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State of the Sagebrush: Implementing the Sagebrush Conservation Design to Save a Biome☆

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ABSTRACT

This special issue of Rangeland Ecology and Management is dedicated to applying the Sagebrush Conservation Design (SCD) to improve conservation outcomes across the sagebrush biome in the face of pervasive ecosystem threats. This special issue provides new science and real-world examples of how we can implement the SCD to save a biome. The SCD is a tool to identify intact sagebrush areas and address the largest threats to the ecosystem. The SCD focuses on first protecting intact and functioning sagebrush ecosystems, called Core Sagebrush Areas, then works outward toward more degraded areas (i.e., "Defend the Core"). The premise behind the Defend the Core approach is simple: focus resources first on preventative actions that retain ecosystem services in Core Sagebrush Areas because they are more cost-effective and more likely to be successful. The opening article of this special issue creates a foundation for the 19 following papers, providing a coherent path for implementing the SCD. The overarching themes are: 1) Business-As-Usual Won't Save the Sagebrush Sea, 2) Better Spatial Targeting Can Improve Outcomes, 3) Conservation Planning is Needed to Develop Realistic Business Plans, 4) Targeted Ecosystem Management: Monitoring Shows Managing for Sagebrush Ecological Integrity is Working, 5) Maintaining Sagebrush Ecological Integrity is Ecologically Relevant, and 6) There is Only Hope if We Manage Change. The collective articles show that there is no shared plan to save the biome, yet a business plan for the

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biome could ensure realistic goals. The sagebrush biome still has vast expanses of open spaces with high ecological integrity at a scale that is rare in other ecological systems within the lower 48 states. If we focus on the common ground of the main drivers of ecosystem change, implementing the SCD and Defending the Core are viable strategies to help save a biome.

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An evolving conservation model in sagebrush country

Despite being among the least developed places in the world, the sagebrush biome of the U.S. faces numerous threats and is among the most imperiled in the country (Fig. 1). Loss and degradation of sagebrush rangelands, and resulting impacts to wildlife, were showcased since 1941 when Aldo Leopold warned society of the perils of cheatgrass (Leopold 1941). In the mid-1970s, concern was expressed about the effects of human alteration of sagebrush habitats to improve livestock production (Vale 1974; Baker et al. 1976). By the late 1990s, large-scale loss and degradation of sagebrush due to wildfire, cheatgrass invasion, agricultural conversion, and other ecosystem-based threats like conifer expansion garnered further worry about the future of this iconic American biome and its wildlife (Knick 1999; Wisdom et al. 2005).

There are no more iconic species in sagebrush than the greater sage-grouse (hereafter, sage-grouse; *Centrocercus urophasianus*). As a sagebrush obligate game bird, sage-grouse is a high-profile species of concern whose population declines closely track sagebrush ecosystem loss and degradation, prompting wildlife managers to develop the first-ever range-wide sage-grouse Comprehensive Strategy in 2006 (Stiver et al. 2006). However, the most consequential event bringing sagebrush country into the forefront of American conservation occurred in 2010 when sage-grouse was petitioned for protection under the Endangered Species Act of 1973 (ESA; 16 U.S.C. 1531 et seq) and determined to be 'warranted but precluded' (USFWS 2010).

Regulatory ramifications of a potential ESA listing galvanized stakeholders and partners across the West to come together to implement necessary conservation measures ahead of a court-ordered status review of the species in 2015. In an unprecedented national effort, collaborations between federal, state, and local governments, private landowners, and non-governmental organizations precluded the need for federal protections through the

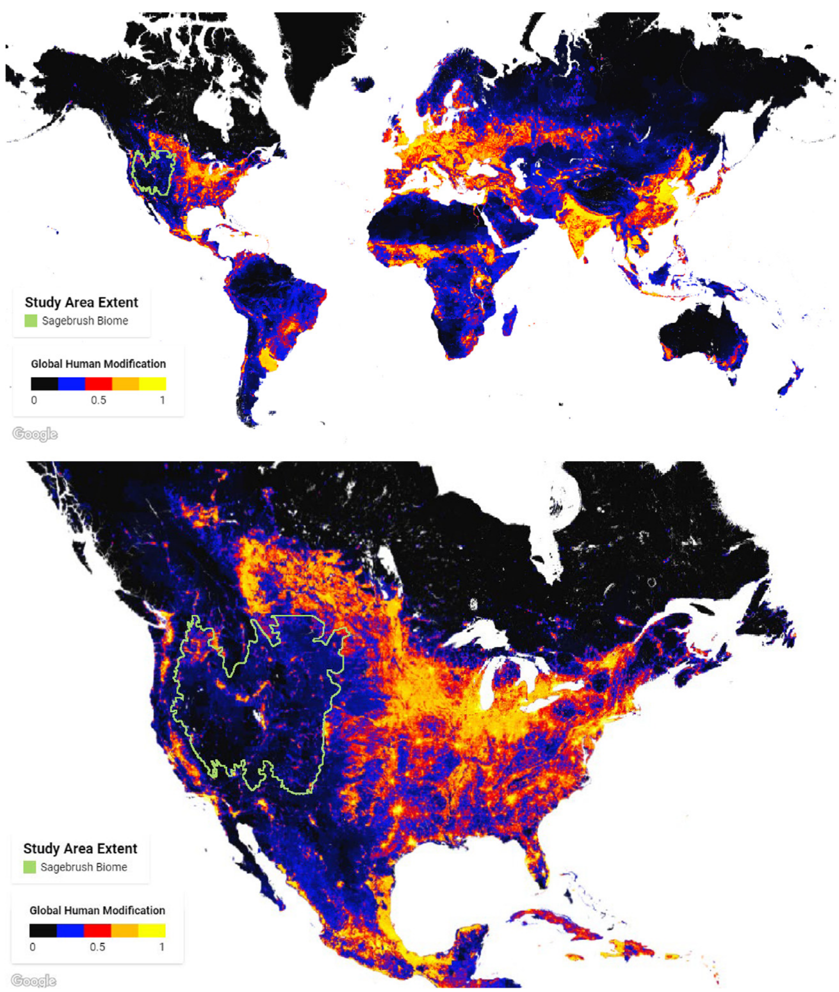

Figure 1. The Global Human Modification Index (Theobald et al. 2020) and its relationship to the sagebrush biome of the United States of America. The sagebrush biome is the largest contiguous portion of the Lower 48 States with the lowest amount of human modification.

adoption of policy changes and conservation actions (USFWS 2015). Governors from 11 western states provided leadership through the development of state-based conservation plans and implementation of Executive Orders and on-the-ground conservation and restoration (Connelly et al. 2004). For the first time in history, the Bureau of Land Management (BLM) and U.S. Forest Service (USFS) amended all federal land use plans throughout the western U.S. specifically to incorporate sage-grouse habitat needs. On private lands, the Natural Resources Conservation Service (NRCS) created and funded the Sage-Grouse Initiative (SGI) to empower landowners to be part of the solution through voluntary and incentive-based Farm Bill conservation (NRCS 2015). In 2015, the U.S. Fish and Wildlife Service (USFWS) determined sage-grouse no longer warranted protection under the ESA. Then-Secretary of the Interior Sally Jewell and current Secretary of Agriculture, Tom Vilsack, in a joint news release from the White House stated, "*The greater sage-grouse conservation strategy comprises the largest landscape-level conservation effort in U.S. history and demonstrates that through strong Federal, state, and private collaboration, the ESA can be an effective and flexible tool in encouraging conservation and providing the certainty needed for sustainable economic development in our states and communities*."

Since 2015, partners in the sagebrush country have remained committed to implementing conservation measures for sage-grouse (Range-wide Interagency Sagebrush Conservation Team 2024) and innovating to better quantify outcomes and inform adaptive management (Coates et al. 2021). Simultaneously, partners have been embarking on the next frontier in sagebrush conservation planning and delivery: expanding from a bird to a biome. In support of the Department of Interior's Integrated Rangeland Fire Management Strategy, interagency scientists and managers developed the Science Framework for the Conservation and Restoration of the Sagebrush Biome to help prioritize management strategies based on the needs of sage-grouse and underlying ecosystem resilience and resistance (Chambers et al. 2017; Crist et al. 2019). The NRCS provided an early example of ecosystem-based conservation delivery, expanding its SGI to a framework for Conservation Action in the Sagebrush Biome that focused voluntary efforts on addressing the primary threats to ecosystem resilience (NRCS 2021a).

Most recently, the Western Association of Fish and Wildlife Agencies (WAFWA) led a diverse coalition of experts and stakeholders to create the Sagebrush Conservation Strategy (hereafter, Strategy; Remington et al. 2020)—a proactive effort to extend conservation beyond grouse to benefit the people and wildlife that depend on the sagebrush ecosystem. The Strategy synthesizes the wildlife and ecology of the sagebrush biome and key challenges. It provides a powerful tool to support and inform the Strategy, and the Sagebrush Conservation Design (SCD) (Doherty et al. 2022). The SCD leverages advancements in remotely sensed land cover products to provide spatially explicit maps of sagebrush rangeland conditions and ecosystem threats through time.

Finding common ground to expand the conservation tent

From the 1950s until recently, challenges to the sagebrush biome have been largely framed as a species-habitat use issue, primarily sage-grouse, but also mule deer and pygmy rabbits. The threat of an Endangered Species Act listing and/or declines in priority wildlife species, such as mule deer, were the avenues that brought the challenges of the sagebrush ecosystem to the policy forefront. A complication of this species-specific conservation framing is that not all people living and working within this biome value wildlife as much as they value human use (e.g., Utilitarian/Traditionalist vs. Mutualist [Manfredo, et al. 2018]). Countrywide, States that encompass the sagebrush biome have some of the highest densities of Traditionalists, who value human well-being above wildlife, and the lowest densities of Mutualists, who believe that wildlife are entitled to the same rights as humans (See Manfredo et al. 2018, maps 1 and 2). Another limitation of this species-centric approach is that most management recommendations focused on species-specific responses to human developments (e.g., sage-grouse lek buffer distances, Holloran and Anderson 2005, sage-grouse core area delineations, Doherty et al. 2011; and mapping of mule deer winter habitats, Sawyer et al. 2009). Inevitably, species-specific framing resulted in conflicts when trade-offs were perceived between protecting wildlife habitat (mutualist values) and permitting other human uses (utilitarian/traditionalist values).

Addressing the issue of large-scale ecosystem degradation requires a different approach that simplifies the complex causes of ecosystem degradation into easily understandable and comparable categories of ecosystem conditions instead of traditional species-specific interventions. For this approach to succeed, the categories of past, current, and potential future ecosystem conditions must align with and appeal to a diverse range of stakeholders who may have different value structures, such as traditionalists, mutualists, and others (Salafsky et al. 2008). A clearly defined set of benefits from improving ecological conditions can motivate stakeholders to implement solutions at scale by bringing different stakeholder groups together through shared common interests (e.g., Johnson et al. 2019). Collaborating with a diverse set of stakeholders to create categories of ecological conditions (e.g., desired traits, undesirable threats) can also facilitate the development of a shared conservation vision by translating complex ecological information into tangible and implementable projects (Biggs et al. 2011). This shared vision is necessary because regulatory interventions have not effectively controlled the individual threats causing the largest changes to the biome, such as invasive annual grasses, altered wildfire regimes, or drought (Boyd et al. 2014).

The SCD focuses on five ecological metrics, three of which are shared values between diverse stakeholders (+ perennial grass, - invasive annual grass, - expanding conifer), one is neutral (sagebrush), and one has caused large-scale disagreements (human modification). Perennial grasses are vital for maintaining the ecological stability and resiliency of sagebrush ecosystems, serving as the foundation of rural grazing communities. Combatting invasive annual grasses and conifer expansion is also a shared challenge. This special issue quantifies that 87% of documented losses in Core Sagebrush Areas (Doherty et al. 2022) were due to increases in two threats (invasive annual grasses and conifers), while the loss of perennial grasses (a desired condition) accounted for an additional 4% of the loss of Cores Sagebrush Area (Fig. 2). This means stakeholders share common values for 91% of the underlying causes of the degradation of the sagebrush biome. Conversely, human modification has been a point of contention between stakeholder groups with conflicting interests. This special issue demonstrates that over the last two decades, 3% of the loss of Core Sagebrush Areas was directly caused by human modification. Focusing solutions on where we have common ground, fighting shared threats and shared value (perennial grasses), has a proven track record of bringing stakeholders together through common interests within the sagebrush biome (Johnson et al. 2019).

The Sagebrush Conservation Design (SCD): supporting proactive, ecosystem conservation

In 2021, WAFWA assembled a working group of experts to develop a spatially explicit conservation design that could inform and support a biome-wide Sagebrush Conservation Strategy. This group represented a diverse set of disciplines, including climatology, conservation biology, fire ecology, landscape ecology, rangeland

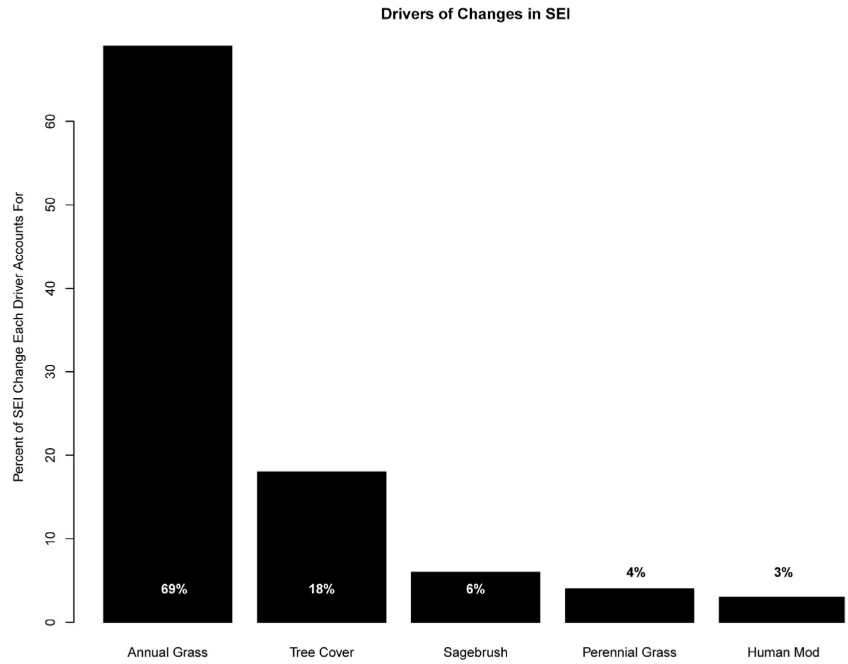

Figure 2. The overall percentage of each of the five components of sagebrush ecological integrity, which caused the landscape to decline from being classified as a Core Sagebrush Area from 2001 to 2020.

ecology, spatial ecology, and wildlife biology. The overarching goal of the effort was to provide a common basis for understanding the state of sagebrush rangelands through time. Within this special section, our goals were to produce the science to 1) help unify conservation delivery efforts to proactively reduce primary ecosystem threats, 2) facilitate and promote discussion among stakeholders to set ecosystem-level objectives, and 3) inform a comprehensive and strategic adaptive management framework. The conservation design was built around a shared vision of helping conservation partners identify and retain large and functioning sagebrush landscapes.

The primary goal of the Sagebrush Conservation Design (SCD; Doherty et al. 2022) was to locate regions that had high-quality sagebrush habitats as determined by sagebrush ecological integrity (SEI). The authors accomplished this by creating a map that classified these areas by management classes based on their SEI rankings. The SCD parses sagebrush rangelands across the biome into three categories: 1) Core Sagebrush Areas, 2) Growth Opportunity Areas (GOA), and 3) Other Rangeland Areas (ORA) (Fig. 3A). Core Sagebrush Areas represent intact and functioning sagebrush ecosystems with few landscape threats. Growth Opportunity Areas are relatively functioning sagebrush ecosystems impacted by one or more landscape threats. Other Rangelands Areas contain the lowest SEI due to more severe threat impacts or are non-sagebrush rangeland habitats. These mapped categories helped to identify large, functional sagebrush landscapes that had healthy native perennial grass understories and were at low risk of threats. The resulting SCD leveraged cutting-edge advancements in remotely sensed landcover products to develop spatially explicit maps of sagebrush rangeland conditions and landscape threats through time (Fig. 3B).

Importantly, the SCD goes beyond assessing the state of the biome by providing a foundation for implementing a new proactive conservation approach: “Defend the Core, Grow the Core, Mitigate Impacts” (NRCS 2020, 2021b; WGA 2020). This broad strategy focuses on first protecting intact and functioning sagebrush ecosystems (“cores”) and then working outward to improve the management and restoration of more degraded landscapes rather than initially starting with the most degraded areas (Fig. 4; NRCS 2021b). The premise behind the “Defend the Core” approach is simple: focus resources first on preventative actions that retain ecosystem services in Core Sagebrush Areas because they are more cost-effective and more likely to be successful. Cores serve as anchor points for conservation allowing land managers to be more effective given the favorable landscape context. Given sufficient resources, managers are then encouraged to grow the core by implementing targeted restoration in Growth Opportunity Areas. Finally, actions in Other Rangeland Areas may be warranted to minimize catastrophic impacts of threats or restore other high-value resource areas.

Papers within this special issue provide tools to create an *actionable path* for the “Defend the Core” strategy, helping us understand the conservation volume needed to be successful in fighting threats as well as an honest discussion on questions such as: 1) Given current and/or potential increased conservation resources: where and how much Core can we successfully defend? 2) Where and how much Core can we grow from existing Growth Opportunity and Other Rangeland Areas? 3) Can we be successful in defending the remaining Core? 4) Given the rate of ecosystem change and current levels of ecosystem threats, which Other Rangeland Areas are unlikely to return to Cores?

Key themes of the special issue

This special issue of Rangeland Ecology and Management is dedicated to applying the SCD to improve conservation outcomes across the sagebrush biome in the face of pervasive ecosystem threats. Through this collection of 20 peer-reviewed articles, authors leverage the SCD to explore potential futures for the sagebrush biome, present spatial targeting tools to reduce threats more effectively, illustrate how those tools can be applied to enhance planning and support monitoring, show the relevance of ecosystem-based management for a variety of services and values, and discuss the importance and challenges of making the social change needed to save the biome from irreparable ecosystem losses. We have organized these papers into six themes to better

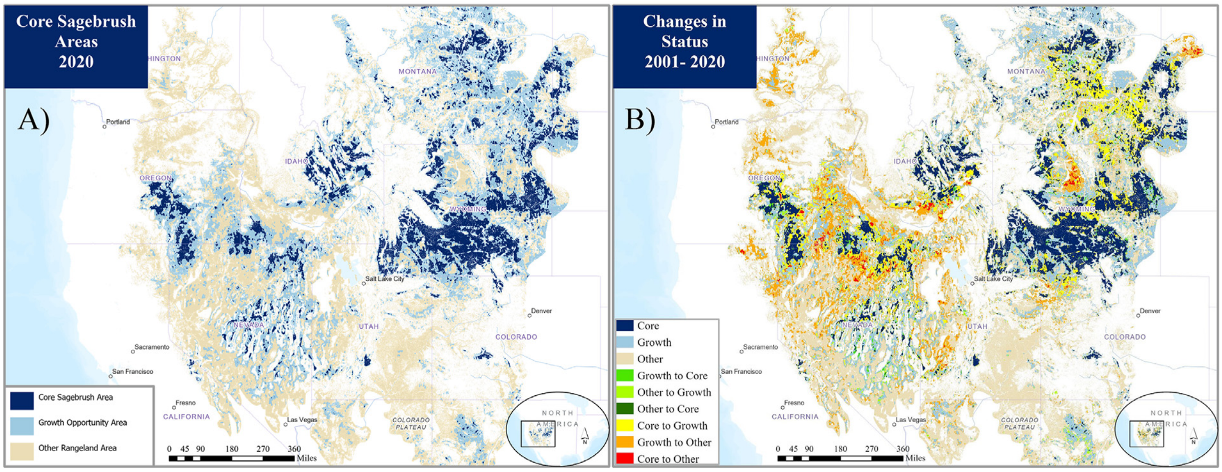

Figure 3. Location: (A) and change over time in size and extent (B) of Core Sagebrush Areas, Growth Opportunity Areas, and Other Rangeland Areas from 2001–2020 within the sagebrush biome of the United States of America. Warm colors (Yellow, Orange, and Red) represent losses to the Biome. Shades of Green represent increases. Colors that stay the same between panels A and B represent no change in status. Credit: Doherty et al. (2022).

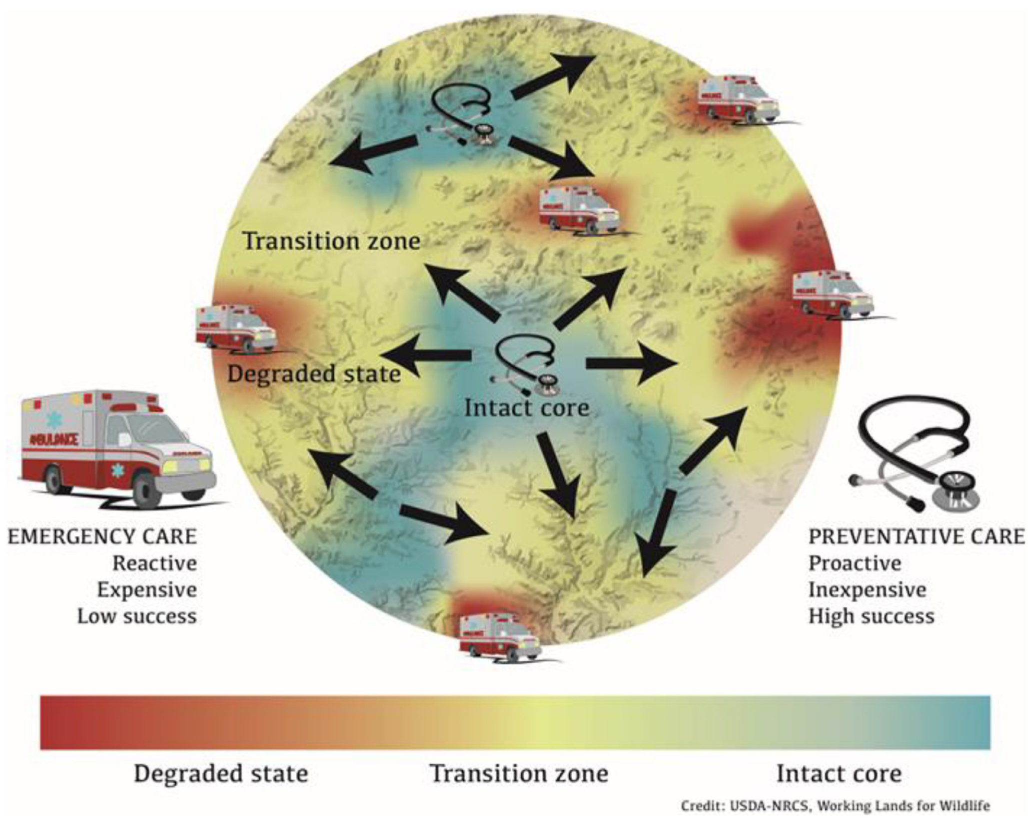

Figure 4. New spatial landcover products now make it possible to map the condition and degradation of sagebrush rangelands through space and time. The "Defend the Core" strategy leverages this technology to identify intact "cores" and emphasizes proactive management of these areas as a top priority (NRCS 2020). Once preventative management has been provided to keep cores healthy, more aggressive restoration and management can then be implemented to grow cores through time. Credit: USDA-NRCS Working Lands for Wildlife.

articulate the main points anticipated to support proactive ecosystem conservation.

Theme 1: Business-As-Usual Won't Save the Sagebrush Sea

We started the special issue with three papers focusing on biome-wide ecosystem context. Collectively, the first three papers highlight that a "business-as-usual" strategy will not be successful because the rate of losses drastically outpaces our ability to deliver effective conservation under the current conservation targeting regime. This section specifically provides insight into questions such as, "What are the trade-offs and consequences of the status quo versus different strategic levels of conservation targeting?" To have a realistic vision for the biome grounded in science, we need to frame the conservation problem on a biome-wide scale. Mozelewski et al. (2024) contrast the ecological trajectory of all biome losses with all conservation actions to improve SEI. The authors empirically ask, "Can we Defend the Core with current allocations and spatial prioritization of effort?" They show the conservation community is off by orders of magnitude in closing the yearly conservation gap between the area of conservation we are currently implementing vs. the annual area of ecosystem lost each year. However, the authors then show how decisions in our control today on the allocation of effort, spatial targeting, coordination with other existing programs, and new funding sources like the Bipartisan Infrastructure Law (BIL; "H.R. 3684 -117th Congress: Infrastructure Investment and Jobs Act") and Inflation Reduction Act (IRA; "H.R. 5376 – 117th Congress: Inflation Reduction Act of 2022"), can close or come close to closing the conservation gap over the next decade. Holdrege et al. (2024) show that climate change and associated climate-vegetation-fire interactions are likely to decrease the future extent of Core Sagebrush Areas by 34%. Their results provide a long-term future perspective on the sensitivity and sustainability of sagebrush habitats to climate change that could inform strategies for climate adaptation and prioritization of conservation and restoration investments. For example, they located the areas that have high SEI currently and are projected to have high SEI in the future. These climate-resilient locations may be used as anchors for long-term biome-wide strategies. Theobald et al. (2024) calculated the structural connectivity of the sagebrush ecosystem (SEI-C) for each year from 2001–2021. They spatially identified the Core Sagebrush Areas, which form the connectivity "backbone" of the ecosystem. Their analyses also show that, much like SEI, structural connectivity has declined over the last two decades, and focused conservation efforts are going to be needed to defend the backbones of the biome.

Theme 2: Better Spatial Targeting Can Improve Outcomes

The goal of the second theme of the special issue is to highlight where conservation actions have higher probabilities of management success. The four papers in this theme help answer questions such as, "How can I start to develop a strategy to defend the cores in my area of interest?" Each of the papers within this theme provides practical examples of how spatial ecology and threat modeling for conifer encroachment, invasive annual grass, cropland conversion, and wildfire can be linked with the Defend the Core framework to develop conservation strategies across different scales. Reinhardt et al. (2024) develop a framework for identifying areas where targeted conifer management could produce the greatest return on investment and have the least undesired impacts. Their analysis demonstrates how a collaboratively informed decision analysis combining stakeholder values with spatially explicit models using multi-criterion decision analyses has the potential to result in a "no regrets" conifer management prioritization for the sagebrush biome. Boyd et al. (2024) present a timely, relevant, and simple strategic management framework to begin to address invasive annual grasses, the single largest cause of ecosystem declines over the last two decades (69% of core losses, see Fig. 2). Their strategy focuses on *maintaining* habitats that we can least afford to lose to invasive annual grasses and *improving* those habitats where success is most likely to regain large landscapes of core sagebrush rangelands. To help make this framework actionable, they created spatial data showing the locations of *maintenance* and *improvement* areas and locations of areas where restoration is not probable; thus, impacts from these areas on immediately adjacent areas should be mitigated. Bedrosian et al. (2024) quantify the cropland area of the sagebrush biome and identify where the highest quality sagebrush rangelands are most at risk of future cropland conversion. The study found that higher levels of cropland conversion risk were rare biome-wide and generally clustered geographically, presenting an opportunity for strategically targeting easements on landscapes most at risk. Most notably, many areas of the northern Great Plains show high concentrations of future cropland risk. This paper also highlights the concept of an ecological neighborhood and how the permanent protections of conservation easements on private lands can extend ecological benefits to adjacent public lands. Lastly, Christ et al. (2024) quantify the spatial overlap of Core Sagebrush Areas and Growth Opportunity Areas with annual wildfire burn probability within the sagebrush biome. They found that > 84% of CSA and 70% of GOAs were in the lowest burn probability classes. This paper is the first to quantify the risk of fire in CSAs and GOAs, showing that this risk is lower than fire risk across the rest of the biome. The authors also found that the risk of fire is not spatially uniform; some priority areas in the Great Basin, such as Northern Nevada and Southern Idaho, will require effective implementation of active fire management to remain viable sagebrush ecosystems into the future. Conversely, investments in fire prevention may not be needed to defend core areas at very low risk of fire.

Theme 3: Conservation Planning Ensures Realistic Business Plans

A common question that arises when new science is produced is: "How does our Agency or group align with the findings and what does this mean for our decision-making?" Developing a business plan can provide answers to important questions such as how much high-priority land is available in good ecological condition, the level of risk faced by high-priority lands, the rate at which they are changing, and the amount of funding that is available to address these issues. There are two papers within this theme to provide examples of how to answer these questions. Sparklin et al. (2024) is the opening step in the technical transfer of the SCD to the entire U.S. National Park (NPS) and U.S. Fish and Wildlife Service (USFWS) Refuge System within the sagebrush biome. These analyses provide high-level insight into how these agencies can contribute to overall biome-wide efforts as well as needed context to internally prioritize efforts. For example, the authors show that the cost of treating all conifer and invasive annual grass within all refuges and parks is financially infeasible, but that focusing on the areas that have the highest SEI can decrease costs by an order of magnitude. They also show that the NPS has 98% of their Core Sagebrush Areas and Growth Opportunity areas in 5 National Parks and the USFWS has 91% of their Core Sagebrush Areas (CSA) and Growth Opportunity Areas (GOA) in 5 refuges. Not all conservation groups employ spatial analysts dedicated to replicating the analyses of Sparklin et al. (2024). Therefore, Olimpi et al. (2024), present a new online tool developed to support the implementation of the SCD for planning and evaluation. The authors introduce a new freely available online user interface that easily calculates the changes in CSA, GOAs, and ORAs through time, and that shows which components of SEI are causing the changes. This simple tool allows users to understand what volume of conservation is needed to defend the core at whichever spatial scale is of interest, from biome-wide to regional management areas.

Theme 4: Targeted Ecosystem Management: Monitoring Shows Managing for Sagebrush Ecological Integrity is Working

The fourth theme provides a template for program evaluation, accountability, and monitoring of treatment effectiveness through the lens of SEI and the population response of a high-priority wildlife species. Mozelewski et al. (2024) highlight the importance of effectiveness in treatments to the overall amount of core sagebrush areas we will be able to maintain in the future. Ultimately, they show it is *not* dollars spent or acres treated that will lead to an increase in Core Sagebrush Areas; it is *effective conservation aligning with an overarching strategic ecosystem vision*. Therefore, monitoring and program evaluation to understand "are we doing, what we think we are doing" will be needed. The three papers in this theme aim to do just that.

Naugle et al. (2024) demonstrate the utility of SCD in evaluating the efficacy of SGI for conserving Core- and Growth priorities on private lands. They show that the NRCS was highly targeted, having either reversed (7 landscapes) or halted (2 landscapes) the degradation of nine legacy landscapes from woodland expansion. From an adaptive management perspective, they also show that SGI needs to address annual invasive grasses in areas where conifers were removed to maintain the integrity of initial investments (i.e., maintenance costs). Finally, they show that saturating Core areas with the right conservation treatments can increase the effectiveness of resulting outcomes by 20%.

Smith et al. (2024) use the SCD to demonstrate measurable increases in ecological integrity and the response of invasive annuals following conifer management in Idaho. This paper shows how satellite imagery (Rangeland Analyses Platform and RCMAP) and the response curves of the individual components that make up SEI (i.e., Q curves, Doherty et al. 2022) can be used to evaluate strategic goals in legacy landscapes.

In the original SCD paper, Doherty et al., (2022) demonstrate that populations of sage-grouse were stable within Core Sagebrush Areas during the last two decades. In the last paper of this subsection, Coates et al. (2024) evaluate whether conservation treatments aimed at increasing SEI also increase the population performance of sage-grouse. This paper quantitatively shows that what is good for SEI is also good for sage-grouse. Furthermore, they show that certain management actions targeting the behavioral biology of sage-grouse unrelated to SEI can also have a positive effect. This result shows that while managing for SEI is highly beneficial for sage-grouse, species-specific research, and conservation actions remain important needs. Papers within our fourth theme provide tractable real-world examples of delivering conservation at volume, monitoring outcomes, and providing recommendations based on program evaluation.

Theme 5: Maintaining Sagebrush Ecosystem Integrity is Ecologically Relevant

The main objective of the SCD was to identify areas with high-quality sagebrush habitats as measured by SEI. By quantitatively defining and mapping the relative rankings of SEI for the biome and placing them in management classes the authors mapped large and functioning sagebrush landscapes with native perennial grass understories and low levels of threats. In this special issue, we have three new papers that dive deeper into the ecological relevance of SEI.

Prochazka et al. (2024) specifically link all components of SEI to sage-grouse population trends across the species 11-state range. This paper provides insight into how managing for components that make up SEI can increase sage-grouse populations and provides further evidence that managing for SEI is also good for sage-grouse. This paper also highlights that while there has been an overall population decline since Doherty et al. (2022), populations were still stable within Core Sagebrush Areas and declining steeply in both Growth Opportunity Areas (-22%) and Other Rangeland Areas (-64%). Kumar et al. (2024) go on to link the abundance and trends of sagebrush songbirds to SEI across the biome. Authors show bird abundance is up to 10-fold higher in Core Sagebrush Areas than in Other Rangeland Areas. They also quantify a 58% decline in birds that accompanies the transition of Cores to ORAs in the last two decades. O'Connor et al. (2024) wraps up this section with a conceptual framework for measuring changes in carbon security through the proactive management of Core Sagebrush Areas.

The three papers in Theme 5 collectively provide further data on ecosystem services that managing for SEI provides. These papers highlight that dichotomies such as managing for sage-grouse vs. SEI or enhancing Carbon Security vs. SEI are false. The ecological relevance of SEI presented in this paper demonstrates there is plenty of room for nuance and context to help balance ecological goods and services with managing SEI because they are ultimately complementary strategies.

Theme 6: There is Only Hope if We Manage Change

The first theme shows that business-as-usual won't save the sagebrush sea, and this final theme offers four conceptual frameworks to stimulate the thought processes needed to create the change. Olsen et al. (2024) highlight that the adoption of new science is often limited because current approaches to science delivery are regularly top-down, detached from on-the-ground realities, and disempowering because of the complexity of scientific products and the lack of synthesis across studies. The authors present a compelling framework for people working in technical transfer and extension to bridge the gap between emerging science and on-the-ground practical realities. Wollstein et al. (2024) highlight that a focus on ecological importance alone will not result in the change (Fig. 5, Credit Wollstein et al. 2024). The authors developed a simple, but powerful conceptual framework to align ecological values guided by science with the social capacity needed to deliver conservation. They go on to discuss the importance of conducive administrative conditions needed to direct resources to high-priority areas and support the people doing the "dirt" work by removing barriers to efficiency. Ultimately, ecological importance, social capacity, and conducive administrative conditions are needed to deliver conservation at scale and the absence of any of the pillars may cause inefficiencies and could lead to failures. Remington et al. (2024) provides long-term perspectives on what is required to make a significant change in the sagebrush system. The authors are professionals who started their careers working in the sagebrush as early as 1974. In addition to presenting practical pathways forward, they make the point that the current conditions, which represent the best-case scenario based on the Sagebrush Conservation Design's (SCD) projections, still result in significant losses of sagebrush ecological integrity compared to the early 2000s, let alone the 1970s. Finally, Cahill (2024) shares his experience of managing change in the sagebrush and emphasizes the need for optimists and pessimists to work together to effectively manage change.

Difficult decisions lie ahead

Prioritization of conservation and management actions is crucial when there isn't enough money to cover all necessary tasks. Understanding how people working at different scales think is key, because the spatial extent to which a person generally works can strongly influence how an individual views biome-wide efforts such as the SCD. To foster communication, the team that developed this special issue also developed terminology to help people working at different extents better understand one another: *Open Decision Space & Defined Decision Space*. *Open Decision Spaces* refer to large extents, such as the sagebrush biome or a State, that are large enough that prioritization of areas and efforts is obviously needed. Open Decision Spaces are more likely to use the SCD to plan strategic allocation of effort and funds, discuss overall strategies for the biome, and decide which locations are the "best" investments. *Defined Decision Spaces* refer to a smaller spatial extent, such as a county, BLM field district, or other regional areas with defined boundaries, such as a U.S. Fish & Wildlife Service National Wildlife Refuge or a park within the U.S. National Park system. Managers and landowners within Defined Decision Spaces are deeply passionate about their area and think more often about how they can move the needle within their work area than how their management areas align with national or biome-level priorities.

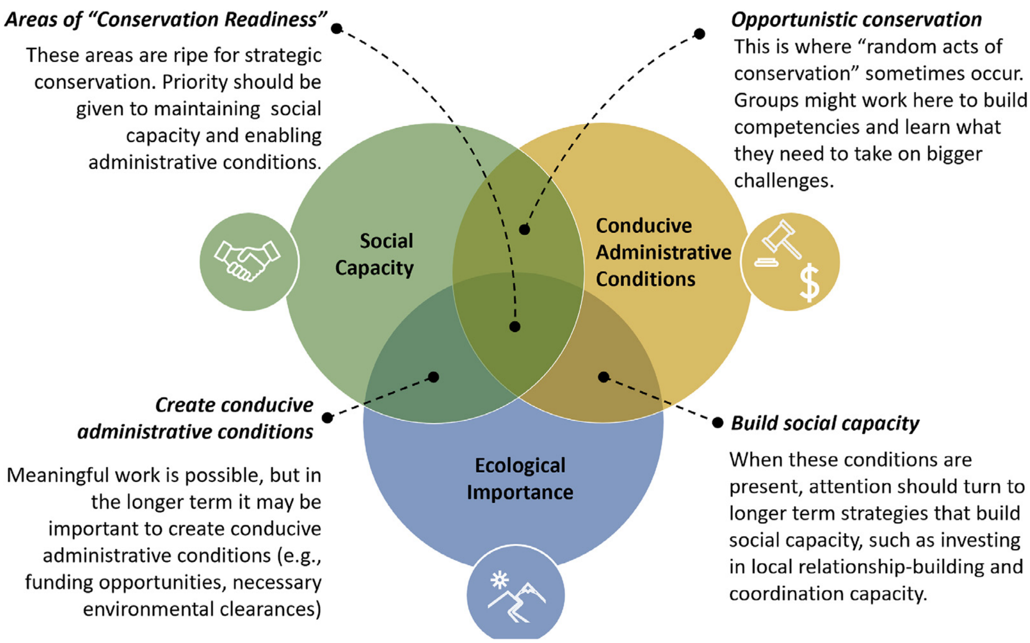

Figure 5. A framework to align ecological values with social capacity and management leadership to deliver conservation at volume (Credit Wollstein et al., Chapter 18, 2024). Conservation at scale requires all three pillars: Ecological Importance, Social Capacity, and Conducive Administrative Conditions. That is, strategic conservation involves not only work in ecologically important areas; it's an approach that must also include efforts to support or enhance social capacity and conducive administrative conditions.

What is clear, is that if resources needed to implement all business plans developed in Defined Decision Spaces are orders of magnitude greater than the resources available to allocate within Open Decision Spaces, hard choices on prioritizing efforts will have to be made. In this special issue, Sparklin et al. (2024) demonstrate that both the U.S. National Park Service and U.S. Fish and Wildlife Service National Refuge System within the Sagebrush Biome will need to prioritize areas to Defend the Core, because the status and trends of threats drastically exceed resources available to fight losses. Sparklin et al. (2024) provide an excellent example of how to defend the core in the most important landscapes by prioritizing actions. As a community, There is benefit to a willingness to prioritize certain areas to have the resources to say "yes" to facing their conservation challenges. However, in so doing, we must also acknowledge that other areas will be of lower priority.

It's critical to understand that both open and defined decision spaces are ultimately needed and deference to either spatial scale is a folly. The social capacity and ecological expertise required to deliver conservation projects are critical to achieving the required conservation volume within Defined Decision spaces (see Wollstein et al. 2024). We must also acknowledge that developing an effective strategy requires understanding the context, vision, priority areas, and required resources (financial and logistical). It also requires conducive administrative conditions for successful implementation. Developing an effective strategy and creating conducive administrative conditions largely occur in the Open Decision Space. Currently, most conservation efforts are largely driven by ranking submitted field-based conservation projects that are not linked to an overarching strategy developed at a State or Biome level. Mozelewski et al. (2024) showed us our current business-as-usual approach to conservation resulted in a conservation gap that was multiple orders of magnitude larger than all current conservation efforts across all State, Federal, and NGO organizations.

Given the current ecosystem trajectory, it is evident that the resources required by all stakeholders in the biome are significantly larger than what is available in the most optimistic scenario (Mozelewski et al. 2024). Consequently, a challenging decision that the community is confronted with is what to do in areas that are of lower priority. New ideas from the climate change literature suggest there is a need to be more flexible in approches to ecosystem changes (Schuurman et al. 2022). Instead of trying to resist all changes, accepting some functional changes or directing ecosystem processes towards a new state that may not match the historical baseline condition could be more beneficial (aka, resist, accept, direct, RAD, Schuurman et al. 2022). This doesn't mean the abandonment of lower-priority areas, but rather finding ways to create value for society through them. The RAD framework represents a breakthrough because it acknowledges that managing ecosystems solely based on their historical dynamics may not always be possible due to limited resources and a lack of ecological conditions needed to do so. Managers in the sagebrush biome have initiated a conversation on how to coexist with invasive annual grasses in the sagebrush ecosystem, as mentioned in a recent study by Davies et al. (2021). The group's fundamental idea is to accept that certain areas cannot be restored, and instead, we must learn to adapt and coexist with them.

Although spatial prioritization of effort makes sense in concept, it is much easier for practitioners working in Open Decision Spaces to acknowledge. Prioritizing landscapes allows for more success as resources can be targeted towards landscapes with a higher likelihood of achieving goals. Said another way, managers in Open Decision Spaces are not faced with the very hard decision to abandon fighting in localized areas they are deeply passionate about. The challenge of conservation arises when most of the Decision Space is in a reactive emergency care status (i.e., ambulance areas, see Fig. 4). In such cases, it may not be possible to restore historical baseline conditions within those areas.

Take-home messages

The papers should be papers not paper supporting the six themes within this special issue provides insight into how the SCD can be implemented to save a biome. Theme 1 shows that business-as-usual won't work to save the sagebrush sea. Currently, there are excellent examples of successful collaborative partnerships in the biome working to reduce ecosystem threats at watershed scales and larger (see case studies within Chapter A and in Chapter N of Part II of the WAFWA Conservation Strategy; Remington et al. 2024). However, the loss rates documented in the SCD (1.3 million acres per year, Doherty et al. 2022) and papers in Theme 1 (Mozelewski et al. 2024; Holdrege et al. 2024; Theobald et al. 2024) all indicate we will not be successful unless we have increased conservation capacity, a shared vision, coordinated actions, and are much more strategic in when, where, how, and whether we resist changes at the biome scale. Further, decisions within our control today on spatial targeting are the single most important steps to close the conservation gap. Mozelewski et al. (2024) document we are currently invested in a reactive conservation strategy (i.e., ambulance Fig. 4) with <10% of the invasive annual grass and ~23% of conifer treatment acres being targeted towards preventative conservation and Defending the Core (i.e., stethoscope in Fig. 4). Unless we prioritize Defending the Core, we cannot expect that we will be successful in stopping losses of Core Sagebrush Areas.

Theme 2 shows how better spatial targeting can improve outcomes and introduces four tools to help with spatial targeting. While Theme 1 shows changes to spatial targeting are needed to help close the conservation gap, Theme 2 presents practical analyses of where those changes could occur to maximize uplift. Improved spatial targeting goes well beyond using the tools presented here and could include localized models developed within defined areas. Ultimately, the success of targeted ecosystem management will likely occur when managers align project-level decisions with the core concepts of the SCD (i.e., the strategic vision of Defend and Grow the Core) and the definition of success shifts from project-level effectiveness (i.e., treatment success) to strategic goal(s) evaluation of “Are we Defending and Growing the Core.” Both the invasive annual grass (Boyd et al. 2024) and conifer (Reinhardt et al. 2024) papers took the novel step of taking the acreages identified within their respective highest priority areas and in just Core Sagebrush Areas asked how long it would take to treat identified areas once. Using the most optimistic conservation scenario from Mozelewski et al. (2024), the authors found it would take around a decade of focused effort.

Theme 3 demonstrates how conservation planning is essential to develop realistic business plans. The largest point to take home from Theme 3 is that understanding the status and trends of threats and desired traits within one’s management boundaries is critical to developing a business plan grounded in data. This concept is critical as it demonstrates how aligning conservation needs across all defined decision spaces (USFWS refuges and National Parks) with goals, objectives, and financial resources in an open decision space leads to realistic business plans. Sparklin et al. (2024) show how the USFWS and NPS would both need to prioritize in the open decision space (i.e., the Park and Refuge systems) if their goal was to Defend the Core within the highest priority sagebrush refuges and parks.

Theme 4 shows that targeted ecosystem management and monitoring are working. Overall, this special issue highlights that effective conservation needs to align with an overarching strategic ecosystem vision to guide treatments. The current best example of large-scale habitat treatments that are guided by a strategic vision is the USDA Working Lands for Wildlife program led by the NRCS (Natural Resources Conservation Service 2021a). The NRCS found that when treatments were saturated into legacy landscapes, they saw a 20% increase in effectiveness in Defending the Core (Naugle et al. 2024). These papers provide real examples of delivering conservation at volume, monitoring outcomes, and providing recommendations based on program evaluation. Importantly, this theme also shows that satellite-based monitoring can be used to understand treatment effectiveness as well as the longevity of treatments (i.e., NRCS legacy landscapes maintenance costs). These examples provide hope, that despite major threats to the biome, we have been successful, and we can be again at even larger scales.

Theme 5 provides further evidence of the ecological importance of the SEI to sagebrush obligate songbirds, sage-grouse, and carbon sequestration. We hope that the history of conservation in the sagebrush biome and finding common ground sections above create a compelling vision of why we need to move beyond single-species management and myopic focus on single metrics such as carbon counting. We also recognize that other priorities such as single-species and a one-size-fits-all effort that solely relies on the SCD are not practical. The NRCS programmatic evaluation showed NRCS work primarily aimed at sage-grouse aligned with the SCD. Both Coates et al. (2024) and Prochazka et al. (2024) show that conservation actions geared towards SEI increased population performance of the Bi-State Sage-grouse and populations within Core Sagebrush Areas are stable despite large range-wide declines. However, Prochazka et al. (2024) also indicates that understanding specific behavior responses would help manage human modification to the biome. Ultimately, linking the current conceptual model of SEI or new conceptual models that link to other priority ecosystem metrics that have shared value, such as water quality or riparian areas, would help expand and refine the current SCD.

The final theme clearly articulates more factors than ecology, science, or publications are essential to implement change within the sagebrush biome. Making the science we have more actionable is critical to adoption, especially in the defined decision space where projects are implemented (Olson et al. 2024). Second, change management involves human social aspects, its not just ecology. Understanding and leading people are essential skills to implement conservation and streamline the systems to fund and coordinate conservation (Wollstein et al. 2024; Remington et al. 2024; Cahill 2024).

Defending the Core is a powerful strategy that is already working to catalyze diverse stakeholders to work together to fight threats to the ecosystem in efforts such as the Cheatgrass Challenge (NRCS 2020). However, resistance to ecosystem change cannot be the only tool employed when trying to manage an entire biome with a long-established invasive species problem (Boyd et al. 2024) during a rapidly changing climate (Holdrege et al. 2024; Schuurman et al. 2022). The special issue collectively articulates that the status quo will not suffice and envisions a strategic game plan for attacking multiple ecosystem threats. The sagebrush biome still has wide open places with high ecological integrity at a scale that other ecological systems within the lower 48 states do not have (Figs. 1–2). Therefore, Defending the Core and the SCD are still viable strategies to find common ground among diverse stakeholders, and begin the conversations to organize the conservation community to develop a shared plan to save the sagebrush biome.

Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The lead author is a guest editor for the special issue entitled State of the Sagebrush: Implementing the Sagebrush Conservation Design to Save a Biome. This article does not present new work. Instead, it provides a coherent path to link the 19 other chapters into a coherent issue. All other authors do not have any financial interests/personal relationships to declared.

CRediT authorship contribution statement

K.E. Doherty: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing. **J. Maestas:** Conceptualization, Writing – original draft, Writing – review & editing. **T. Remington:** Conceptualization, Writing – original draft, Writing – review & editing. **D.E. Naugle:** Conceptualization, Writing – review & editing. **C. Boyd:** Conceptualization, Writing – review & editing. **L. Wiechman:** Conceptualization, Writing – review & editing. **G. Bedrosian:** Conceptualization, Methodology, Resources, Writing – review & editing. **M. Cahill:** Conceptualization, Methodology, Resources, Writing – review & editing. **P. Coates:** Conceptualization, Methodology, Resources, Writing – review & editing. **M. Crist:** Conceptualization, Methodology, Resources, Writing – review & editing. **M.C. Holdrege:** Conceptualization, Methodology, Resources, Writing – review & editing. **A.V. Kumar:** Conceptualization, Methodology, Resources, Writing – review & editing. **T. Mozelewski:** Conceptualization, Methodology, Resources, Writing – review & editing. **R.C. O'Connor:** Conceptualization, Methodology, Resources, Writing – review & editing. **A. Olsen:** Conceptualization, Methodology, Resources, Writing – review & editing. **B.G. Prochazka:** Conceptualization, Methodology, Resources, Writing – review & editing. **J.R. Reinhardt:** Conceptualization, Methodology, Resources, Writing – review & editing. **J.T. Smith:** Conceptualization, Methodology, Resources, Writing – review & editing. **W.D. Sparklin:** Conceptualization, Methodology, Resources, Writing – review & editing. **D.M. Theobald:** Conceptualization, Methodology, Resources, Writing – review & editing. **K. Wollstein:** Conceptualization, Methodology, Resources, Writing – review & editing.

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