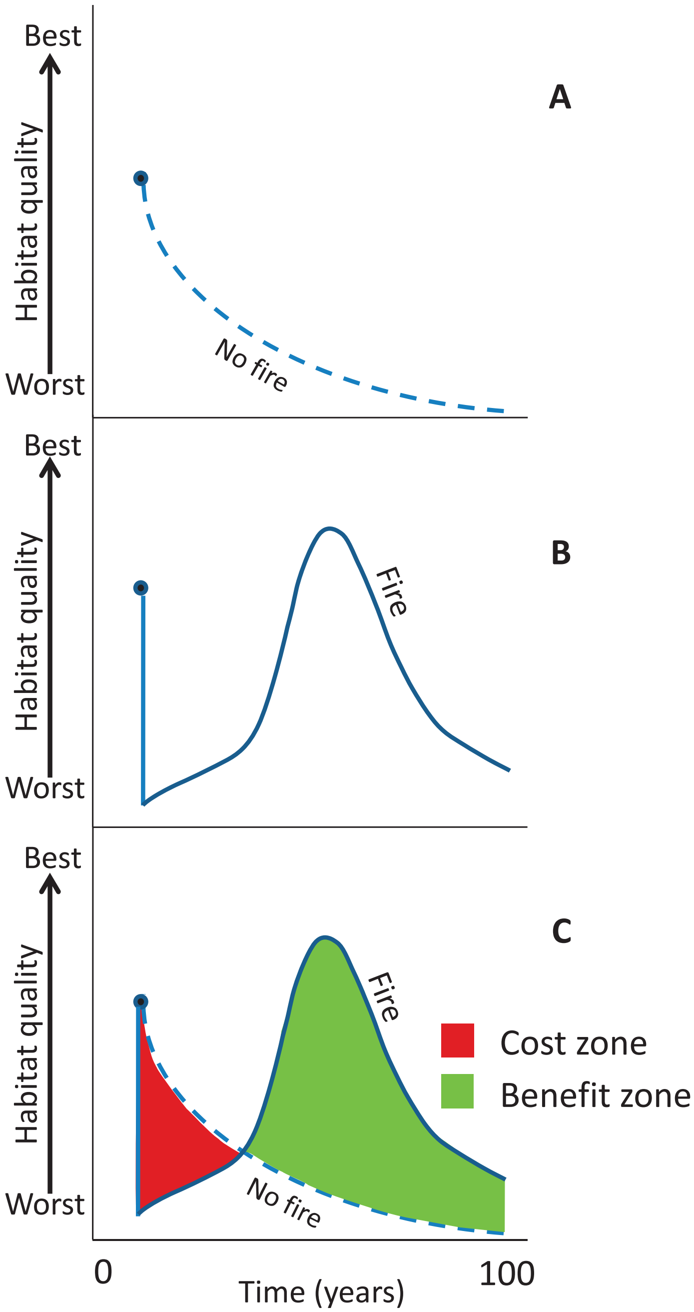

Figure 3. Conceptualized temporal changes in quality of high-elevation sagebrush/bunchgrass habitat (cool and moist soil temperature and moisture regime) for greater sage-grouse under conditions of, **A**, conifer encroachment in the absence of fire and, **B**, with fire. Without fire, juniper increases in plant community dominance and shrubs and grasses may be lost. Fire reduces or temporarily removes juniper from the site but causes initial declines in habitat quality due to short-term shrub loss; habitat quality improves as shrubs recover but begins to decline again as conifer expansion increases with time since fire. Comparison of with- and without-fire scenarios, **C**, suggests that fire is a short-term cost but a long-term benefit to sage-grouse habitat quality.

grass invasion of low-elevation habitat. Simply put, there is no one factor or group of factors that can be minimized using a regulatory framework to alleviate this problem. In reality, dealing with the annual grass issue is a three-component problem involving 1) reduction of annual grass dominance, 2) reintroduction of desired species, and 3) treating the problem long term (Fig. 1). An appropriate strategy for addressing the annual grass issue begins with determining the cause(s) of annual grass infestation, and these causes will vary over both space and time, as will the tools necessary to minimize their presence in the plant community (Krueger-Mangold et al. 2006). Similarly, reestablishing desired vegetation (e.g., sagebrush and large perennial bunchgrasses) involves determining the ecological barriers (which will vary in space and time) to seedling establishment and developing a management strategy for overcoming those barriers. On less resilient, sites this will likely involve adaptive use of emerging technologies since existing techniques have proven ineffective in reestablishing desired vegetation on these sites (Madsen et al. 2013). Importantly, successful restoration of desired vegetation is not a permanent solution, and continuous management through time will be necessary to minimize the probability of annual grass reinvasion (e.g., using fuels management to reduce fire risk and using appropriate livestock grazing management where relevant) and to treat the problem when it inevitably reoccurs. Thus, a regulatory approach is clearly inadequate for adaptively addressing the complex ecosystem problem of exotic annual grass invasion.

One of the more difficult aspects of finding a suitable path among competing approaches (Fig. 1) is that best available knowledge used in the decision-making process is context dependent. To repeat an above example, in high-elevation habitats, fire kills juniper, which promotes sage-grouse habitat in the future, but fire also temporarily destroys sage-grouse habitat in the near term. Both are true statements, but which is the "best" best available information? Part of the answer lies in the temporal perspective as described previously, but we also argue that when faced with seemingly contradictory information, how the management process begins largely determines future direction. If we begin our conversations by asking "how do we immediately do good things for sage-grouse?," then fire might be viewed as a negative influence. If we begin our conversations by asking "what is the problem and how do we fix it?," then fire may be viewed as a value-neutral disturbance factor within a dynamic ecosystem that profoundly impacts vegetation composition and ecosystem function over time. In reality, fire could be good or bad for sage-grouse dependent on the temporal horizon and ecological setting, and best available information depends on how the problem is initially stated, the ecological context, and whether we have a complex problem rooted in ecosystem dysfunction or a problem that can be addressed through regulatory action.

RISK AND REWARDS IN SENSITIVE SPECIES MANAGEMENT

Our concern is not a lack of recognition of the important ecosystem problems underlying much of the sage-grouse decline; indeed, that recognition is well referenced, and agreement is broad based. Our concern is that the historical inertia of the regulatory paradigm will cause management initiatives needed to address complex ecosystem problems to take a backseat to the need to develop sage-grouse–specific regulatory mechanisms, thus bolstering a species-centric approach to conserving this species (Benson 2012). For example, consider the recent BLM effort to revise Resource Management Plans relative to sage-grouse management issues (BLM 2012). In Oregon, the management alternatives presented in the draft Environmental Impact Statement (BLM 2013) focus primarily on developing regulatory mechanisms for land uses associated with nearly 6 000 000 ha of sage-grouse habitat. This was largely in response to the USFWS determination that current local regulatory mechanisms for sage-grouse management were inadequate (USFWS 2010). Interestingly, the primary threats to sage-grouse in Oregon are wildfire, invasive plants, and conifer expansion (Hagen 2011; USFWS 2013). As described above, these are complex ecosystem problems for which effective regulatory mechanisms are difficult to design. In fact, on page 5–30, the authors of the draft Oregon BLM document concluded that

> overall trends toward habitat loss and fragmentation are likely to continue from the spread of invasive weeds, isolation, wildfire, and conifer encroachment. The BLM has limited ability to manage these threats through implementation of regulatory mechanisms. Thus, the major threats are likely to continue . . . under all alternatives.

By including the above text, we are not trying to find fault with BLM conclusions but want to make the point that emphasis on a regulatory-based approach has a major influence on the conservation process, even when the problems themselves are not amenable to regulatory-based management.

When it comes to the complex ecosystem-based problems facing sage-grouse, what is the reward for effectively minimizing the role of ecosystem management under the guise of species-specific regulatory imperatives? The answer may well be that there is no reward but instead a systemic culture of *disincentives* that focuses management efforts on species per se and emphasizes the consequences of short-term failure over the possibility of long-term success, dubbed by others as "precautionary decision making" (see Doremus 2007) . Precaution is encouraged by the fact that the time line for human decision making is generally much shorter than the ecosystem benefits. For example, an individual career may be a few decades, the duration of a BLM Resource Management Plan is 15 yr, and the life span of a grazing Environmental Assessment is only 10 yr. These sorts of institutional temporal benchmarks further intensify pressure to avoid short-term costs of management actions (e.g., Fig. 3c) and bolster the case for adhering to regulatory actions without short-term negative outcomes (including legal challenges). Precautionary efforts reinforce and in turn are reinforced by actions taken in association with regulatory and legal processes (Doremus 2007), resulting in increasing emphasis on sage-grouse-specific concerns in the face of an ecosystem in critical conservation status (Davies et al. 2011).

RETHINKING REGULATORY CONSERVATION

Traditional regulatory mechanisms (e.g., prohibitions on development or regulation of species take) have little bearing on complex ecosystem problems, in part because management of such problems is a continuous process as opposed to a measureable discrete event in time. The purpose of this article, however, is not to argue against the need for the regulatory actions in general or the ESA specifically. Indeed, both regulatory actions and the ESA have produced notable success stories when appropriately applied (Mann and Plummer 1996) and can be used to address regulatable problems. However, it would be naive to think that our vision of using regulation as a management tool should not be adapted to address the changing face of conservation challenges regarding management of sensitive species within dysfunctional ecosystems. We believe that addressing complex ecosystem problems within a regulatory framework such as the ESA is possible, but effectively doing so will involve merging important elements of the regulatory and ecosystem approaches, specifically, expanding (not replacing) our notion of "regulation" from one of interdictory policy to one of adaptively promoting appropriate management trajectories.

Ecologically Based Frameworks

Defining appropriate management trajectories starts with a conceptual framework that represents best available knowledge of how and why ecosystem properties change in space and time. This model serves as the basis for conservation planning and threat assessment and should at minimum include 1) a characterization of potential vegetation communities and their value to target wildlife species, 2) some ranking of which potential vegetation community states are most desired from an ecological standpoint, and 3) an indication of factors that promote change between these plant community states. Thus, we propose using relatively simple state-and-transition models that capture current understanding of drivers and associated indicators of ecosystem change to serve as the core element of an ecosystem-based approach to sage-grouse conservation. Similar approaches have previously been described for use with other wildlife species (e.g., see Holmes and Miller 2010). Westoby et al. (1989) were the first to describe state-and-transition terminology within a management-oriented framework that could be used to capture and organize knowledge of patterns and mechanisms of ecosystem response to natural and anthropogenic drivers. State-and-transition models have been widely used to interpret assessment and monitoring data and to direct management and conservation actions (Carpenter and Brock 2006; Forbis et al. 2006; King and Hobbs 2006; Kunst et al. 2006; Barbour et al. 2007). In their most rudimentary form, state-and-transition models are simple, conceptual box-and-arrow diagrams containing boxes representing plant community states and arrows representing transitions between states that occur in response to natural or anthropogenic drivers. This modeling framework can be used at a scale compatible with landscape-level assessment and management and accommodates modeling the influences of management actions, natural disturbances, and their interactions (Stringham et al. 2003; Briske et al. 2006). Importantly, because state-and-transition models are probabilistic rather than deterministic, they can be populated with a combination of empirical data and professional opinion (when empirical data are lacking), making them robust, workable modeling tools despite an incomplete knowledge base (Bestelmeyer et al. 2003; Stringham et al. 2003; Knapp et al. 2011).

The overall goal of an ecosystem approach that employs state-and-transition modeling concepts is to facilitate maintenance of or transition to desired ecological states that can serve species-specific habitat needs. Desired ecological states, in this case, are defined by indicators of ecosystem function, based on the premise that the ecological integrity of sagebrush rangeland ultimately underpins the present and future value of sage-grouse habitat. Therefore, by addressing threats to the ecosystem using this approach, we are also addressing major threats to the continued existence of sage-grouse.

State-and-transition modeling was recently used as the basis for developing a sage-grouse Candidate Conservation Agreement with Assurances (CCAA) in Harney County, Oregon (USFWS 2014), an agreement that has the potential to impact habitat conservation on nearly 500 000 ha of privately held rangeland. Briefly, a CCAA is a cooperative agreement between participating landowners and the USFWS that exempts landowners from additional regulatory burdens if a Candidate Species is listed under ESA provisions. In return, the landowner agrees to a site-specific management plan that limits impacts to and improves/maintains habitat conditions for the target species. Multiple state-and-transition models were developed within the CCAA, and here we focus on the low-elevation sagebrush model (Fig. 4) to illustrate use of the concept.

The low-elevation sagebrush model uses "native plant community resilience" to indicate the potential of the plant community to recover to a native plant–dominated state following disturbance, as suggested by the predisturbance abundance of large perennial bunchgrasses (Fig. 4; Chambers et al. 2007; Davies 2008). Desired ecological states are sagebrush/perennial herbaceous codominated or perennial herbaceous dominated. These two states have the potential to provide year-round (green shaded) or seasonal (yellow shaded) habitat based on the presence of specific vegetation components that comprise different elements of sage-grouse habitat (Crawford et al. 2004). Sagebrush-dominated sites with a diminished perennial grass understory (i.e., "Degraded Sagebrush State") have the potential to serve as winter habitat for sage-grouse and are thus labeled as seasonal habitat (Fig. 4). However, this state is not ecologically desirable due to a lack of perennial herbaceous species, which decreases the resilience of these plant communities. The final state (exotic annual grass state) is indicative of nonhabitat conditions and is shaded red (Fig. 4). Arrows connecting states indicate management- and nonmanagement-related factors capable of causing transition between states. When these factors move the plant community along a trajectory from a more desired to a less desired state (e.g., green to red), they are considered threats to sage-grouse habitat (Fig. 4). Conversely, factors that move the plant community along a trajectory from less desired to more desired states (e.g., red to yellow) are considered conservation measures. Obviously, this model is very general, but it provides a framework for local management planning that can be more finely tuned during development of site-specific plans with individual landowners. The CCAA provides for periodic assessment of the spatial extent of year-round, seasonal, and nonhabitat states to determine trends in habitat condition for sage-grouse and for use as a feedback mechanism in guiding adaptive management.

Management Trajectories as a Regulatory Mechanism

We suggest an expanded view of regulatory mechanisms focused on promoting management trajectories consistent with achieving desired ecosystem and sage-grouse habitat conditions at multiple scales. We use the word "trajectory" because focus should be on maintenance of desired conditions or movement from undesired to desired conditions (e.g., see "Conservation Measures" in Fig. 4) as opposed to promoting the tools or practices used to realize these trajectories. The most effective tools and practices will vary over space and time and with the logistical capacity of practitioners. Identifying impactful management trajectories is contingent on accurate state-and-transition models appropriate to the ecosystem and species in question. Assigning regulatory value to appropriate management trajectories and programs to promote these trajectories would increase incentives for ecosystem management efforts within the context of the ESA and would likely increase the amount of resources that private and public land managers and agencies are willing to put toward addressing important ecosystem problems.

The idea of valuing efforts to facilitate appropriate trajectories is also robust across institutional scales and across problems of different levels of difficulty. For example, state-and-transition models can be used to determine desired management trajectories for local and regional scales as described above. At the programmatic scale, the concept of management trajectories could be used to determine efficient allocation of conservation resources. For example, with knowledge-limited problems such as restoring habitat dominated by exotic annual grasses, resource allocations should reward programs that encourage a trajectory of limiting the size of the existing problem (e.g., firebreaks around existing infestations) and of promoting research and adaptive management to increase knowledge of how to restore these areas to desired vegetation (Evans et al. 2013). Here, the expectation is less about "solving" a problem and more about containing a problem while actively searching for better solutions. For implementation-limited problems such as conifer control, where basic management strategies to at least temporarily address the problem have largely been worked out (Miller et al. 2005; Davies et al. 2011), resources should be allocated in preference to management programs that focus on implementation of these strategies (Boyd and Svejcar 2009).

A good example of a program that has used the trajectory concept to positively impact sage-grouse habitat is the Sage-Grouse Initiative (SGI; Baruch-Mordo et al. 2013). Launched by the Natural Resources Conservation Service in 2010, SGI is a voluntary, incentive-based conservation effort that focuses existing funding available through the Farm Bill to help private landowners implement projects that improve habitat from undesired to desired conditions. From a programmatic scale, SGI resources are prioritized toward lands located in and around sage-grouse strongholds so that management actions maximize biological return on investment. However, SGI conservation measures at the local level are designed to be ecologically appropriate for the site and emphasize proactive

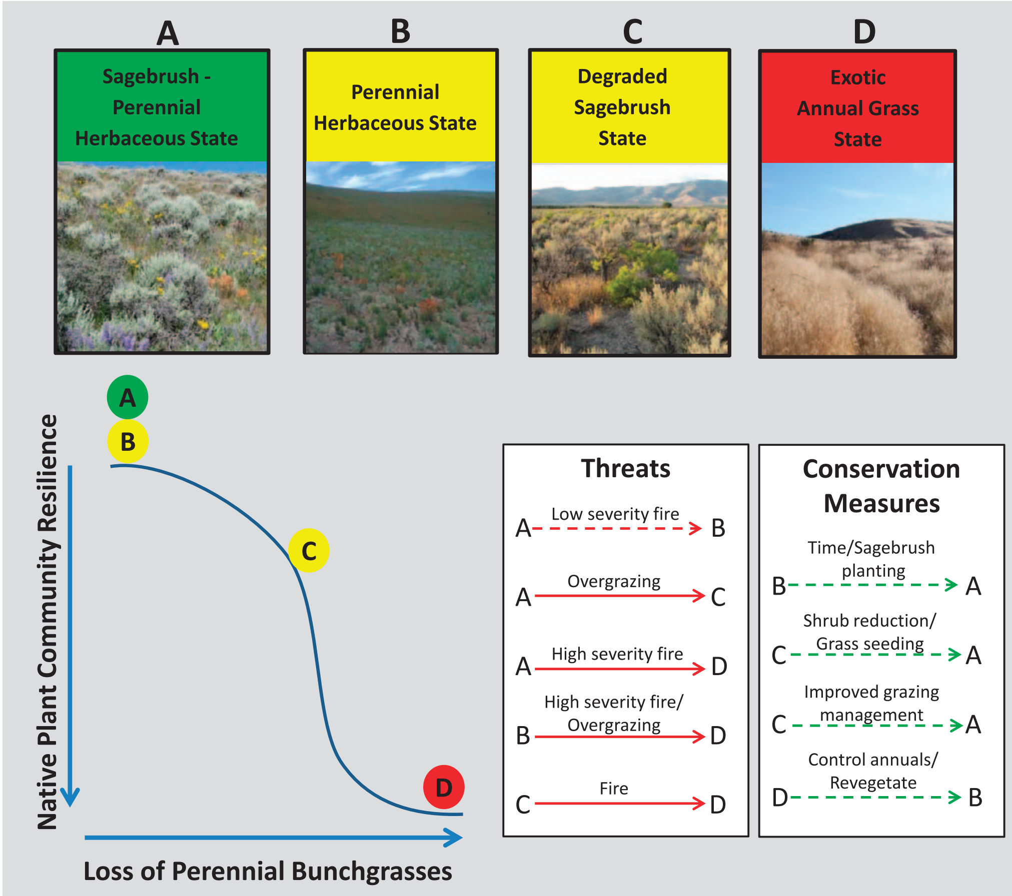

Figure 4. Conceptual ecological framework for managing sage-grouse habitat using a generalized state-and-transition model for low-elevation sagebrush plant communities in southeastern Oregon. States (top) shaded in green indicate potential year-round habitat suitability for sage-grouse. States in shaded yellow and red indicate potential seasonal habitat and nonhabitat, respectively. ''Native plant resiliency'' (lower left) indicates the relative likelihood of a plant community to recover to a native plant–dominated state following disturbance and decreases with loss of large perennial bunchgrasses. Persistent transitions (lower right) between states are depicted with solid arrows, while nonpersistent transitions are arrows with dotted lines.

strategies to prevent undesired ecological shifts over delay-and-repair restoration approaches. For example, a significant focus of SGI is on preventing sagebrush/bunchgrass communities in the early stages of conifer encroachment from becoming dense woodlands (undesired condition). SGI fosters a management trajectory for these communities consistent with moving composition toward a desired condition of sagebrush/bunchgrass without conifers present. In its first three years, SGI treated conifers on over 80 000 ha of sage-grouse habitat (SGI 2014). While conifer removal under SGI has focused primarily on mechanical removal in order to retain sagebrush cover in the near term, SGI is not a "tree-cutting program" but is instead based on attaining appropriate management trajectories that are firmly rooted in an ecosystem framework that incorporates state-and-transition models.

Empowering Local Management

We believe that more specifically valuing efforts to promote appropriate management trajectories within the ESA creates strong incentive to engage complex ecosystem problems and creates an important mechanism to more easily give credit to programs already doing this. However, making this change will involve a fundamental paradigm shift regarding the roles of local vs. national scale elements of conservation and regulatory agencies. To better understand the nature and challenges of this paradigm shift, we need to first characterize the roles of different conservation scales under a traditional regulatory approach and then present our vision of how those roles need to change to impact complex ecosystem problems.

Consider the issue of anthropogenic development as it relates to sage-grouse habitat conservation. This issue represents a simple, by our definition, problem that is well suited to management with regulatory action. Using this approach, conservation roles vary strongly across a conceptual gradient from local to programmatic scales (Table 1). At the programmatic level, activities might focus on making decisions on regulations governing the allowable extent of development relative to the large-scale habitat needs of sage-grouse. For example, administrators might use best available information (e.g., Knick et al. 2013) to develop regulations that define specific limits to anthropogenic disturbance to help ensure persistence of sage-grouse populations. The role of conservationists at more local scales would be one of directed action aimed at implementing regulatory policy. Put another way, local actions would be strongly shaped by the cumulative regulatory guidance from higher decision-making scales.

Table 1. Generalized conservation roles for local and programmatic scales when using the traditional regulatory-based approach to address anthropogenic development in sage-grouse habitat (top row) vs. using a modified regulatory approach to address a complex ecosystem problem (bottom row).

	Conservation roles	
Problem type	Programmatic scale	Local scale
Regulatable (e.g., anthropogenic development of sage-grouse habitat)	Regulatory decision making	Directed action
Complex ecosystem (e.g., exotic annual grass invasion)	Empowering conservation at more local scales	Defining/implementing management actions and adaptive decision making

Now consider the issue of loss of sage-grouse habitat due to exotic annual grass invasion. As discussed previously, this is a complex ecosystem problem and as such does not lend itself to regulatory action. To assign appropriate regulatory value to efforts to manage the annual grass problem, we must modify the roles of local and programmatic level scales. At the local scale, conservation would focus on defining the problem set using state-and-transition modeling (e.g., Fig. 4) and making adaptive decisions regarding strategies to achieve desired management trajectories (Table 1). Since prohibitive regulations would be of limited value, the role of programmatic-scale administrators would be to create conditions necessary to empower effective conservation at more local scales (Table 1; Frampton 1996). This “empowerment” could take a number of forms, including ensuring adequate funding for conservation projects, leading large-scale planning efforts that identify important regional conservation targets, or altering existing agency policies that limit management effectiveness at local scales (Mayer et al. 2013). Importantly, programmatic scales should be cognizant of maintaining sufficient “decision space” at local scales. When programmatic guidance becomes too heavy-handed, decision space will become limited at local scales and impair progress on complex problems (i.e., work against adaptive management). Similarly, programmatic leadership should stress broad-based management trajectories as opposed to specific management practices. Otherwise, the conservation agenda at local scales can become more driven by what practices are being funded than by what trajectories local habitats need to move in to attain desired conditions (Twidwell et al. 2013).

We want to emphasize that the interpretation of scale in Table 1 will vary strongly by context. For example, the Harney County CCAA empowers local managers with guidance on acceptable management trajectories to meet sage-grouse habitat conservation objectives and provides a rather exhaustive catalog of potential conservation measures to help realize these trajectories. But what measures are ultimately implemented and how they are implemented is based on a site-specific planning process that recognizes the unique ecological conditions present within each enrolled property and the operational capabilities of each landowner (i.e., the CCAA document provides sufficient decision space to make these decisions). At a larger scale, SGI program administrators distribute funds necessary for cooperatively funded conservation projects and provide local employees with both tools for guiding spatial allocation of the implementation effort (e.g., Baruch-Mordo et al. 2013) and continuing educational workshops to ensure that they are designing management projects in line with best available scientific knowledge. As with the Harney County CCAA, specific SGI habitat improvement projects are developed at local scales using an ecological framework that accounts for site and year variability and with tools appropriate to both ecological conditions and local logistical capabilities.

MANAGEMENT IMPLICATIONS

Uncertainty and disagreement surrounding how to best approach the issue of declining sage-grouse populations across the West may be related to a lack of a unified vision of conservation success. We believe that a significant factor underlying such derision is that many of the problems impacting this species are complex ecosystem problems that may not be adequately valued under a regulatory framework that was originally designed to promote regulatory-based/species-centric objectives and associated metrics. For example, there has been much debate over the importance of determining appropriate residual stubble height, sagebrush cover/height, and forb abundance in sage-grouse habitat while the primary factors driving habitat fragmentation and loss are ultimately tied to complex ecosystem problems. Species-specific needs of sage-grouse should not be ignored in conservation planning; however, we are arguing that the needs of the ecosystem that produces sage-grouse and many other sagebrush obligate and facultative wildlife species should receive priority and be the primary focus for sage-grouse conservation in areas where nonregulatory threats are predominant. An approach focusing on the maintenance or enhancement of the ecosystem inspires a common, unified vision of successful conservation because it complements not only the needs of sage-grouse but also numerous other uses and services that large areas of intact sagebrush rangeland provide. Redirecting the discussion to focus on complex ecosystem problems dramatically expands the number of stakeholders that are willing to take a seat at the table and work toward a common vision of successful conservation (Scott et al. 2010). Frankly, it is difficult to unite diverse groups of stakeholders around a sage-grouse conservation approach if it does not prioritize complex ecosystem problems, such as conversion to exotic annual grassland and conifer woodland (Goble et al. 2012).

That said, it is difficult to mount intellectually substantive argument in opposition to the idea that both traditional regulatory actions and management of complex ecosystem problems have an important place in contemporary sage-grouse conservation. It would also be naive to ignore the fact that sage-grouse have generated not only publicity for the cause of conserving sagebrush habitats but also conservation dollars. However, the elephant in the room is 1) that our most powerful sage-grouse conservation tool is regulatory based (i.e., the

ESA), and 2) across much of its range, our most significant sage-grouse habitat challenges are complex ecosystem problems and not amenable to traditional regulatory fixes. In our view, a productive way forward for managing sage-grouse habitat resources must involve expanding the regulatory focus of the ESA to empower local and ecologically based management of the plant communities that provide sage-grouse habitat. This article represents our best effort to think through this daunting challenge in a way that we hope will stimulate a larger conversation about how we value management of complex ecosystem problems within the ESA. But no clear and preexisting solution is available—and for good reason: never in the conservation history of the United States have we collectively attempted to address a problem set this complex, at this large of a scale, while working within the bounds of the ESA. Thus, an important implication of this article is that natural resources professionals of all stripes must collectively keep an active and open mind while working through these challenges and not become limited by past paradigms and ideas. This is new territory and should be treated as such.

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