DISSERTATION

KNOWLEDGE MANAGEMENT FOR ADAPTIVE PLANNING AND DECISION-MAKING IN FEDERAL LAND MANAGEMENT AGENCIES

Submitted by

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ABSTRACT

KNOWLEDGE MANAGEMENT FOR ADAPTIVE PLANNING AND DECISION-MAKING IN FEDERAL LAND MANAGEMENT AGENCIES

Scholarship on environmental governance emphasizes the importance of institutions with the capacity to integrate scientific knowledge from multiple scales of assessment into decision-making processes at multiple levels of governance. A major gap in our knowledge exists around the design of policies and administrative strategies that can support knowledge management and address scalar challenges for adaptive governance in public organizations such as land management agencies. This research examines challenges and opportunities for improving knowledge management for multiscale monitoring, which is a fundamental component of public land planning and decision-making for the U.S. Forest Service, the Bureau of Land Management (BLM), and the National Park Service (NPS). My objective is to expand our understanding of the governance institutions that support improved knowledge management, looking specifically at the legal and administrative variables that impede and promote improved knowledge generation and application in a hierarchical public bureaucracy. In the U.S. Forest Service, I found that limited capacity, decentralized decision-making structures, and organizational culture are critical barriers for implementing forest and broader-scale monitoring associated with recent regulations for National Forest planning under the National Forest Management Act of 1976. However, there are opportunities for addressing these challenges through partnerships, investment in "administrative knowledge brokers," and formalized collaborative processes. While these policies and practices can generate efficiencies and address scalar challenges for knowledge

management, leadership commitment and capacity are needed for implementation. Both the BLM and NPS used similar policy tools to address capacity and commitment challenges for effective knowledge management among administrative actors, including: clear goals linked to agency mission and mandates; funding and specialized staffing positions dedicated to inventory and monitoring at multiple levels of administration; centralized authority for implementation, coordination, and budgetary allocation; and structured collaborative processes. However, there are also differences in tools that reflect the unique administrative context and constraints faced by each agency.

Collectively, my findings highlight several important considerations for future research on environmental governance. Rather than characterizing institutional actors as knowledge users, producers, and intermediaries, I argue that it is more appropriate to evaluate the specific capabilities and multiple roles of diverse actors in different knowledge management processes. Given the complexity of today's management challenges, administrative structures dedicated to knowledge management and embedded in public organizations are needed to link knowledge to action across scales of governance. I also highlight the problematic assumption that decentralization and flexibility are essential for adaptive practice; the critical barrier in my findings is not limited flexibility, but limited administrative capacity. My research suggests that hierarchical governance structures and a diverse mix of policy tools are essential for addressing mismatches between the temporal and spatial scales of assessment and decision-making, realizing efficiencies for implementation, and linking knowledge to action across levels of governance.

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CHAPTER 1: INTRODUCTION

1.1. Introduction

'In the face of current environmental management challenges, it is essential that institutional structures and processes support learning and adaptation (DeCaro et al., 2017). Yet there are often barriers to the generation, exchange and application of useable knowledge in environmental management contexts. Managers often rely on experiential knowledge and lack knowledge at appropriate scales, creating a disconnect between knowledge and action. These challenges are often a product of institutional boundaries between scientists and managers, mismatches between the scales of assessment and decision-making, and legal and administrative governance structures that emphasize stability and control at the expense of flexibility and adaptation (Cash and Moser, 2000; Folke et al., 2005; Sarewitz and Pielke, 2007).

To bridge the knowledge-to-action gap in environmental governance, recent research on environmental knowledge management[1] emphasizes the importance of social processes and intermediaries, such as boundary organizations and knowledge brokers, for overcoming scalar challenges and epistemic barriers between knowledge users and producers in specific decision-making venues (Fazey et al., 2013; Nguyen et al., 2016). Scholarship on adaptive governance investigates the structural characteristics of multilevel governance regimes that are thought to support effective knowledge management processes across institutional boundaries and scales of socio-ecological organization. Legal frameworks, networks, and nested non-hierarchical

[1] Also called knowledge exchange, knowledge mobilization, knowledge transfer (Fazey et al. 2013). Knowledge management is defined as the "process of generating, storing and circulating new knowledge and identifying, bringing together and applying existing knowledge to achieve a specific objective" (Reed et al. 2013).

governance regimes are fundamental components of this paradigm (Chaffin et al., 2014). However, the emphasis on governance, networks and non-state actors has meant that that there has been little attention to opportunities for improving adaptive governance in existing state institutions, which dominate North American land management, through purposive policy design and administrative practice (Dovers and Wyborn, 2014; Morrison et al., 2017). While some scholars have called attention to the importance of "enabling policies" that promote effective multi-scale knowledge management, within the literature these are often limited to general recommendations for collaboration, decentralized decision-making, or legal reform, unmoored from specific legal and administrative contexts (Cash and Moser, 2000; Lockwood et al., 2010; Craig et al., 2017).

One opportunity for improving the link between knowledge and action in existing state agencies is through policies and administrative practices that support multiscale ecological inventory and monitoring (I&M) (i.e. ecological inventory, assessment, and monitoring conducted at multiple temporal and spatial scales of ecological organization, and coordinated by actors at multiple levels of governance). Multiscale I&M is a fundamental source of knowledge for evidenced-based environmental policy, planning, and decision-making in an era of rapid change (Hutto and Belote, 2013; Joyce et al., 2009; Lindenmayer and Likens, 2010). However, while the challenges for implementing multiscale I&M in land management agencies are well documented, there has been little investigation of policies and governance regimes that can support it (Biber, 2013). This is a critical gap given the increasing promotion of monitoring and adaptive management by federal land management agencies, and the pressing need for relevant information for adaptive management and planning in an era of climate change (Joyce et al., 2009; Williams et al., 2009; Archie et al., 2012).

This dissertation investigates challenges and opportunities for the design and implementation of multiscale ecological monitoring strategies in federal public land management agencies. In recent years, the US Forest Service, the Bureau of Land Management, the National Park Service, and the United States Forest Service have all developed policies for multiscale inventory and monitoring that can address scalar challenges, leverage partnerships, and support adaptive management and planning (Waltz et al., 2017; Toevs, 2011; Fancy, 2009). These efforts therefore provide an important opportunity to understand challenges and opportunities for supporting effective knowledge management and adaptive governance in existing state institutions. To address this objective, the overarching questions associated with my dissertation were: What are the knowledge management challenges for multiscale inventory and monitoring in federal land management agencies? What are the policy tools and administrative practices that support the generation, exchange, and application of monitoring information in land management planning and decision-making contexts?

To answer these questions, I used document analysis, participant observation in collaborative interagency workshops, and over 100 semi-structured interviews with individuals from land management institutions, science based NGOs, and scientists in the western United States. Most of this data collection was associated with research conducted by the Ecological Restoration Institute at Northern Arizona University and the Colorado Forest Restoration Institute, and supported through a funding agreement with the Washington Office of the US Forest Service (Waltz et al., 2017). Additional document analysis and interviews were subsequently conducted to support research on multiscale monitoring implementation in the BLM and NPS in 2017. The following section provides an overview and roadmap for the rest of the dissertation.

Chapter 2, in preparation for *Journal of Forestry,* highlights advantages and information needs, challenges, and opportunities associated with the implementation of broader-scale monitoring strategies required by the 2012 planning rule. This disciplinary chapter is targeted towards a practitioner audience, as well as forest management researchers. My findings in this chapter emphasize advantages of broader-scale monitoring identified by interviewees and workshop participants, such as efficiencies for forest planning and monitoring, and improved communication and coordination internally and with partner organizations. However, I also highlight challenges for implementation posed by limited capacity, decentralized decision-making structures, and organizational culture. While these challenges may be difficult to surmount, I argue there are opportunities for building capacity incrementally by exploiting partnerships, and investing in staff dedicated to broader scale monitoring implementation.

Chapter 3, in preparation for *Journal of Environmental Management,* addresses current research and debates associated with environmental knowledge management—a burgeoning research agenda. Here, I integrate scholarship on ecological monitoring and public sector and environmental knowledge management to investigate challenges and opportunities associated with the co-production, exchange, and application of knowledge within and across levels of forest service administration, and among diverse institutional actors. I argue that partnerships, formalized collaborative processes, and investment in administrative knowledge brokers are essential for mitigating temporal and spatial mismatches between monitoring implementation and forest planning. I also highlight problematic assumptions and conceptualizations found in the literature on knowledge management and adaptive governance, such as the importance of decentralized decision-making structures and the central role of external actors for mediating knowledge management process, particularly in spatially distributed governance contexts where external capacity is scarce. I also note that distinctions such as knowledge users, producers and intermediaries are problematic in the context of multiscale knowledge for ecological monitoring, and that it is more useful to characterize the capabilities of different actors for specific knowledge management processes.

In Chapter 4, in preparation for *Review of Policy Research,* I investigate the policy design of multiscale inventory and monitoring programs in the Bureau of Land Management and the National Park Service. Using Schneider and Ingram's (1990) policy tools framework, I highlight the policy tools used by administrative actors to address commitment and capacity challenges associated with I&M implementation, the ways in which administrative contexts shape the selection of policy tools, and the implications of tool choice for I&M outputs and outcomes. To address institutional challenges associated with decentralized decision-making structures, limited capacity, and commitment, both agencies created new autonomous and multilevel organizational structures internal to each agency dedicated to inventory and monitoring implementation. However, differences in administrative context also led to different "mixes" of policy tools at different levels of administration—differences that are evident in tradeoffs in the scale and scope of implementation outputs and outcomes. This chapter contributes to the literature an empirical example of policy tools and organizational structures that support long term and multiscale inventory and monitoring—a critical gap in the literature. It also highlights important opportunities for improving adaptive practice in existing institutions through administrative policy design, rather than legal reform, and suggests that multilevel and hierarchical administrative structures are needed to generate comparable and scalable information for resource allocation and planning decisions at multiple levels of governance. Chapter 5 concludes with a summary of my findings, and research considerations for scholarship on public policy and administration, knowledge management, and adaptive governance.

REFERENCES

Archie, K. M., Dilling, L., Milford, J. B., & Pampel, F. C. (2012). Climate Change and Western Public Lands: a Survey of U. S. Federal Land Managers on the Status of Adaptation Efforts. *Ecology and Society*, *17*(4), 20.

Biber, Eric. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4).

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120.

Chaffin, B. C., Gosnell, H., Cosens, B. A., Works, M., & Situating, A. G. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society*, *19*(3), 56.

Craig, R. K., Garmestani, A. S., Allen, C. R., Tony, A., Birgé, H., DeCaro, D., Gosnell, H. (2017). Balancing stability and flexibility in adaptive governance: The new challenges and a review of tools available, *22*(2), 1–31.

DeCaro, D., Chaffin, B. C., Schlager, E., Garmestani, A. S., & Ruhl, J. B. (2017). Legal and Institutional Foundations of Adaptive Environmental Governance. *Ecology and Society*, *22*(1), 1689–1699.

Fancy, S. G., Gross, J. E., & Carter, S. L. (2009). Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1–4), 161–174.

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C. L., … Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*, *40*(1), 19–36

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annu. Rev. Environ. Resour.*, *30*, 441–473.

Hill, H. C. (2003). Understanding Implementation: Street-Level Bureaucrats' Resources for Reform. *Journal of Public Administration Research and Theory*, *13*(3), 265–282.

Joyce, L. A., Blate, G. M., McNulty, S. G., Millar, C. I., Moser, S., Neilson, R. P., & Peterson, D. L. (2009). Managing for multiple resources under climate change: national forests. *Environmental Management*, *44*(6), 1022–1032.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., & Griffith, R. (2010). Governance Principles for Natural Resource Management. *Society & Natural Resources*, *23*(10), 986–1001

Morrison, T. H., Adger, W. N., Brown, K., Lemos, M. C., Huitema, D., Hughes, T. P., … Hulme, M. (2017). Mitigation and adaptation in polycentric systems: sources of power in the pursuit of collective goals. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(5), 1–16.

Nguyen, V. M., Young, N., & Cooke, S. J. (2016). A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. *Conservation Biology*, *0*(0),

Reed, M. S., Fazey, I., Stringer, L. C., Raymond, C. M., Akhtar-Schuster, M., Begni, G., Wagner, L. (2013). Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development*, *24*(4), 307–322.

Schneider, A., Ingram, H., & Schneider and Helen Ingram, A. (1990). Behavioral assumptions of policy tools. *Journal of Politics*, *52*(2), 510.

Sheelanere, P., Noble, B. F., & Patrick, R. J. (2013). Institutional requirements for watershed cumulative effects assessment and management: Lessons from a Canadian trans-boundary watershed. *Land Use Policy*, *30*(1), 67–75.

Sarewitz, D., & Pielke, R. a. (2007). The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science and Policy*, *10*, 5–16.

Toevs, G. R., Karl, J. W., Taylor, J. J., Spurrier, C. S., Karl, M. "Sherm" S. "Sherm," Bobo, M. R., & Herrick, J. E. (2011). Consistent Indicators and Methods and a Scalable Sample Design to Meet Assessment, Inventory, and Monitoring Information Needs Across Scales. *Rangelands*, *33*(4), 14–20.

Waltz, A., Wurtzebach, Z., Esch, B., Wasserman, T., Schultz, C. (2017). *Developing A Framework for the U.S. Forest Service Broader-Scale Monitoring Strategy: Processes and Outcomes*. Northern Arizona University Ecological Restoration Institute Technical Report. Online at: http://sweri.eri.nau.edu/PDFs/BSMSStrategyReport_2_23_17_with%20appendices.pdf

Westgate, M. J., Likens, G. E., & Lindenmayer, D. B. (2013). Adaptive management of biological systems: A review. *Biological Conservation*, *158*, 128–139

Williams, B. K. (2011). Passive and active adaptive management: approaches and an example. *Journal of Environmental Management*, *92*(5), 1371–1378.

Wyborn, C., & Dovers, S. (2014). Prescribing adaptiveness in agencies of the state. *Global Environmental Change*, *24*, 5–7.

Young, O. R. (2002). *The institutional dimensions of environmental change: fit, interplay, and scale*. MIT press.

CHAPTER 2: BROADER-SCALE MONITORING FOR FOREST PLANNING: CHALLENGES AND OPPORTUNITIES

2.1 Introduction

Scholarship on natural resource management emphasizes the importance of integrating information on social and ecological trends and conditions from multiple scales into land management planning and decision-making processes (Lindenmayer, 2008; Reed et al. 2013). Monitoring information from multiple scales of assessment, from fine to regional scales of socioecological organization, is a critical source of information in this respect (Lindenmayer and Likens, 2010; White et al., 2017). While question driven "effectiveness" monitoring is important for evaluating the effectiveness of management activities for achieving goals and objectives, information from broader-scale "surveillance" monitoring programs is essential for cumulative effects analysis, and evaluating trends in species distributions and landscape patterns and processes (Deluca et al., 2010; Hutto and Belote, 2014; Potter et al., 2016). In recent years, land management agencies such as Parks Canada, the National Park Service, and the Bureau of Land Management have all developed policies designed to support effective multi-unit and multiscale monitoring (Fancy et al. 2009; Toevs et al. 2011; Wurtzebach and Schultz 2016). In the context of forest management, multiscale monitoring is also emphasized in recent regulations for National Forest planning. In addition to requirements for forest level monitoring, regions are also directed to develop "broader-scale" monitoring strategies to evaluate resource trends and conditions at scales greater than individual units. However, multi-scale monitoring is an emerging science as well as practice, and there has been little investigation of the policies and administrative practices needed to effectively implement in public land management contexts (Biber 2013; Carter et al. 2017).

This article reports on research conducted in collaboration with the US Forest Service in support of broader-scale monitoring implementation in Regions 2 and 3 of the US Forest Service. Our goal was to explore challenges and opportunities for implementation, and identify policy relevant recommendations that will help the agency meet the goals and intent of the 2012 planning rule. To support ongoing implementation, we structured our investigation around three questions: 1) What are the advantages and information needs a broader-scale monitoring strategy provide? 2) What are challenges for implementing broader-scale monitoring strategies? 3) What are some actionable opportunities for implementing broader-scale monitoring strategies?

2.2. Literature Review

2.2.1. The Process of Designing Multi-Scale Monitoring

Generating and integrating information from broader-scale monitoring programs into land management decision-making processes requires several iterative processes. The first and most important step is design, as it sets the stage for all subsequent steps. Effective design requires the identification of goals and information needs, measureable indicators of ecological resources, and data collection, data management, and analysis protocols that can generate information for decision-making at appropriate temporal and spatial scales (Niemeijer et al., 2008; Lindenmayer and Likens, 2010). Collaboration among scientists, managers, and stakeholders during design is essential for ensuring monitoring programs will be efficient and feasible to implement, and produce information that is accurate, credible, and relevant to decision-making (Fancy et al., 2009; Tulloch et al., 2011). After monitoring programs have been designed, consistent data collection, data management and analysis is essential for the generation of information on ecological trends and condition (Lovett et al., 2007; Lindenmayer and Likens, 2010).

There are additional processes and capabilities associated with the transfer or exchange of existing data and information across organizational boundaries and scales of assessment. Interorganizational data and information, for instance, requires managerial capacity and leadership for effective collaboration and coordination (Dawes et al., 2009). Generating broader-scale information from monitoring data collected at mid to fine scales requires the use of consistent measurement and data management protocols. Coordination across jurisdictions, or the use of statistical modeling and decision-support tools is often essential. (Veblen et al., 2014). "Downscaling" data collected across broader scales also typically requires additional data collection, data synthesis, and significant statistical expertise (Corona, 2010; Potter et al., 2016). After analysis, information must also be effectively communicated to relevant institutional actors in a timely and interpretable format. Effective communication is particularly important for actors who were not involved in the generation of information (Dilling and Lemos, 2011).

To support effective decision-making, information from multiple sources and scales must also by synthesized and interpreted for its relevance to decision-making, as information from one scale or resource is often insufficient to effectively inform decision-making (Doremus, 2008). Discussion and deliberation—ideally with stakeholders— may be particularly important for evaluating the relevance of information and the costs or risks associated with applying knowledge in practice (Gregory et al., 2006). Linking monitoring information to land management planning decisions also often depends on the development of clear and measureable objectives or targets associated with plan components (Nie and Schultz, 2012).

2.2.2 Multi-Scale Monitoring in the Forest Service Context: Challenges and New Initiatives

In land management contexts, the implementation of these iterative processes is often complicated by institutional variables. One fundamental barrier is human, financial, and technological resource capacity. Agencies often lack staff with sufficient expertise to effectively design robust monitoring programs, or manage, analyze, interpret, and integrate information into decision-making processes (Biber, 2011; Lindenmayer and Likens, 2010). Problematic data management systems are an especially common barrier for the generation of useable information, even if data is collected consistently (Lovett et al., 2007). Commitment is another challenge. Monitoring is often the first program cut when budgets are tight, and managers are often reluctant to allocate scarce human and financial resources to monitoring when it is not legally required (Biber, 2011). There are also barriers associated with organizational structure and culture. Decentralized decision-making structures and parochial and risk-averse organizational cultures often create coordination, communication and commitment challenges for consistent implementation across temporal and spatial scales of land management planning (Stankey et al., 2003; Biber, 2011; Benson and Garmestani, 2011). Within the US Forest Service, these barriers have created significant challenges for implementing robust monitoring above the scale of local management actions. Forest plan monitoring is often not scientifically credible, or substantively linked to forest plan components and decision-making processes (Nylen, 2011). The systematic use of existing broader-scale datasets and the development of new internal multi-unit monitoring strategies has been limited (Holthausen et al., 2005; Schultz, 2010).

Decentralized decision-making structures, organizational culture, and resource scarcity also create capacity and commitment challenges for policy implementation (Sabatier, 1986). However, scholars of public policy note that there are tools for addressing these issues through effective policy design (May, 2012). One important consideration for design is statutory clarity. Clear statements of policy goals, their rationale, and the means for achieving them are important for ensuring commitment among implementing officials (Sabatier, 1986). Additional commitment building provisions include incentives to implement programs, publicity about policy goals, and communication strategies that emphasize the importance and benefits of implementation processes (Goggin et al., 1990). In contexts where hierarchical authority is diffused, and organizational resources are limited, "capacity building" policy provisions are often needed to support implementation (May, 2012). Capacity building provisions include funding for implementation, technical training, formal guidance, and managerial oversight—tools that provide administrative actors with the resources to implement policies (Hill, 2003; May, 2012). Collaboration with external organizations is another important strategy for leveraging capacity for policy implementation, though funding and human resources are often needed for steering and network management (Hill, 2003; Agranoff, 2006). However, the development and use of capacity and commitment building strategies is often dependent upon effective leadership. Leadership is essential for clarifying and communicating policy goals, operationalizing implementation strategies for specific contexts, allocating resources, and steering collaboration and network implementation structures (Lynn et al. 2000; Moynihan and Landuyt 2009).

In 2012 the US Forest Service developed new regulations for forest planning under the authority of the National Forest Management Act of 1976 that place a strong emphasis on multi-scale monitoring and adaptive planning. The new "planning rule", as it is called, emphasizes a three-part iterative cycle of assessment, planning, and monitoring in a continuous feedback loop (36 C.F.R. §219.19 [2012]). Monitoring is meant to support the assessment process and evaluate plan implementation over time by testing relevant assumptions, tracking relevant changes, and measuring management effectiveness and progress toward achieving or maintaining desired conditions or objectives (36 CFR § 219.5). This planning framework is designed to "inform integrated resource management and allow the Forest Service to adapt to changing conditions, including climate change, and improve management based on new information and monitoring" (36 CFR § 219.5 (a)).

There are two complementary tiers of monitoring in the new planning rule. In addition to forest plan monitoring, each of the nine Forest Service Regions, the administrative level above individual forests, are required to develop "broader-scale monitoring" strategies that address resource trends and conditions at spatial scales broader than a single plan area. Broader scale monitoring is intended to generate efficiencies, and complement forest plan monitoring strategies (36 CFR § 219.12 (b)). Broader-scale monitoring approaches may include: the use of existing broader-scale monitoring information collected by National or Regional USFS staff; the development of new regionally coordinated monitoring strategies; the aggregation of data collected by forest staff that is analyzed in a unique way; and the analysis and communication of existing monitoring information collected by external organizations. In developing broader-scale monitoring strategies, Regions are also directed to collaborate with "other Forest Service units, Federal, State or local government agencies, scientists, partners, and members of the public" (36 CFR § 219.12 (b)), to utilize "best available scientific information" (36 CFR § 219.3), and to ensure that monitoring results are integrated back into planning and decision-making cycles through biennial reporting cycles (36 CFR § 219).

2.3. Methods

Data collection occurred as part of a broader research project supported by the Washington Office of the US Forest Service during three different phases from August 2014-December 2016. During the first phase, we conducted semi-structured interviews with 93 respondents drawn from Forest, Regional, and National operational and research branches of the Forest Service, science-based NGOs who work the Forest Service, state agencies, and other federal land management organizations.

Table 2.1. Interviewees

General Group of Interviewees	**Specific Agencies or Groups**	**Final Interviewee Totals**
NGOs	The Nature Conservancy The Wilderness Society Defenders of Wildlife Western Watersheds Project Conservation Science Partners Forest Guild Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory)	13
Other Federal Land Management Or Regulatory Agencies	US Fish & Wildlife Service National Park Service Bureau of Land Management US Geologic Survey Natural Resources Conservation Service Bureau of Reclamation Environmental Protection Agency	20
State Agencies	State Fish and Wildlife Natural Heritage Programs* State Forestry	9
Forest Service: Total		47
National Staff		5
Regional Staff		17
Forest Level Staff		20
Research Station Staff		5
Academic Partners (monitoring or subject-matter experts)		4
Totals		93

With guides tailored to different groups of interviewees (i.e. internal and external to the forest service), we asked about advantages and information needs associated with a broader-scale monitoring strategy, and existing challenges, and opportunities; we also queried for examples of successful broader-scale monitoring programs in Region 2 and 3, other agencies, and other Regions (see Appendix A).

Our sample of interviewees was identified through purposive and snowball sampling techniques (Patton, 2002; Singleton and Straight, 2009). Drawing on publicly available lists, we first conducted interviews with Regional planners and program managers in the Washington Office, and Regions 2 and 3 of the US Forest Service (i.e. wildlife, watershed, rangeland, timber, and recreation program managers), and monitoring specialists at regional and national levels of other federal and state agencies. Through these interviews, we identified additional respondents from other relevant government and non-governmental organizations, and planners, program specialists, and line officers on individual forests who could provide greater insight on challenges and successes in Regions 2 and 3. We also asked respondents to identify examples of successful agency monitoring initiatives in other regions, and we interviewed respondents who were familiar with those initiatives. Interviews were conducted until we reached saturation, meaning we gained few new perspectives associated with our research questions (Scott and Carrington, 2011).

Interviews were conducted over the phone or in-person, averaged around one hour in length, and were recorded and transcribed. Interview data was organized using codes linked to our research and interview questions, and subcategories of codes that were identified inductively over time. We also coded several texts together to ensure intercoder reliability, analyzed and grouped codes, and discussed themes that emerged from our analysis (Miles and Huberman, 1994; Charmaz, 2006). Our findings from this first phase were used to produce a first-year report (Waltz et al., 2015), and develop four interagency workshops in Colorado, New Mexico, Arizona, and Wyoming in collaboration with the US Forest Service. The goal of the workshop phase was to explore opportunities for collaboration with partners, and share and learn about innovative broad-scale monitoring practices and procedures (for more information on workshops see Waltz et al., 2017). Break-out groups were initiated at the end of each workshop to capture existing opportunities for partnerships, and institutional needs for broader-scale monitoring implementation. Notes from these discussions were captured through participant observation methods, coded, and integrated with interview results (Dewalt and Dewalt, 2002).

2.4 Results

2.4.1 Potential advantages of increasing broader-scale monitoring and information needs

When we asked interviewees about the value that broader-scale monitoring would bring, the most commonly cited advantages were consistency, efficiency, and effectiveness in generating useable information for forest planning. Forest Service staff noted that by providing forests with information that they lack the capacity to generate on their own, broader-scale monitoring strategies have the potential to save time and resources for forest plan assessment and monitoring. According to a Regional planning employee,

> I'm not sure that we need broad scale monitoring, because we need a certain set of information. What I'm looking at is broad scale monitoring can hopefully make our monitoring process more efficient… I think collectively, we will improve on the performance across all forests, because we're collecting a set of data that's consistent and can be used by all the forests.

Interviewees also noted that monitoring data collected consistently across units can provide context for planning and decision-making at forest levels, allowing managers to compare trends and conditions within the plan area to those across regional or sub-regional scales. A Regional wildlife program manage highlighted this consideration, noting that "these approaches that are scalable and developed to allow inferences to be made at different levels and comparisons… it provides another tool to understand the context of that unit in the broad landscape and see what's going on here versus elsewhere."Another important benefit highlighted by agency and external respondents was for coordination and communication among agency staff and external partners. Regionally coordinated monitoring initiatives were perceived to offer advantages for data and information sharing, and to promote coordination across jurisdictions. Another anticipated advantage of these combined effects was for improved communication with citizens and politicians in Congress. As a forest planner in Region 2 explained, "if we were coordinated and collecting information in a coordinated way, then when somebody asks what's the status of your alpine ecosystems, we would be able to give an answer. I think there is an inherent benefit to that."

One information need highlighted by respondents was consistent and credible information on the status and trend of vegetative structure and composition in forest, range, and riparian systems at mid to ecoregional scales. Respondents from Region 2 noted that this is a particularly relevant consideration for forest ecosystems, as the available budget for forest-level inventory data collection has been decreasing. Some interviewees from forest-level fuel programs also said that while they were often able to gather the information they need for project level management decisions, a broader-scale strategy could allow them to evaluate the effectiveness of fuel treatments for achieving goals associated with restoration and hazard reduction across units and cross-jurisdictional landscapes. Respondents also indicated that information of associated with wildlife populations, habitat quality, and connectivity were also an information need a broader-scale strategy could provide. Despite its emphasis in the planning rule, several respondents noted that forests are not evaluating or assessing trends and conditions associated with connectivity at landscape scales, and a broader-scale monitoring strategy could help address this issue.

A consistent theme from workshops was also the importance of integrating information on ecological resource trends and conditions with information on climate change, such as uncharacteristic disturbance regimes, invasive species cover, and trends in precipitation, temperature, and extreme weather events. Several respondents noted that broader-scale information on social and economic trends would also be valuable, highlighting indicators such as trends in recreation type or activity (e.g. motorized, mountain biking, etc.), visitor use, urbanization in the wildland urban interface, population growth, and demographics. Another theme that emerged in workshops was that integrating information from multiple scales and sources is often essential for answering relevant management and planning questions. For instance, respondents noted the importance of linking broader scale information associated with "stressors" such as noxious weeds, uncharacteristic disturbance regimes, and climatic variation to information on species distributions, and ecological structure, function, and composition at multiple scales. These considerations are evident in the priority questions identified by workshop participants, and summarized for consistency by our research team.

Table 2.2. Priority questions and indicators

Forests	How are key characteristics of forest structure, function and composition changing over time in relation to desired conditions and HRV at the landscape and ecosystem scale?
	How are climatic variables and disturbance processes (such as wildfire and insects/disease outbreaks) affecting key characteristics of forest structure, function, and composition at the landscape and ecosystem scales?
	Are plan components and management treatments effectively protecting social and ecological values at risk, and promoting ecosystem resistance and resilience to climate change and disturbance at the stand and landscape scale?
Wildlife	What is the status and trend of focal species?
	What is the status and trend of TES/SCC populations?
	What are the status and trends in the ecological conditions needed to support TES/SPCCs, and how are climate change and other stressors (e.g. uncharacteristic fire, insect and disease outbreaks, recreation, extreme weather events, etc) affecting them?
	Are plan components and management actions effective at promoting the maintenance and recovery of TES/SCCs populations, and the resilience of key ecological conditions on which they depend?
	What are the status and trends in wildlife habitat and connectivity, particularly for TES/SCC and focal species?
Range	What are the status and trends of grassland community composition, structure, and productivity?
	What are the status and trends in disturbance processes in rangelands? Natural processes? Grazing related disturbance? Infrastructure/development disturbance?
	What are the status of non-native invasive species across the landscape? How are distributions changing over time?
	What are the effects of climate change and drought on grassland community composition and structure, productivity, and soil condition?

Water	What are the status and trends of water quality and hydrologic functions within the watershed and HUCs?
	What are the status and trends in the structure, function, composition and connectivity of lotic systems (i.e aquatic, riparian, springs, seeps)?
	How is water temperature, snowpack, runoff, flow, groundwater level and recharge, and precipitation changing as a result of climate change?
	What are the status and trends in the structure, function and composition of lentic systems?
Social/ Economic/ Cultural/ Recreation	What are the trends in economic contributions and provisions of NFS lands, for different resources and to different demographics?
	What are the status and trends in recreational uses of USFS lands?
	What are the status and trends in visitorship?
	What are the status and trends in ecosystem service provision and demand?

2.4.2. Challenges

According to our interviews, challenges for broader-scale monitoring implementation are many and include limited capacity, commitment, coordination, communication, and linkages to forest planning processes. Limited human and financial resource capacity and commitment were the most commonly cited challenge. While the 2012 planning rule directs Regions to develop broader-scale strategies, there is no additional funding to support implementation, and Regional respondents noted that Regional leadership is often unwilling to fund Regionally coordinated monitoring initiatives unless they are associated with legal requirements, such as the Endangered Species Act. According to Regional program lead in Region 3:

> Every year there's a little bit of a call for projects that we feel like need to be regional-based and take that money off of there, but for the most part, what ends up being prioritized is implementation-based projects instead of anything that is either planning or monitoring-based.

Resource scarcity also creates tensions between the forests and the regions. Some interviewees and workshop participants from forests were concerned that Regionally coordinated broader-scale monitoring strategies would reduce the funding available for forest-level monitoring, yet provide little relevant information for units. Staffing limitations were another common challenge cited by interviewees. Several respondents noted the Regional staff often have multiple responsibilities, and are often "on detail," filling in for other positions. This limits their capacity to develop new monitoring approaches in cooperation with partners, or acquire, analyze, and communicate existing information to end users on forests. In Region 2, for instance, there is little use of broad-scale monitoring data collected by Forest Service Research's Forest Inventory and Analysis program (FIA), an issue respondents from FIA noted was due in part to persistent vacancies in Regional forest vegetation analysis positions.

Coordination and communication were additional challenges highlighted by participants, particularly for broader-scale approaches that would involve the aggregation and analysis of existing data collected by forest staff. Across Region 2 and 3, interviewees noted that measurement protocols for common resources often vary significantly across forests, and cumbersome agency databases create challenges for consistent data entry and data management. A common theme from agency respondents was that while it is relatively easy to enter data into many agency databases, it is difficult to get data out or use them for analysis, and as a result, forest staff often utilize *ad hoc* data management strategies. According to one Regional specialist in Region 3, "there's a lot of data that's in file cabinets. It's in Excel spreadsheets, it's in someone's maybe Access database. Getting those out of those formats and into the format of our national database is a real challenge". Several respondents noted that consistency of data collection and data management varies across forests in relationship to available funding, staffing, and leadership commitment. According to respondents from external organizations, these issues create significant challenges and transaction costs for acquiring agency data, and acquisition often depends on social relationships with staff on individual forests. Indeed, a few respondents from external organizations noted that they could provide assistance with analysis—a critical chokepoint for the generation of useable information—if there was greater consistency in data collection and data management, and more transparency and commitment for data sharing. Several agency and external respondents noted that these challenges stem from the agency's decentralized structure, and an organizational culture that emphasizes local autonomy. Referencing challenges for coordination across units, one interviewee from the Washington Office of the agency noted: "We place such a strong cultural value on that decentralized model, that local decision making, that those things that really should be centralized, such as databases and those sorts of things, we don't value or put the resources towards". Indeed, a regional respondent from Region 3 noted that efforts to improve the consistency of forest resource data collection through standardized protocols were complicated by unit level staff's tendency to modify them to meet the needs of specific projects, and generate efficiencies for data collection. Linking broader-scale monitoring to forest planning was another challenge highlighted by interviewees and workshop participants. According to several respondents, Forest plan components are often vague or outdated, which makes it difficult to determine what information might signal the need for change. Many respondents from forests also noted they were unaware of or how to use existing data (such as data collected by FIA) for forest plan assessment or monitoring and evaluation. Respondents from some forests also voiced concerns about the relevance of Regionally coordinated monitoring strategies for forest planning, given significant differences in ecological systems on many forests, particularly between southern and northern forests in Region 2.

2.4.3. Opportunities

Given capacity limitations and organizational barriers, interviewees and workshop respondents highlighted several opportunities for building capacity for broader scale monitoring through partnerships and investment in staff dedicated to implementation. One opportunity frequently cited by respondents in Region 3 was for increased collaboration with staff from the Forest Service Rocky Mountain Research Station (RMRS) and FIA. While some respondents highlighted administrative barriers such as funding and problematic incentives, there was a consensus among workshop participants that collaboration with Forest Service research staff is important for prioritizing broader-scale monitoring questions, and evaluating opportunities for leveraging existing data collected by the agency or partner organizations. As one Regional specialist noted, staff at the Rocky Mountain Research station "have that kind of expertise to think about scale and take what people want to monitor or think they can monitor and then try to see how it's actually implemented at a very large scale". Respondents from Region 1 highlighted the importance of leveraging Forest Service Research Scientists early on in broad-scale monitoring design, and working with Regional and forest line-officers and resource specialists to identify relevant information needs. A few respondents also noted that there may be opportunities to work with agency scientists to develop decision support tools that promote effective analysis and communication of existing data. The Rocky Mountain Research Station's NORWEST stream temperature monitoring program, for instance, aggregates stream temperature data collected by forest staff and uses sophisticated modeling to provide estimates of stream temperature trends at Regional scales through an accessible web-based portal.

Collaboration with the Forest Inventory and Analysis program, and the Geospatial and Technological Applications Center (GTAC) were also identified as important opportunities, particularly give the relevance of FIA and remote sensing application for broader-scale assessment and monitoring, and its limited application in Forest planning processes. Respondents and workshop participants highlighted several examples of existing broader-scale monitoring programs developed with these partners. Region 3, for instance, recently collaborated with staff from FIA to develop a broader-scale monitoring strategy that uses FIA data to evaluate trends in Mexican Spotted Owl habitat over time.

Respondents and workshop participants also highlighted opportunities for leveraging external partners for broader-scale monitoring implementation. Other federal agencies, state wildlife management agencies, state heritage organizations, and science focused NGO's such as the Nature Conservancy were identified as the most important partners in this regard. One opportunity highlighted by several respondents was to leverage interagency funding for collaborative multi-party monitoring strategies, potentially implemented by partners such as State Heritage organizations. They noted that in addition to generating efficiencies and leveraging scarce resources, such approaches can also be used to evaluate the status and trend of crossboundary resources across jurisdictions. Respondents from state heritage agencies in Colorado, for instance, highlighted the potential benefits for consistency and efficiency of an interagency wetland assessment and monitoring strategy currently being developed with joint funding support from the national BLM and USFS offices

Agency and external respondents also emphasized the importance of leveraging partners with specialized expertise for specific implementation processes, such as data collection and data management, through regionally funded agreements. Regional respondents in both Regions 2 and 3 noted that funding agreements with partners generate efficiencies and provide consistency for implementation over multiple fiscal years and across units. As one regional respondent noted: “Usually we can build agreements for up to five years so we can kind of allocate that money for that time-frame. While we at the Forest Service can't use our own funding past the fiscal year, so we can't fund our crews past that with that money… agreements allow us to use these monies that tend to show up at the end of the fiscal year and need to be used quickly. Agency staff in Regions 2 and 3 also highlighted several examples of existing monitoring efforts implemented in collaboration with external partners. The SWERIs, people pointed out, conduct forest vegetation monitoring; state wildlife and Heritage agencies conduct wildlife and rare plants monitoring; and science based NGOs such as the Springs Institute and Bird Conservancy of the Rockies conduct spring systems and multispecies avian monitoring. In addition to data collection, many of these organizations also manage, analyze, and deliver information to forest staff. However, several respondents noted most partnerships occur at forest rather than regional scales, and indicated there may be opportunities for generating efficiencies and improving the consistency of specific approaches through regional coordination and funding.

In addition to partnerships, a consistent theme from respondents and workshop participants was the importance of staff dedicated to broader-scale monitoring implementation, particularly at Regional levels. Workshop participants noted that collaboration, partnership coordination, and data acquisition and exchange takes significant time and effort; it cannot be just another “duty as assigned” to staff with limited time and competing responsibilities. “You really need a regional monitoring team. It can't just be done by some part-time folks who's part of their job's in this forest and they get to go once a year. You need somebody that can look across and say, "Okay, here's the common measurement. Here are the protocols that we really need. Here's the most important questions we got. We need consistent protocols for those." Respondents from Region 1 noted that the Region has invested in a team of vegetation analysts, and developed innovative databases and decision-support tools that integrate stand level data collected by forest, FIA data, and remote sensing products. Regional specialists provide forest level end-users with tailored that can be used to answer unit level questions, and help them identify cost-effective temporal and spatial data collection intensification strategies that can provide information with sufficient statistical power for decision-making at relevant scales. Region 1 is also leveraging existing Regional capacity to develop approaches for analyzing and communicating broader-scale aquatic and riparian monitoring data collected by the Pacific Inland Fish Biological Opinion program, and guidance for the use of broader-scale information at forest levels. Respondents from Region 1 noted that while initial investment in administrative capacity was driven by litigation over standards for old-growth forests, the Region invested in additional positions once the benefits for efficiency and effectiveness became apparent.

Improving the consistency of data collected by forest staff was another opportunity highlighted by several internal and external respondents that might appeal to local leadership if they presented potential resource savings. As one forest specialist noted:

> I think we could demonstrate a lot of cost savings by using existing protocols that have been peer reviewed and used, maybe by our agency, maybe by other agencies… and having a crew that would be able to go out and do those consistently.

Indeed, respondents from the NWFP noted that standardized protocols analysis generate efficiencies for technical training, data collection, data management and analysis—a benefit also highlighted by respondents from the BLM and NPS. Some agency respondents in Regions 2 and 3 also indicated there may be opportunities for developing consistency through a bottom up approach, by “scaling up” innovative monitoring approaches developed on individual forests.

Respondents and workshop participants also highlighted opportunities for linking broader-scale information to forest planning. One is the co-development of broader-scale monitoring strategies for regionally or sub-regionally consistent plan components—an approach many indicated has the potential to generate efficiencies for both planning and monitoring. As an agency research scientist observed:

> I'm seeing now that the Northwest Forest Plan as a regional strategy provides a vehicle for speeding up plan revision because it provides a broad framework that maybe applies to many of the forest and then the individual forest can do their plans, can add some variation to the plans but a lot of what's being learned from the monitoring will feed into that… into the assessment which feeds into planning efforts for all the natural forests.

Some respondents indicated there were opportunities for developing measureable plan components that can be evaluated with existing broader scale strategies, such as FIA data. However, these approaches would nonetheless require effective communication and coordination, either between the regions and the forests, or across different forests. This was a consistent theme from respondents. One respondent from the NWFP monitoring program highlighted the value of workshops that teach forest specialists how to integrate NWFP monitoring data into NEPA analysis and documentation, a strategy they noted could be used to link broader scale monitoring to forest planning processes. In addition to creating efficiencies for both planning and monitoring, linking broader-scale monitoring strategies directly to plan components promotes adaptive forest plan decision-making—a central goal of the 2012 planning rule.

2.5. Discussion

Findings from workshops and interviews indicate that broader-scale monitoring programs have the potential to generate efficiencies for forest planning processes, improve the consistency and effectiveness of monitoring implementation, and promote effective coordination and communication with partners and stakeholders. Yet there are significant challenges for realizing these benefits. Human, financial, and technological resource limitations, decentralized decision-making structures, and an organizational culture that emphasizes local autonomy and discretion represent critical barriers for implementation (Sabatier, 1986; Winter, 2012). While there are opportunities for building capacity for implementation incrementally through partnerships and administrative action, substantively addressing the requirements of the planning rule will likely require significant organizational change. To provide support future implementation, we focus our discussion on critical challenges, near term opportunities, and long term considerations for supporting broader-scale monitoring implementation that can fulfill the intent of the 2012 planning rule.

Our findings suggest there are a few critical barriers that interact to create significant challenges for broader-scale monitoring implementation. One is limited human and financial resource capacity (Sabatier, 1986). While the new rule requires Regions to develop broader-scale monitoring strategies, there is no provision of funding to support implementation. Given incentives and pressure for substantive management outputs, Regional line officers are often unwilling to invest in monitoring related activities unless they are associated with legal mandates. This creates commitment challenges for building capacity for partner coordination, and developing new broader-scale monitoring initiatives. Effective coordination is another challenge that stems from the agency's culture of autonomy and local decision-making. Many respondents noted that Regional mandates and directives are often seen as optional by forest staff; this is a particular barrier for the development and use of standardized protocols for data collection and data management. These issues may also limit the willingness of Regional staff to develop coordinated approaches in some contexts. Despite these challenges, however, there are opportunities for partnership and capacity building that may be pursued incrementally, particularly given the opportunities for generating efficiencies for forest planning processes.

Leveraging existing data and partnerships for broader-scale monitoring implementation are likely the most feasible near-term opportunities, given existing organizational constraints. Funding agreements allow the agency to exploit the capacity of external partners, and ensure commitment for consistent implementation over multiple fiscal years and across multiple units. While these approaches are the most cost-effective, they nonetheless require some investment in administrative capacity. A consistent theme from interviews and workshops was that leveraging partners requires staff with dedicated time and skills in collaboration and partnership coordination (Agranoff, 2006; Ansell and Gash, 2008). Similarly, acquiring, analyzing existing data, and communicating relevant information to forests also requires significant time and technical expertise. While providing existing staff with time to accomplish these tasks or investing in additional human resource capacity may be difficult under existing budgetary constraints, our findings suggest that there are significant benefits in terms of efficiency and effectiveness that justify the investment; building technical and managerial capacity at regional levels can reduce transaction costs associated with collaboration and partnership coordination, and generate efficiencies for the analysis and communication of broader-scale monitoring information. This is particularly important given limited capacity for monitoring implementation and interpretation at forest levels. In Region 1, for example, it is far easier for forest staff to acquire tailored and highly credible FIA information from the Regional office than coordinate directly with staff from FIA on a forest by forest basis. There may also be opportunities for leveraging interregional resources for initial investment in regional capacity; Regions 8 and 9, for example, have recently invested in a shared FIA analyst. However, the development of inter-regional strategies will also likely require some investment in coordination and communication.

Investment in formal administrative processes is also an important near term opportunity for building capacity for broader-scale monitoring. In Region 1 and the NWFP area, steering committees composed of external scientists, resource specialists, and line officers have been important for leveraging external expertise, and identifying and building commitment for broader-scale monitoring strategies among line officers. Our findings suggest that these collaborative structures and processes can be used to identify and prioritize specific broader scale approaches, demonstrate cost savings and benefits, and communicate the importance and relevance of broader-scale monitoring for decision-making processes. The co-development of regionally or sub-regionally consistent forest plan components and broader-scale monitoring strategies is another important procedural opportunity for generating efficiencies and linking monitoring information to forest plan decision-making. This may occur at Regional levels, as in Region 3, or at sub-regional scales where adjacent forests are going through the plan revision process at similar times. Formal processes, guidance, and training for interpreting broader-scale monitoring information at forest levels may also be important for linking broader-scale information to forest planning. In addition to creating efficiencies for both planning and monitoring, linking broader-scale monitoring strategies directly to plan components promotes adaptive forest plan decision-making—a central goal of the 2012 planning rule.

There are also longer-term considerations for broader-scale monitoring implementation. Given scarce resources, limited commitment from line officers, and the agency's culture of local autonomy and discretion, strong leadership at national levels of the agency will likely be needed to address systematic database management issues, improve the consistency and effectiveness of forest level data collection, and communicate the value of broader-scale and forest level monitoring for land management planning (Moynihan and Landuyt, 2009). While there may be opportunities for improving coordination and accountability through the use of performance management incentives and budgetary oversight, effectively generating, analyzing, and communicating information from multiple partner and multiple scales will likely require significant organizational change (Fernandez and Rainey, 2006). Respondents from the Fish and Wildlife Service, the BLM, and the National Park Service noted that each agency has recently created new administrative structures dedicated solely to inventory and monitoring implementation—capacity building tools that have promoted the development and use of standardized monitoring protocols, and created efficiencies for broad-scale implementation and compliance with regulatory requirements for land management planning. Indeed, there may be opportunities for leveraging existing knowledge and capacity across different agencies, and developing interagency strategies for effective broader-scale monitoring, though such initiatives will require national leadership and initiative from national Forest Service staff.

2.6. Conclusion

Multiscale monitoring is essential for promoting adaptive planning and decision-making in an era of rapid change, yet there has been little investigation of the organizational strategies that support effective implementation in public land management agencies. This research highlights institutional challenges and opportunities for implementing broad-scale monitoring in the context of the US Forest Service. We found that despite a clear intent and set of requirements in policy, limited capacity, decentralized organizational structures, and the agency's culture of autonomy were critical institutional challenges for broad-scale monitoring. However, our research indicates that there are also opportunities for building capacity for implementation through partnerships and investment in staff dedicated to coordination, analysis, and communication at Regional levels of forest service administration. These strategies have the potential to generate efficiencies, and improve the consistency, credibility, and effectiveness of monitoring implementation, and support the adaptive intent of the 2012 planning rule.

REFERENCES

Agranoff, R. (2006). Inside Collaborative Networks: Ten Lessons for Public Managers. *Public Administration Review*, *66*(s1), 56–65

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571.

Benson, M. H., & Garmestani, A. S. (2011). Can we manage for resilience? The integration of resilience thinking into natural resource management in the United States. *Environmental Management*, *48*(3), 392–399

Biber, E. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4), art68.

Carter, S. K., Hickey, J., & Wood, D. J. (2017). Understanding a Landscape Approach to Resource Management in the Bureau of Land Management Prepared in cooperation with the Bureau of Land Management Multiscale Guidance and Tools for Implementing a Landscape Approach to Resource Management in the Bureau. *Open-File Report*, (January), 79.

Corona, P. (2010). Integration of forest mapping and inventory to support forest management. *IForest*, (*3*), 59–64.

Dawes, S. S., Cresswell, A. M., & Pardo, T. A. (2009). From "need to know" to "need to share": Tangled problems, information boundaries, and the building of public sector knowledge networks. *Public Administration Review*, *69*(3), 392–402.

DeLuca, T. H., Aplet, G. H., Wilmer, B., & Burchfield, J. (2010). The Unknown Trajectory of Forest Restoration: A Call for Ecosystem Monitoring. *Journal of Forestry*, *108*(September), 288–295.

DeWalt, K. M., & DeWalt, B. R. (2002). *Participant Observation: A Guide for Fieldworkers*. *Participant Observation A guide for fieldworkers*. Rowman Altamira.

Dilling, L., Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689.

Doremus, H. (2008). Data gaps in natural resource management: Sniffing for leaks along the information pipeline. *Indiana Law Journal*, *83*(2), 407–463.

Fancy, S. G., Gross, J. E., & Carter, S. L. (2009). Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1–4), 161–174.

Fernandez, S., & Rainey, H. (2014). Theory to Practice Managing Successful Organizational Change in the Public Sector. *Public Administration Review*, *66*(2), 168–176.

Goggin, M. L. (1990). *Implementation theory and practice: Toward a third generation*. Scott Foresman & Co.

Gregory, R., Failing, L., Ohlson, D., & Mcdaniels, T. L. (2006). Some Pitfalls of an Overemphasis on Science in Environmental Risk Management Decisions. *Journal of Risk Research*, *9*(7), 717–735.

Hill, H. C. (2003). Understanding Implementation: Street-Level Bureaucrats' Resources for Reform. *Journal of Public Administration Research and Theory*, *13*(3), 265–282.

Holthausen, R., Czaplewski, R. L., DeLorenzo, D., Hayward, G., Kessler, W. B., Manley, P., & Van Horne, B. (2005). Strategies for monitoring terrestrial animals and habitats. *US Department of Agriculture, Forest Service, Rocky Mountain Research Station*.

Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management*, *289*, 183–189.

Lindenmayer, D., Richard, J., Montague-, R., Alexandra, J., Bennett, A., Cale, P., Fischer, J. (2008). A checklist for ecological management of landscapes for conservation. *Ecology Letters*, *11*(1), 78–91.

Lindenmayer, D. B., & Likens, G. E. (2010). The science and application of ecological monitoring. *Biological Conservation*, *143*(6), 1317–1328.

Lovett, G. M., Burns, D. A., Driscoll, C. T., Jenkins, J. C., Mitchell, M. J., Rustad, L., … Haeuber, R. (2007). Who needs environmental monitoring? *Frontiers in Ecology and the Environment*, *5*(5), 253–260.

May, P. J. (2012). Policy Design and Implementation. *The Sage Handbook of Public Administration*, 279–291.

Moynihan, D. P., & Landuyt, N. (2009). How Do Public Organizations Learn? Bridging Cultural and Structural Perspectives. *Public Administration Review*, *69*(6), 1097–1105.

Nie, M. A., & Schultz, C. A. (2012). Decision-Making Triggers in Adaptive Management. *Conservation Biology*, *26*(6), 1137–1144.

Niemeijer, D., de Groot, R. S., Groot, R. S. De, & de Groot, R. S. (2008). A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*, *8*(1), 14–25.

Nylen, N. G. (2011). To Achieve Biodiversity Goals, the New Forest Service Planning Rule Needs Effective Mandates for Best Available Science and Adaptive Management. *Ecology Law Quarterly*, *38*(2), 241–291.

Potter, K. M., Koch, F. H., Oswalt, C. M., & Iannone, B. V. (2016). Data, data everywhere: detecting spatial patterns in fine-scale ecological information collected across a continent. *Landscape Ecology*, *31*(1), 67–84.

Reed, M. S., Fazey, I., Stringer, L. C., Raymond, C. M., Akhtar-Schuster, M., Begni, G., … Wagner, L. (2013). Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development*, *24*(4), 307–322.

Sabatier, P. (1986). Top-Down and Bottom-Up Approaches to Implementation Research: a Critical Analysis and Suggested Synthesis. *Journal of Public Policy*, *6*(1), 21.

Schultz, C. (2010). Challenges in Connecting Cumulative Effects Analysis to Effective Wildlife Conservation Planning. *BioScience*, *60*(7), 545–551.

Scott, J., Carrington, P. J., & Scott, J. (2011). The SAGE Handbook of social network analysis. Introduction. *The SAGE Handbook of Social Network Analysis*.

Stankey, G. H., Bormann, B. T., Ryan, C., Shindler, B., Sturtevant, V., Clark, R. N., & Philpot, C. (2003). Adaptive management and the northwest forest plan. *Journal of Forestry*, (*101*), 40–46.

Toevs, G. R., Karl, J. W., Taylor, J. J., Spurrier, C. S., Karl, M. “Sherm” S. “Sherm,” Bobo, M. R., & Herrick, J. E. (2011). Consistent Indicators and Methods and a Scalable Sample Design to Meet Assessment, Inventory, and Monitoring Information Needs Across Scales. *Rangelands*, *33*(4), 14–20.

Tulloch, A., Possingham, H. P., & Wilson, K. (2011). Wise selection of an indicator for monitoring the success of management actions. *Biological Conservation*, *144*(1), 141–154.

Veblen, K. E., Pyke, D. A., Aldridge, C. L., Casazza, M. L., Assal, T. J., & Farinha, M. A. (2014). Monitoring of Livestock Grazing Effects on Bureau of Land Management Land. *Rangeland Ecology & Management. 67*(6), 68–77.

White, M. A., Cornett, M. W., & Wolter, P. T. (2017). Two scales are better than one: Monitoring multiple-use northern temperate forests. *Forest Ecology and Management*, *384*, 44–53.

CHAPTER 3: KNOWLEDGE MANAGEMENT FOR MULTISCALE MONITORING AND FOREST PLANNING

3.1. Introduction

Meeting social-ecological goals in environmental governance requires integrating scientific information from multiple scales of assessment into decision-making (Cash et al., 2006; Lindenmayer and Likens, 2010). However, managers often rely on experiential knowledge and lack knowledge at appropriate scales, creating a disconnect between knowledge and action as a result of epistemic boundaries, "mismatches" between the scale of knowledge generation and that of decision-making, and legal and administrative structures that limit flexibility and collaboration (Archie et al., 2014; Folke et al., 2005; Sarewitz and Pielke 2007). To improve the knowledge-to-action gap in environmental governance, researchers emphasize the importance of social processes and intermediaries, such as boundary organizations and knowledge brokers, for overcoming scalar challenges (Fazey et al., 2012; Raymond et al., 2010; Nguyen et al., 2016). A major gap in our knowledge exists around the design of policies and administrative strategies that can improve knowledge management. In particular, we have limited knowledge of how to develop institutions that can support effective knowledge management and create pathways for overcoming scalar challenges in public organizations (Wyborn and Dovers, 2014).

Within the context of public land management, multi-scale ecological monitoring is a critical source of scientific knowledge for planning and decision-making that is receiving greater emphasis in recent years from land management agencies across North America (Lindenmayer and Likens, 2010; Biber 2011; Carter et al., 2017). Monitoring is a critical component of climate change adaptation, biodiversity conservation, and ecological restoration—key priorities for land managers in an era of rapid change (Moser and Eckstrom, 2010; Heller and Zavaleta, 2009;

Deluca et al., 2010). Effective multi-scale monitoring is an emerging science and practice, and there has been little investigation into governance strategies that can effectively promote it (Carter et al., 2017; Biber ,2013). In this article, we examine challenges and opportunities for improving knowledge management in the context of multi-scale monitoring in US national forest planning processes. Our objective is to expand our understanding of the governance institutions that support improved knowledge management, looking specifically at the legal and administrative variables that impede and promote improved knowledge generation and application in a hierarchical public bureaucracy.

3.2. Literature Review: Knowledge Management, Public Organizations, and Ecological Monitoring

3.2.1. Knowledge Management and Ecological Monitoring

Knowledge management refers to the "process of generating, storing and circulating new knowledge and identifying, bringing together and applying existing knowledge to achieve a specific objective" (Raymond et al., 2013). Knowledge is information that has been interpreted in light of context, experience, or theory and may be mobilized for action (in contrast to data, which are raw facts and numbers that have been processed or analyzed to produce information) (Tsoukas and Vladimirou, 2001). While scholars emphasize the importance of numerous types of knowledge for effective decision-making at different scales, our primary focus in this article is the generation of scientific knowledge produced through the application of the scientific method that may be used instrumentally to inform land management decision-making processes (see Raymond et al., 2010). Balancing human uses with conservation goals requires the generation and integration of scientific knowledge produced at multiple scales into multiple levels of decision-making (Cash and Moser, 2000; Folke et al., 2005).

Generating scientifically robust monitoring information that is functionally, spatially, and temporally matched for a specific decision-making venue requires four critical processes: design, data collection, data management, and analysis. Effective design sets the stage for all subsequent steps and involves identification of: goals, objectives and information needs; specific resources or ecological attributes to be targeted for monitoring; and data collection strategies (e.g. measurement protocols and sampling design) that can generate relevant information at appropriate scales with sufficient statistical power for reliably informing decision-making (Niemi and McDonald, 2004; Lindenmayer et al., 2010). Effective design requires significant expertise in ecological systems and statistical design, as well as knowledge of social values, administrative processes and budgetary constraints. Since no individual or single group holds all of this knowledge, prior research suggests collaborative processes and structured decision criteria that promote deliberation among scientists, managers, agency specialists, and public stakeholders are important for ensuring that monitoring information will be relevant, scientifically credible, and feasible to implement (Failing and Gregory, 2013; Tullouch et al., 2011). Once designed, data must be collected consistently over time and space, a particularly important consideration for long-term monitoring associated with slow ecosystem processes (Moir and Block, 2001; Lindenmayer et al., 2011).

Effective multi-scale knowledge management requires collaboration, boundary organizations, and the exploitation of scale-dependent comparative advantages that leverage technical capacity and functional specialization across different organizations and levels of governance (Cash and Moser, 2000). Social processes and intermediary actors, such as boundary organizations or knowledge brokers, link individuals with diverse types of expertise and knowledge and promote the co-production or exchange of knowledge for a specific decision-making venue (Phillipson et al., 2012; Fazey et al., 2012). While interorganizational data and information sharing may be facilitated by information technology, social networks and relationships are often essential for identifying information needs, navigating legal and proprietary issues, and coordinating data and information transfer, especially across scales (Dawes et al., 2009; Yang and Maxwell, 2011). Once data or information from different scales or sources has been acquired, it must often be analyzed or synthesized with other data to alleviate "mismatches" between the scale of monitoring and the scale of decision-making. This might involve aggregating information collected at fine scales, which often requires the use of consistent or compatible measurement protocols at smaller scales—an undertaking that requires coordination, particularly across jurisdictions—or the use of statistical models and decision support tools (see Veblen et al. 2014). By contrast, the interpretation of coarse resolution regional or broader-scale data at smaller scales of decision-making requires down-scaling or "disaggregating" data.

After analysis, information must often be effectively communicated to decision-makers and managers within institutional contexts and, again, often at different scales; this is particularly important if these individuals were not involved in data collection design, execution, or translation (Dilling et al., 2011). Once information from different scales has been generated or acquired, integration into decision-making requires effective synthesis and interpretation (Doremus, 2008). While timely documentation and written reporting is essential, formal interdisciplinary processes also are important for the interpretation and evaluation of information; decision-makers often prefer to acquire and evaluate information through qualitative discussions rather than quantitative reports (Moynihan, 2005; Brown and Brudney, 2003). Discussion and deliberation—ideally with stakeholders— may be particularly important for evaluating the relevance of information and the costs or risks associated with applying knowledge in practice (Gregory et al., 2006). Therefore, effective multiscale knowledge management involves a complex set of iterative processes that typically require coordination and collaboration among managers, scientists, and stakeholders across organizational boundaries and levels of governance.

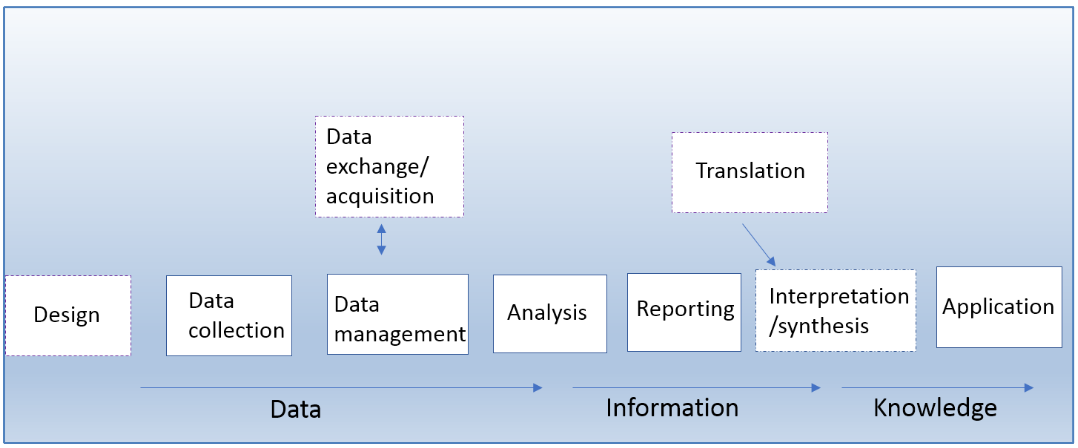

Figure 3.1. Multiscale Knowledge Management Processes. Boxes with dotted lines represent processes that entail significant social interaction, while boxes with solid lines represent technical processes.

Because of the diverse expertise required, along with the mismatches between the scales at which land managers operate and the scales at which data collection processes must be designed, coordinated, executed, and interpreted, it is important to capitalize on scale-specific comparative advantages (Cash and Moser, 2000).

3.2.2. Institutional Design and Knowledge Management

Knowledge management processes and capabilities are heavily influenced by the institutional context in which they are embedded (Contandrianopoulous et al., 2010; Fazey et al., 2012). Resource scarcity is often the primary impediment to the development of inter-organizational knowledge sharing activities (Dawes et al., 2009). The development of proactive knowledge management strategies, such as robust data collection and analysis procedures, are often dependent on the availability of "slack" organizational resources not dedicated to critical organizational tasks. When resources are scarce, organizations react to emergent issues and problems, focus on legal compliance, and emphasize core activities associated with future budgetary allocation (Berends et al., 2003; Brown and Brudney, 2003). Funding limitations also often create temporal inconsistencies in monitoring. Technological resource limitations, such as cumbersome databases, also constrain effective storage, transmission, and analysis (Lovett, 2007). Land management staff members often lack the scientific or technical expertise and training needed to design monitoring programs, develop or utilize databases, and analyze or translate monitoring information (Deluca et al., 2010; Hutto and Belote, 2014).

Laws and organizational structures also constrain flexibility needed for effective cross-scale knowledge management. Administrative laws that emphasize prediction and stability over learning and adaptation constrain the generation and application of knowledge in iterative decision-making processes (Benson and Garmestani, 2011; Ruhl, 2011). Centralized decision-making structures, budgetary structures, siloed departments, and highly formalized practices and procedures limit the flexibility of staff and units to develop new knowledge through experimentation, collaborate and share information across specialized departments and organizations, and integrate new knowledge into procedures and decision-making processes (Kim and Lee, 2006; O'Dell and Grayson, 1998). Within the context of forest management, for instance, laws and organizational incentives created barriers to adaptive management in the Pacific Northwest (Stankey et al., 2003). Program-focused budget lines have been found to affect coordination and collaboration between staff areas (Schultz et al., 2015). Organizational culture and staff expertise also can influence receptivity to new knowledge (Cheng et al., 2015). The temporal scales of budgetary, promotion, and decision-making cycles, which include annual appropriations and performance review cycles limit the incentives to build enduring monitoring efforts. In addition, there are few incentives to coordinate data collection across jurisdictional boundaries, even within the same organization (Cash et al. 2000; Biber 2011).

While the importance of collaboration and networks for realizing scale dependent comparative advantages for knowledge management is frequently acknowledged, effective collaboration and networking faces significant institutional constraints in the broader governance environment. For instance, collaboration with other government and non-governmental organizations on knowledge management initiatives often relies on individual initiative and its appeal is dependent on compatible capabilities, missions, and culture (Bardach, 1998; Dawes et al., 2009). Collaboration with academic researchers is often complicated by researchers' incentives to generate publishable research, which is often not the product of land management monitoring efforts (Dilling et al., 2009; Lemos et al., 2015). Collaboration with citizens and stakeholder organizations is limited by socioeconomic factors, limited social capital and trust, and the scales at which individuals have the interest or capacity at which to participate (Reed, 2008).

Considering the legal and institutional challenges, some argue that leveraging scale-dependent comparative advantages may depend on new enabling laws and policies, such as the reform of administrative law, the decentralization of decision-making authority, or the creation of functionally specialized boundary organizations or roles and responsibilities in specific organizations (Benson and Garmestani, 2013; Cash and Moser, 2000; Lockwood et al., 2010). Specialized monitoring agencies may help to alleviate scalar mismatches, but there may also be administrative strategies for improving knowledge management in individual organizations under existing authorities (Biber, 2011). One potential and underexplored opportunity for administrative policy change in public organizations is investment in functionally specialized positions focused on knowledge brokering. Knowledge brokers provide several critical functions for effective knowledge management, such as facilitating collaboration, building capacity, and linking and supplying knowledge and expertise to end users (Turnhout et al., 2013). For instance, Burgess and Currie (2013) highlight the importance of knowledge brokers at “middle manager” levels of public health organizations who are knowledgeable of both medical practice and management decision-making. They leverage this knowledge, and skills in networking, translation, and mediation, to facilitate knowledge management across levels of an organization and across organizations. Another critical point for attention is leadership—the most frequently cited enabler of administrative policies for effective organizational knowledge management (Moynihan, 2008; Rashman et al., 2009; Yang et al., 2011). Leadership is essential for allocating resources, developing organizational structures for knowledge management initiatives, promoting interorganizational knowledge sharing, and communicating the value of knowledge management for achieving organizational goals and objectives (Dawes et al., 2009). Formal requirements for data collection and reporting may be seen as nothing more than a burdensome requirement if their value is not demonstrated by leadership. As Moynihan and Landuyt (2009) note “the more leaders devote time, attention, and resources to make clear that information systems are central to important decision, the more likely it becomes that employees will use them too.” In the face of the many institutional challenges, strategies exist to improve knowledge management and application through collaboration, leadership, the support boundary organizations, and the creation of internal knowledge brokers.

3.2.3. Multi-scale monitoring and land management planning in the U.S. Forest Service

In public land management agencies monitoring has often failed to generate scientifically credible information about critical ecological processes at temporal or spatial scales appropriate to the variable of interest (Biber, 2011; Lindenmayer and Likens. 2010). In forest management, land management plans, which guide all subsequent project level action, are required under the National Forest Management Act of 1976 (NFMA), and must include monitoring plans to evaluate the effectiveness of plan components. The US Forest Service has struggled to implement consistent and credible monitoring and evaluation strategies that support adaptive and landscape scale ecosystem management (Biber, 2009; Nylen, 2011). In recognition of these challenges, the agency promulgated new regulations for Forest planning in 2012 designed to "inform integrated resource management and allow the Forest Service to adapt to changing conditions, including climate change, and improve management based on new information and monitoring" (36 CFR § 219.5 (a)). Under the new regulations, the Forest Service is required to monitor "key characteristics" of ecological integrity or attributes of ecological structure, function, process, and composition associated with ecosystem resilience and the persistence of biodiversity. There are also two complementary tiers of ecological monitoring in the new planning rule: monitoring plans on each national forest within the land management plan, and, in addition, "broader-scale monitoring programs" developed by each of the nine Forest Service Regions, the administrative level above national forests (Figure 3.2). Broader-scale monitoring is intended to generate efficiencies and complement forest plan monitoring; it is specifically meant to be applicable for resources that should be assessed consistently and at a scale greater than the individual national forest (36 CFR § 219.12 (b)). Broader-scale monitoring approaches may involve new monitoring initiatives, the translation of existing broader-scale datasets, or the aggregation of data collected by forests. The rule also calls on the agency to collaborate with "other Forest Service units, Federal, State or local government agencies, scientists, partners, and members of the public" (36 CFR § 219.12 (b)), to utilize "best available scientific information" (36 CFR § 219.3), and to ensure that monitoring results are integrated back into planning and decision-making cycles through biennial reporting cycles (36 CFR § 219). The Forest Service's focus on multi-scale monitoring is not unique; other agencies including the National Park Service, Bureau of Land Management, and Park Canada also have recently embraced similar approaches, making this an opportune time to look at multi-scale knowledge management barriers and opportunities in public land management organizations.

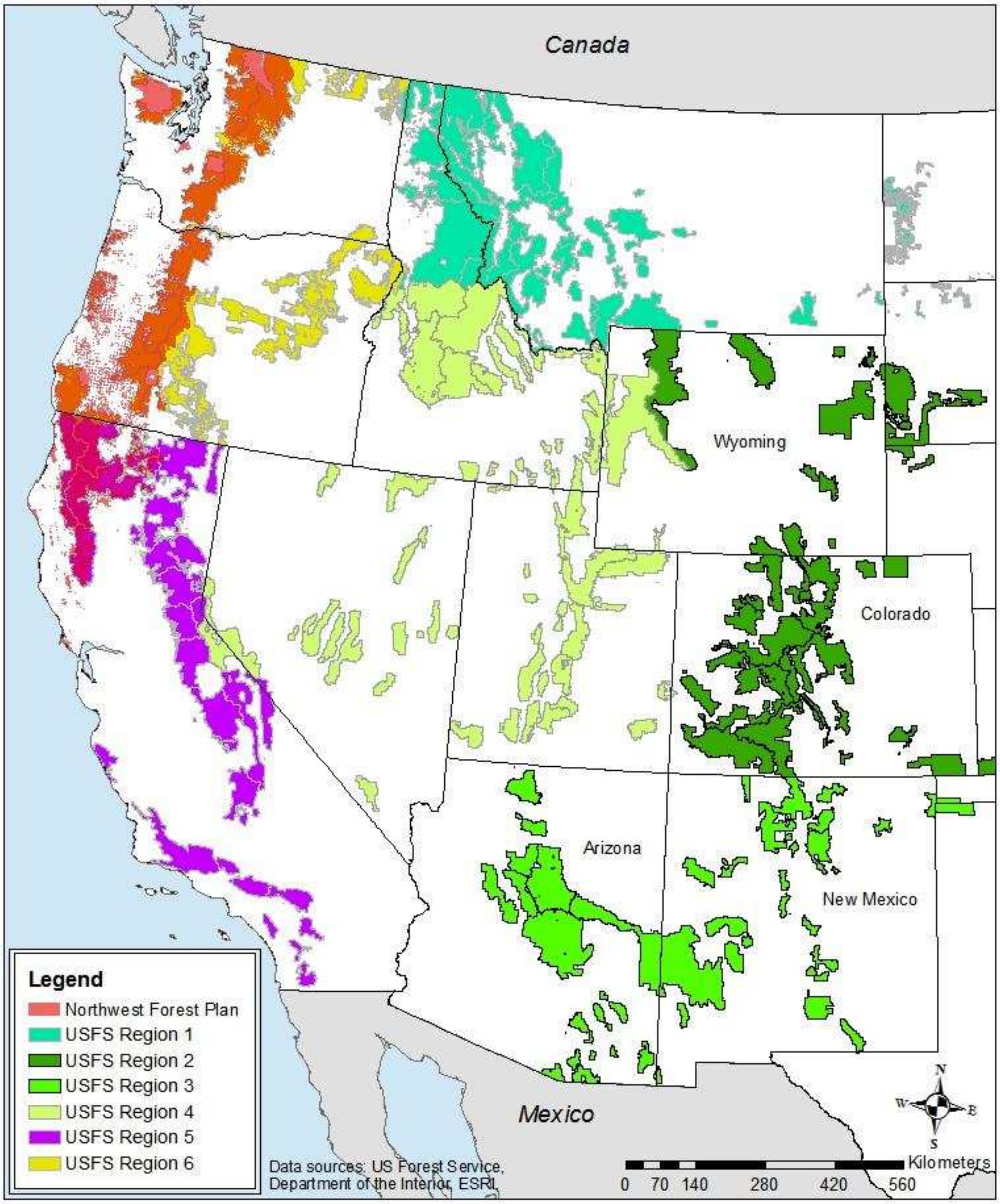

Figure 3.2. Map of USFS Region and administrative forest boundaries in the Western United States.

3.2.4 Summary and Research Questions

While scholars suggest that enabling policies, institutional diversity, and functional specialization in knowledge brokering are important for multi-scale knowledge management, opportunities for the development of specific administrative approaches in public organizations have been less explored in the literature. To address this gap, our research was structured around the following questions:

1. What are the knowledge management challenges for multi-scale ecological monitoring in a public organization?
2. What organizational and institutional mechanisms could improve knowledge management associated with multi-scale ecological monitoring?

3.3. Methods

This paper draws on a project funded by the Washington Office of the US Forest Service between August 2014 and December 2016 to collaboratively develop a strategy for the Rocky Mountain and Southwestern Regions of the Forest Service for meeting the broader-scale monitoring implementation requirements in the 2012 NFMA regulations. These regions were chosen because of their interest in participating in the project and adjacency, which allowed for the possibility that they might coordinate or share strategies and information in developing their broader-scale monitoring strategies (Figure 1). As part of this agreement, researchers at the SWERIs collected semi-structured interview data independently to inform subsequent stages of work (Creswell 2013). These interviews were the primary source of data for this paper. We conducted 95 interviews with staff from unit, regional, and national levels of the agency, as well as personnel with stakeholder organizations, state agencies, and other federal land management organizations. Interviewees were identified through a purposive, snowball sampling strategy that led to a network sampling of interview subjects (Carrington et al. 2005). We started with a list of key program leads and planners in the Regional offices in Regions 2 and 3, planning and monitoring specialists in the Washington Office of the Forest Service, and national and regional monitoring experts in other federal agencies. Through these interviews, we identified additional respondents from other relevant government and non-governmental organizations, and planners, program specialists, and line officers at the National Forest level who could provide greater insight on challenges and successes in Regions 2 and 3. We also asked respondents to identify examples of successful agency monitoring initiatives in other regions, and we interviewed respondents who were familiar with those initiatives (Table 3.1).

Table 3.1. Interviewee groups and sample questions

General Group of Interviewees	**Number of interviewees**	**Sample questions asked of different interviewee groups**
External interviewees: Total	46	*What are your thoughts, perceptions, or experience with forest and broader-scale monitoring in the US Forest Service?* *In your mind, are there obvious impediments to forest or broader-scale monitoring? Are there things we would have to change about agency structure, culture, or funding to make implementation successful?* *When you think of broader-scale versus forest-level monitoring, what are the differences in what these would focus on?* *How could broader-scale monitoring inform forest plans and their ongoing implementation? approach?*
NGOs	13	
Other Federal Land Management or Regulatory Agencies	20	
State Agencies	9	
Academic Partners	4	
Forest Service: Total	47	*In your mind are there obvious impediments to forest and broader-scale monitoring? Are there things we would have to change about agency structure, culture, or funding to make this successful?* *How is monitoring information currently stored and shared? How useful are existing corporate databases for storing or accessing monitoring information? Are they being utilized? What could be improved?* *Do you currently have the capacity to effectively analyze monitoring information and use it in planning? At the forest level? At the regional level? If not, what additional resources are needed?* *Do you partner with Forest Service staff outside your forest or external organizations in monitoring? What kind of monitoring efforts are they involved with or interested in?*
National staff	5	
Regional Staff	17	
Forest Staff	22	
Research Staff	5	
Totals	95	

We also used the information we gained from these interviews to design four inter-agency workshops in Arizona, New Mexico, Colorado and Wyoming that we hosted in partnership with the agency; these in total involved participants from over 20 federal, state, and non-governmental agencies (for more details on workshop design, see Waltz et al. 2016). At the workshops, we documented key barriers, issues, and strategies for success that emerged in group discussions. Interviews and notes from participant observation were recorded, transcribed, and analyzed using an iterative and inductive approach involving coding for themes (Strauss and Corbin, 2008). While our background in science-policy studies, ecological monitoring, and public administration helped to identify initial themes, we identified additional themes that emerged from our data. We used the qualitative data analysis software RQDA to code themes associated with monitoring challenges and opportunities that emerged from our data. We coded several transcriptions together to ensure inter-coder reliability, and frequently discussed our perceptions of relevant findings (Charmaz, 2006). In addition to examining excerpts by code, we also iteratively grouped and modified our codings over time and returned to the literature to make sense of our data.

3.4. Results

3.4.1. Knowledge management challenges

We found that challenges for knowledge management processes were associated with resources, organizational structure and culture, leadership and commitment, and linkages to forest planning.

Table 3.2. Knowledge management challenges

Resources/capacity
I think that there's a physical capacity issue, as far as people available to collect the data, and actually going backwards, a lack of capacity to effectively design good data collection, and then to collect and analyze the data and actually use it. *Forest wildlife program manager, Region 2*
So what happens is when you're putting a forest level monitoring plan together, a lot of our resources are so underfunded for the program that those resource specialists see that as an opportunity to leverage funding. That's why you see a lot of the monitoring items... If they get it into the forest plan, they think they've got a toe hold for funding. *Regional planning staff, Region 2*
We just don't have the capability to do that level of monitoring and we don't have the cooperators or the collaborators to join us in that effort the way that the GMUG [National Forest] does. *Forest planner, Region 2*
The thing about the [USFS] research station is they have no money. If people are going to work on this, the [National Forest System] has to provide resources. *Regional Resource Specialist, Region 3*
Organizational structure and culture
We've got this really detailed Willow browse monitoring that he's been doing and I don't think it fits into any of our corporate databases. He's got, I don't know what he's got, spreadsheets or Word documents, and what, tracking it for a long time but we haven't and I don't think we've got a way to incorporate when he leaves. *Forest Planner, Region 2*
I think that's one of the things that we struggled with here with our budget process. Once money goes out to our Forests, it can be a little bit hit-and-miss on how it gets used compared to how we think it should be used. That's just the reality of the responsible official's jurisdiction and authority and everything else. *Regional planning staff, Region 2*
We attempted to put a protocol together that was region-wide so that we'd have some consistency in data, so we'd have the same protocols across all the forests and something that we could pull up. Getting the forest to adhere to that is really difficult. *Regional resource specialist, Region 3*
The way the work in the Forest Service is there's a lot of personal latitude in terms of what people are able to say no to, whereas in a lot of other agencies, if you're told to do something, you follow that mandate and that's an agency wide mandate, not just a, "Oh, I think you guys should do this," and I think that's how they take it. I think that can be a real issue going up and down the chain. *External partner, Region 3*
Leadership and commitment
I would say that the Forest Service is way behind other agencies in terms of having a vision and following through on ecological monitoring. I know that the desire is there, but whereas the National Park Service and Fish and Wildlife Service and U.S. Geo have national networks in place, the Forest Service has really lagged and I think is not demonstrating much leadership in its ability to conduct ecological monitoring or to create or participate in the monitoring networks that are out there. *Forest planner, Region 2*
Every year there's a little bit of a call for projects that we feel like need to be regional-based and take that money off of there, but for the most part, what ends up being prioritized is implementation-based projects instead of anything that is either planning or monitoring-based. *Regional resource specialist, Region 3*
You've got regional foresters that make decisions, but are they trying to get everybody from below to buy in and drop some of their pet things and think about what is important across the larger scale? When you're a district biologist or hydrologist, you're probably thinking a lot about your specific needs and what you have on the forest. *Non-governmental Partner, Region 3*

Linkages to decision-making and forest planning
I think we're used to being chained to the Forest Plan. We don't view it as a living document, so once it rolls out on the street and it's off the presses, it's sort of written in stone and we don't view ourselves, through our monitoring or anything else, having the ability to modify it. *Forest Line officer, Region 2*
Part of monitoring is to figure out really if something's working or not, or there's some kind of a need for a standard and guide. Sometimes you find that you don't even need a standard, but we'll keep it anyway because it's easier to do so, rather than go through the documentation of change. *Forest Resource Specialist, Region 2*

Each of these structural challenges have implications for specific knowledge management processes. Limited capacity was cited by almost all respondents as a critical impediment to design. Respondents noted that staff often lack the funding, expertise, and social relationships needed to design integrated land management plan monitoring strategies on their own or in collaboration with partner organizations. This was especially true for remote and poorly funded forests that are limited in human and financial capacity and often lack strong local constituencies for monitoring or local partner organizations with whom they can effectively collaborate. In addition, respondents from across the agency emphasized challenges posed by lack of formalization. They noted that forest-wide monitoring plans are often developed at the end of the planning process, with minimal evaluation or documentation of: cost, roles and responsibilities for implementation; monitoring data's potential relevance to forest plan decision-making; or scientific credibility and accuracy. As one Forest planner noted: "with our old forest plan we had this giant monitoring plan, but I couldn't tell you half of what was in it, where the data was going, who was tracking it, or how it was being used".

In addition to poor design, respondents also cited several challenges for consistent data collection. A consistent theme from both agency and external respondents was that consistent data collection is often complicated by human and financial resource limitations, and limited support from line-officers. While there is a dedicated budget line item for landscape level forest plan level monitoring, forest staff have discretion for how it will be spent, and agency respondents noted that it is often used to support non-monitoring related initiatives. According to a Regional planning employee, “once money goes out to our Forests, it can be a little bit hit-and-miss on how it gets used compared to how we think it should be used. That's just the reality of the responsible official's jurisdiction and authority and everything else.” Several respondents from Forest and Regional levels of the agency indicated that budgetary allocation for implementation is often determined per the short-term priorities of leadership or through contentious interdepartmental politics involving different program staff—an issue that complicates continuity for monitoring over time. Pressure to meet performance targets associated with management outputs, and the cost of complying with legal procedural requirements associated with NEPA, were also commonly cited as factors that significantly reduce funds for collecting monitoring data. As one forest line officer noted:

> I think what I've noticed about our structure on our Forest and the way we're funded and how our managers are rated and graded and what's important to them… we don't really at the Forest level have a lot of incentives. I mean monitoring ain't like an output, like having a clean camp grounds or putting out fires or offering a timber sale or administering a grazing permit.

Even when data is collected consistently at the Forest level, challenges for generating useable information remain. Respondents noted that cumbersome information technology infrastructure is a critical barrier for effective storage and analysis. While databases associated with forest vegetation and performance measurement are used relatively consistently, databases associated with other resources and program areas lack accessibility and flexibility for many locally unique monitoring strategies. Agency respondents consistently said it is relatively easy to enter data into agency databases, but difficult to get data out, or use them for analysis. In addition, staff said they often lack the time, resources, and expertise in statistics or database management needed to effectively perform these tasks. Integrating data from different resources or program areas is also complicated by the “siloed” nature of program or resource specific databases, according to many respondents. The consistent utilization of agency databases also varies with unit level funding, and the interest and capacity of individual specialists, with some saying they simply store data on paper or personal hard-drives. According to one Regional program manager, “there's a lot of data that's in file cabinets. It's in Excel spreadsheets, it's in someone's maybe Access database. Getting those out of those formats and into the format of our national database is a real challenge”. Data and information exchange across forests and with other organizations is also limited by capacity. Almost all forest staff noted that the demands of day-to-day management implementation limited their ability to acquire, evaluate, or exchange data and information produced by other organizations. Indeed, many staff noted that they were unaware of the existence of innovative and robust monitoring strategies developed on other forests, or monitoring guidance and resources developed at National levels of the organization.

Specifically for regional, broader-scale monitoring programs, major challenges lie with tensions between Forest and Regional level goals and incentives. For instance, while the new planning rule directs Regions to develop broader-scale approaches, there is no additional provision of funding to support implementation. Forest-level respondents voiced concerns about Regionally funded strategies that might reduce already scarce resources for monitoring at forest levels, yet provide little relevant information, as management priorities, funding, and ecological conditions often vary significantly across many units, such as northern and southern forests in Region 2. Respondents from external organizations and staff from across all levels of the agency noted also that the agency’s culture of autonomy and local decision-making are a significant implementation barrier to Regionally coordinated or centralized strategies. Referencing these challenges, a respondent from the Washington Office said that:

> Because we place such a strong cultural value on that decentralized model, that local decision making, those things that really should be centralized, such as data bases and those sorts of things, we don't value, put the resources towards, or individual support locally towards making those systems more effective.

Indeed, a few agency and external respondents noted that directives and guidance from higher levels are often ignored by unit level staff. For instance, Regional respondents from Region 3 noted that when they attempted to create consistent forest vegetation measurement protocols, Forest staff simply modified them to save money and meet basic assessment needs for specific projects. Without Regional coordination, unit-level discretion for monitoring implementation means that there is significant variation in measurement protocols, sample designs, and database management strategies for common and cross boundary resources across forests—a consideration that complicates the development of strategies that would “aggregate” and analyze forest level data.

Limited capacity and database management challenges at Regional levels also pose barriers to the identification, exchange, analysis, and communication of existing data and information; issues that that may particularly hamper broader-scale efforts. In Region 2, persistent vacancies in vegetation analysis positions have meant there is little to no use of data and information generated by US Forest Service Research’s Forest Inventory and Analysis (FIA) program, a robust national inventory and monitoring program that collects detailed long-term monitoring data on forest resource conditions across the entire United States. While the relatively low intensity of plots mean that FIA data is not relevant for management scale decision-making, respondents from FIA noted that it is the agency’s best source of information for many landscape level trends and conditions relevant to forest planning. Many agency and external respondents also noted that sharing information with high capacity NGOs and other state and federal organizations is complicated by scarce resources, and the fragmented nature of agency data. As one external partner observed:

> If you really want to incorporate other people's data and other people incorporate yours, that's going to be at that huge transition for the agency…That's something that the agency has to think about because scientists or analysts maybe could give them back a useful product if there is a way that they could actually work with that data a little more freely.

Challenges associated with the generation, exchange, analysis, and translation of both internal and externally sourced monitoring information are particularly evident in forest monitoring reports—the "output" of forest plan monitoring implementation. Forest monitoring reports are essentially narrative "accomplishment reports" compiled by individual program staff that detail management outputs associated with budgetary targets, with little to no evaluation or interpretation of ecological trends and conditions. According to a Forest planner:
"the old [monitoring report] was just a lot of bean counting. It was accomplishments, but not necessarily tied to objectives or the work on the ground that needs to be done…It wasn't really setup in a way to inform any type of adaptive management." Forest and Regional respondents noted that resource limitations and the quotidian demands of project implementation and analysis are significant barriers to effective analysis and interpretation, and even if there was sufficient monitoring information and capacity for analysis and interpretation, there would be challenges with using information to make adaptive changes. Most forest plans are over 10 years old, and plan components are often written in such a way that it is difficult to know what the threshold for change may be—a product of the temporal mismatch between plan development and monitoring design. Monitoring plans are also often viewed as being "written in stone", and viewed as "operating licenses" rather than tools for adaptive decision-making, and the cost of complying

with legal process requirements for plan amendment reduces incentives to use monitoring information to change them over time.

3.4.2 Knowledge management opportunities and examples of success

Despite noted challenges, workshop participants and respondents also highlighted several opportunities and examples of successful forest and regional monitoring implementation. Opportunities and successes were associated with collaboration and partnerships, and investment in formalized processes and staff dedicated to knowledge management at different levels of administration—strategies that provide advantages and benefits such as efficiency and consistency for implementation and crossboundary coordination.

Table 3.3 Knowledge management opportunities

Collaboration and partnerships
I feel like having partners is always key for them from the beginning... it's really key to have what you're doing set out up front in a way that will actually get you where you want to go... having partners that can add that capacity and facilitate a little bit more of maybe that knowledge from a research or academic setting to actually kind of get the ball rolling in the right direction. *External partner, Region 3*
You know what helps us with that group is [having] the Game and the Fish folks, State Forestry people, DEQ people there... to help some of the other steering committee members make sense out of all the technical details. *Forest Planning employee, Bighorn National Forest*
Usually we can build agreements for up to five years so we can kind of allocate that money for that time-frame... so we can look to NAU and Highlands University in New Mexico, to have agreements with them to have crews... to go through and do some monitoring in predefined areas and that kind of thing. What that allows us to do is use these monies that tend to show up at the end of the fiscal year and need to be used quickly or allocated quickly so an agreement would then be an instrument for us to put that money into and do that with. *Regional Resource Specialist, Region 3*
I think our carnivore monitoring project is a good example of a successful project of landscape scale monitoring using multiple partners.... It has given us a data set that really was not available before on these key wildlife species that are so important to management and that frankly, we get a lot of our projects appealed or litigated on. It's been huge for us to be able to have that data set. The fact that it was collected not just by the forest service but by partners as well, I think, gives it that extra credence with the public. I think that's a really good example. It's being expanded every year to different forests. *Academic Research partner, Region 1*
We have a regional inter-agency executive committee that has executives from the Forest Service, from the BLM, the EPA, from NOAA, from US fish and wildlife service, from USGS that all coordinate together. It's all of us coming together to kind of help us move forward. So, one other thing that I would recommend with the communication is to engage multiple different agencies and possibly come up with committees that could be done regionally that help facilitate some of these decisions. *Northwest Forest Plan Regional Ecosystem Office employee*

Investment in knowledge brokering positions
You really need a regional monitoring team. You can't just be done by some part-time folks who's part of their job's in this forest and they get to go once a year. You need somebody that can look across and say, "Okay, here's the common measurement. Here are the protocols that we really need. Here's the most important questions we got. We need consistent protocols for those." *Northwest Forest Plan Monitoring program employee*
"I know when I was in Oregon, there was a liaison that worked for the Forest Service and she did a lot more liaison with partners but she was a really great connection between the Forest Service management side and all the partners that could do research... She said, "This is a need from the district. They have this data set. Can you help as an academic institution? See what value is in this data set and if you can answer some of the questions." She was able to go out and look for those connections " *External partner, Region 3*
It really needs to be a centralized focus of management from the very top down, and it really needs to have people strongly and solely dedicated to it as needed to make it work, and I guess that's the bottom line. *Forest Wildlife Program Lead, Region 2*
Scale dependent benefits and advantages
I think that capacity actually goes up as you move into regional offices. They have more sophisticated ecological evaluation teams... I know in Region 1, for example, [they are] partnering with University of Washington and other academic institutions and really bringing in some heavy hitters in terms of intellectual capacity to operate at that regional scale. I think that capacity actually goes up as you go to the regional office because they have those relationships. *External partner, non-profit*
Now with the forest service, the most applicable experience that I have right now involves our region-wide Mexican Spotted Owl monitoring program. Given the challenges of coordinating among different administrative levels and among administrative units at the same level, a decision was made prior to my arrival that this would be handled as a regional project, one, and two, we would solicit outside help. We've been doing this in partnership with the Rocky Mountain Bird Observatory through a participating agreement. *Regional Resource specialist, Region 3*
I'm seeing now that the Northwest Forest Plan as a regional strategy provides a vehicle for speeding up plan revision because it provides a broad framework that maybe applies to many of the forest and then the individual forest can do their plans, can add some variation to the plans and a lot of what's being learned from the monitoring will feed into that. *Research Scientist, US Forest Service Pacific Northwest Research Station*
"I think that's one area [broad-scale monitoring] where we talk about getting the most out of our investments and efficiencies... this is an area where some kind of a top-down approach from a sampling perspective, whatever it may be, is going to help us achieve efficiencies and better serve the public. Straight up. I couldn't say that strongly enough." *Regional Program Lead, Region 2*
Right now I know that there's wolverine monitoring going on in three different units in three different ways and they're spending the IM money for that and they're spending some other dollars for that too. What we'll do is say, you know what? We're going to pull back that money. You guys don't need to do your wolverine monitoring anymore unless you're so special and so different let's make the case for it. We've got that covered. We're going to develop a program here in the regional office for that. *Regional planning employee, Region 1*
So from my perspective, I'm not sure that we need broad scale monitoring, because we need a certain set of information. What I'm looking at is broad scale monitoring can hopefully make our monitoring process more efficient... collectively, we will also improve on the performance across all forests, because we're collecting a set of data that's consistent and can be used by all the forests. *Regional Planning employee, Region 3*
At the Regional office, they've been taking money off the top for our bird monitoring, and that's very very helpful at the forest level, because I don't have to have that battle [for funding] every year on my forest. I know we're covered, and taking it off the top I know we get great value for our money. If it comes back down to the forest, it's going to be a different battle on every forest. *Forest Wildlife Program Lead, Region 2*

Successful monitoring program interviewees discussed strategies they have used that could be replicated elsewhere. Respondents from the Northwest Forest Plan (NWFP) monitoring program highlighted the importance of specialized field crews, and dedicated positions for program coordination, database management, analysis and communication for efficiency and consistency for monitoring and reporting over time—a structure National Park Service staff noted was a model for their national program. A respondent from the NWFP monitoring program also emphasized the importance of collaborative funding, and "service first" interagency staffing structures: "Having it multi-funded, that means both agencies are committed because they're providing money, and they're also providing people, and so we're coordinating and collaborating together with this information. I think that's one of the biggest successes". Other respondents highlighted the example of Region 1's vegetation analysis program. Over the past 15 years, Region 1 vegetation analysts have developed information technology and analytical tools that integrate forest and non-forest vegetation data from local units, the FIA program, and remote sensing products. These tools allow Regional staff to provide tailored information to forest level end-users at multiple scales. Respondents noted that Regional leadership's decision to invest in capacity for information management was driven by litigation associated with standards for old growth, and the Region's inability to demonstrate compliance due to insufficient data. However, leadership subsequently recognized the benefits of initial staff positions, making additional staff investments over time. They also recently developed a Regional policy that requires Forests to evaluate and document the cost of forest plan monitoring strategies so they can be held accountable for the allocation of the dedicated inventory and monitoring budget line. In Region 3, Regionally consistent plan components for ecologically similar forests have created consistencies and efficiencies for plan development and can be used to link broader-scale monitoring information to forest plan evaluation processes. Many of these strategies lead to efficiencies, according to interviews, but require leadership to take an interest in monitoring, invest in initial positions with enough time and capacity to create a visible effect, and to exert some authority to require or incentivize units to participate in regionally led efforts.

Partnerships also were identified as essential to developing successful forest plan monitoring strategies. For instance, in developing a new monitoring plan as part of the plan revision process, the Kaibab National Forest undertook significant internal interdisciplinary deliberation and worked with one of the Southwest Ecological Restoration Institutes (SWERI) to facilitate collaboration with stakeholders and scientists. Similarly, the development of Forest plan monitoring strategies on Wyoming's Bighorn National Forest was facilitated by a state mandated collaborative Forest plan steering committee composed of state and county officials, and representatives from state resource management agencies. On both forests, respondents noted the value of collaborative and deliberative processes to augment capacity, improve communication, and ensure that monitoring was scientifically credible, feasible to implement, and relevant to management—with the additional benefit of improved social relationships and stakeholder investment in monitoring. Regarding collaborative processes on the Kaibab National Forest, one forest specialist noted that "it was focused a little more around the trust issues with stakeholders. What were their greatest concerns about the work that was being proposed… what is it that they're most concerned about that we need to monitor."

At Regional scales, formal collaborative structures and processes have also been important for the development of broader-scale monitoring strategies. Respondents from the NWFP monitoring program highlighted the importance of organizational structures and processes for promoting effective design, including iterative deliberation among a steering committee made up of interagency line officers from participating land management organizations, a US Forest Service management committee composed of line-officers, and a technical committee composed of interagency specialists, and agency and external scientists. Similarly within Region 1, broader-scale monitoring strategies identified by a technical steering committee in collaboration with external partners and scientists are sent to an executive committee composed of Regional and forest line-officers. If approved, they are piloted on one forest to assess relevance and feasibility before they are implemented on others. Respondents from Regions 2 and 3 also highlighted the importance of leveraging the capabilities of partner organizations for data collection, data management, analysis, and communication to augment agency capacity and overcome persistent challenges. According to a Regional program manager:

> We simply do not have the capacity, whether it's capacity in getting people on board, technical capacity of the people who are on board, or the time of people once they are here to actually do the work. I think there is real need to rely on partner networks in a manner that far exceeds what we can do independently.

Multi-year agreements for partner monitoring funded "off the top" of the inventory and monitoring budget line at Regional levels allow the agency to ensure consistent implementation over multiple fiscal years and multiple jurisdictions. State wildlife management and natural heritage organizations, university partners, and non-partisan NGOs with significant scientific expertise and capacity were cited as the most important partners in this regard.

Leveraging partner capabilities, and managing and coordinating internal knowledge management capabilities and processes, works only where there has been investment in organizational positions dedicated to monitoring and knowledge management. Both agency and external respondents and workshop participants noted that identifying partner capabilities, coordinating agreements and partner activities, and coordinating internal capabilities for knowledge management requires significant time and expertise. While Regions and Forests often have dedicated monitoring coordinators, these roles are often just another "duty as assigned" to staff with existing responsibilities, such as planners or resource specialists, which complicate their ability to effectively coordinate and provide oversight for monitoring implementation. A consistent theme from respondents was that capacity for knowledge brokering will be particularly important to develop at Regional levels to realize the potential benefit of a "broader-scale" monitoring strategy, which could provide units with information that they do not have the capacity to generate on their own. In the words of a respondent from the Northwest Forest plan monitoring program, "you really need a regional monitoring team. It can't just be done by some part-time folks who's part of their job's in this forest and they get to go once a year."

3.5. Discussion

3.5.1. Institutional Challenges

We saw institutional challenges related to limited resources, that then interacted with organizational structures and incentives to lead to sub-optimal outcomes. When resources are scarce, organizations are often "reactive", forced to focus on core tasks associated with emergent short-term issues, compliance with legal mandates, and future budgetary allocation (Berends et al., 2003). We found that, at forest levels of administration, scarce financial resources and limited available staff time meant that monitoring data was not often collected unless it is linked to regulatory requirements; the majority of staff time was spent elsewhere, and this typically involves complying with legal process requirements for project planning or administering contracts and implementing management actions (Biber, 2009). Limited human and financial capacity, and problematic information technology also create barriers to the design and implementation of "broader-scale" monitoring strategies that involve the development of new regionally coordinated monitoring strategies or the translation of existing monitoring information produced by the agency or partners. In Region 2, for instance, vacancies in vegetation management positions at Regional levels mean there has been little to no use of FIA monitoring data.

Scarce resources also interact with organizational structures. While knowledge management scholars often emphasize the importance of decision-making flexibility for knowledge management (Pee and Kankanhalli, 2016; Moynihan and Landuyt, 2009), in our findings, flexibility was problematic. Limited formalization, unit-level discretion for budgetary allocation, and programmatic discretion for the implementation of specific monitoring strategies, all examples of flexibility, complicate continuity and integration over time at the unit level, particularly when there is staff turnover. They also create barriers and coordination challenges for the development of broader-scale strategies that would involve the aggregation of existing unit-level data or the adoption of consistent measurement protocols. Therefore, while some flexibility may be needed to innovate and adapt over time, in a multilevel bureaucracy, this needs to be coupled with a high-degree of coordination, accountability, and formalization for knowledge management.

There are also exogenous challenges for both Forest and broader-scale monitoring. Scholars note that external organizational resource capacity, and social capital and trust, are critical contextual factors for knowledge management (Dawes et al. 2009; Fazey et al. 2012; Young et al. 2016). On many Forests, particularly more remote and less well funded Forests, there are often few local NGOs with complementary knowledge management capabilities, and limited constituencies for ecological monitoring and evaluation. This is a critical variable, as line officers are often highly sensitive to local interests and constituencies (Sabatier et al., 1995). Without stakeholders interested in monitoring, it is unlikely to occur given incentives for management outputs.

Overcoming these challenges will be critical to addressing functional, spatial, and temporal mismatches across scales of decision-making. At present, local monitoring often focuses on indicators of ecological health that lack credibility and relevance, such as management outputs, and is designed at project scales, associated with short term legal obligations, or discontinued when there is turnover (Biber, 2009). Interviewees noted that implementation and analysis is highly variable across Forests and information is fragmented, limiting opportunities for the exchange and aggregation of data. At Regional levels, decentralized decision-making, limited capacity, and the agency's culture of local autonomy create barriers to the development of broader-scale monitoring strategies that can match the scale of monitoring to relevant resources.

3.5.2 Institutional Opportunities

Despite considerable challenges, our findings indicate that there are significant opportunities for improving multiscale knowledge management in the US Forest Service. A primary opportunity lies with collaborative knowledge management partnerships. Cash and Moser (2000) emphasize the importance of leveraging the "scale dependent comparative advantages" and functional specialization of different institutional actors to mitigate scalar mismatches between assessment and decision-making. Partnerships allow the agency to leverage information and capabilities they lack, and exploit economies of scale for knowledge management. For example, the Bird Conservancy of the Rockies uses sophisticated multiscale "master" sample frames, consistent measurement protocols, and centralized analytical capacity to generate economies of scale for data collection, data management, and analysis that can be efficiently exploited by the US Forest Service. In our findings, science-focused and non-partisan NGOs, state and federal resource management agencies, and policy-focused research institutes were highlighted as the most important partners because they often have staff with relevant and specialized scientific expertise, capabilities for multiple knowledge management processes, and compatible organizational goals and priorities.

Cash and Moser (2000) also emphasize the importance of functional specialization of key personnel to support multiscale knowledge management. Our findings suggest that investing in organizational structures dedicated to “knowledge brokering” represents an important opportunity and enabling policy in this respect. Internal to agencies, there are scale-dependent comparative advantages for specific roles and responsibilities at different levels of administration; regional knowledge brokers may be most critical to put into place, but there also would be advantages of creating positions dedicated to knowledge management at the local level. While boundary organizations and external knowledge brokers may perform essential functions, there are benefits to having internal knowledge brokers, as agency staff are more familiar with specific end-user information needs and decision-making contexts, and internally produced information is often more trusted than externally produced information in many organizational contexts (Bolson and Broad, 2013). At local scales, for instance, our findings indicate that a single full-time position dedicated to knowledge brokering and monitoring at unit levels has important benefits for collaboration and coordination. Regional knowledge brokers can generate efficiencies by leveraging external resources, and exploiting economies of scale for data collection, data management, and analysis. While investment in the US Forest Service context may be difficult under current budgetary and staffing limitations, there are benefits for efficiency and effectiveness that may make iterative investment in organizational knowledge management capacity feasible

Our findings, when viewed in light of the scholarship, indicate there may be significant opportunities for leveraging scale-dependent comparative advantages of dedicated administrative knowledge brokers at Regional levels of the US Forest Service. One important function at "middle management" levels is steering and project management (Turnhout et al. 2013). This includes participating in networks, identifying internal and external capabilities for knowledge management processes, coordinating partnerships, developing policy frameworks and guidance for staff, and promoting interdisciplinary and interdepartmental integration. Budgeting and oversight is another steering or project management function. While some degree of budgetary discretion and flexibility for monitoring implementation is certainly important for addressing locally unique and management relevant issues at unit levels, Regionally funded monitoring strategies allow the agency to match the scale of monitoring to the scale of resources, mitigate temporal mismatches associated with annual budgetary cycles, and create efficiencies for data collection, partnership coordination, and analysis. Regional budgetary and oversight authority also provide an opportunity to promote accountability for the use of the dedicated inventory and monitoring line item at unit levels, by ensuring funds are appropriately allocated to monitoring initiatives—an important consideration due to strong incentives for management outputs. In addition, Regional staff's separation from management decision-making, and the mismatch between Regional jurisdictions and state boundaries mean that, as one respondent noted, "Regions don't have constituencies"—a consideration that may provide political cover for the implementation of Regionally coordinated strategies and accountability for forest level monitoring implementation. Networking and coordination with external partners is also often more effective and efficient at Regional levels, due to the transaction costs associated with coordination across individual forests, and Regional staff's ability to leverage expertise across larger networks of external institutional actors.

In addition to project management, investment in functionally specialized knowledge brokering positions is also important for more technical and disciplinary knowledge management processes. Staff with expertise in statistics, ecology, and information technology are important for "capacity building" functions, such as training and technical assistance for monitoring design, data collection, database management, and analysis. This is a particularly important consideration, as these processes represent critical chokepoints for knowledge management at forest levels. Regional technical capacity is also particularly important for "supplying" functions, such as the translation of external information for end users on forests. Again, while boundary organizations may have capacity for translation, investment in internal capacity at Regional levels has benefits for both efficiency and effectiveness. For instance, it is far easier for forest staff in Region 1 to acquire tailored information derived from the Forest Inventory and Analysis program through the Regional Office than it is for each forest to coordinate individually with FIA for specific information needs.

While investment in these positions is likely difficult to make under current funding and staffing limitations, we suggest that there are opportunities for incremental investments, though leadership will be needed to initiate and support them. Regions 8 and 9, for instance, have recently invested in a shared full-time FIA and vegetation analyst. The benefits of initial investment in vegetation analysts in Region 1 has also promoted increased investment in Regional capacity for knowledge brokering over time. However, where it is not mandated, our research suggests it is often the cost or potential cost of litigation that spur leadership to invest in knowledge management initiatives. This suggests there are opportunities for administrative staff to build buy in for knowledge management through the development of proposals that demonstrate benefits for efficiency and effectiveness in meeting regulatory requirements for land management planning.

These considerations highlight the importance of and opportunities for the development of internal policies and processes for effective multiscale knowledge management. Tiered and multiscale formalized processes that link monitoring implementation to forest plan decision-making may generate benefits for effectiveness and efficiency. At Regional levels our findings highlight the importance of structured processes that mediate and integrate the different interests and knowledge of administrative staff and external experts. At this level, there are also scale dependent comparative advantages for leveraging the expertise of external institutional actors. At forest levels, formal policies and guidance that emphasize the co-production of Forest plan components and monitoring plans with stakeholders, promote interdisciplinary evaluation of monitoring plans, and transparent documentation of cost, scientific rigor, and roles and responsibilities for implementation may help to ensure monitoring will be relevant to decision-making, cost-effective to implement, and resilient to changes in staffing. At this scale, monitoring and plan development can draw on staff's experiential knowledge to focus on local or sub-regional issues not covered by broader-scale monitoring programs (Raymond et al., 2010). There are also scale dependent advantages for collaboration with local stakeholders at this level, as it is the scale at which citizens often have the greatest interest and capacity to participate (Fraser et al., 2006). We suggest these structural and procedural considerations represent an important path forward for improving monitoring approaches within the agency, capitalizing on partnerships, and effectively utilizing the advantages that rest at different levels of the organization, even in light of flat budgets.

3.5.3. Implications for Future Research on Environmental Knowledge Management and Adaptive Governance

Scholarship on environmental knowledge management often distinguishes between different types of actors, such as knowledge producers, intermediaries, and knowledge users (Nguyen et al. 2016). However, the lines between knowledge users, producers, and intermediaries are heavily blurred in the context of multiscale monitoring. Characterizing agency staff primarily as “users” or “managers” is problematic given the different interests and skills of diverse organizational staff at and across levels of administration (see Brown 2010). Distinctions between knowledge users, producers, and intermediaries are also complicated by the complexity of multiscale knowledge management processes. Forest Service staff may collect data using a protocol designed by a boundary organization, which is then analyzed by external experts or Regional specialists, and then later interpreted by forest staff. The boundaries between administrative knowledge and scientific knowledge are also blurred, as monitoring data collected by agency staff may be used in some contexts for formal scientific research (Hutto and Belote 2014). Rather than classifying different actors as users, producers, or intermediaries, we suggest it may be more useful to evaluate the specific capabilities of different actors for complementary knowledge management processes along the knowledge-to-action linkage and utilize a more context-dependent assessment of individuals’ roles, needs, and potential contributions. This again necessitates skillful knowledge brokers and communication strategies to support effective outcomes.

Scholarship on knowledge management emphasizes the importance of understanding the influence of institutional variables and structures on knowledge management processes (Contandrianopolous et al., 2010; Fazey et al., 2014; Nguyen et al., 2016). Administrative law and bureaucratic governance structures are often thought to limit flexibility needed for experimentation, collaboration, and coproduction among scientists, managers, and stakeholders (Chaffin et al., 2014). In our findings, however, it is decentralized decision-making structures, and limited agency and external capacity that are the primary barriers for effective multiscale knowledge management. And while scholars of knowledge management often recommend and emphasize the importance of coproduction among scientists, managers, and stakeholders at local scales (Wyborn, 2015; Beier et al., 2016), the scarce and uneven distribution of both internal and external capacity is a significant barrier for systematic collaboration and coproduction on many forests (see Sutherland et al., 2017). Recommendations for decentralization are therefore problematic as they may aggravate rather than mitigate scalar challenges for multiscale knowledge management. Given these challenges, existing statutes and administrative laws are often enabling policies in this respect, rather than barriers, as they provide mandates or incentives for collaboration and cross-scale coordination when they would not otherwise occur due to capacity limitations (see Thomas, 2003). One possibility may be to develop separate organizational structures dedicated to "learning" versus "doing" in public land management agencies (see Mintzberg, 1980); other agencies have done this, but our prior research indicates that separations between monitoring and implementing functions, as choices about the governance of knowledge generation and use in an agency, have implications for monitoring outcomes with an array of tradeoffs for data quality, coordination, and management relevance (Wurtzebach and Schultz, 2016).

These considerations highlight important opportunities for future research on environmental knowledge management and its interactions with governance design. This is especially true for public agencies. Existing scholarship on adaptive governance often emphasizes the importance of non-state actors and networks for collaboration and coordination (Chaffin et al., 2014). Yet effective network coordination in public management contexts often requires sufficient administrative resources for steering and collaboration (Agranoff, 2006; Ansell and Gash, 2008). Public organizations and administrative staff also often have comparative advantages for specific knowledge management processes, such as data management and translation (Bolson and Broad, 2013; Pollitt, 2009). Our findings indicate administrative knowledge brokers represent an important policy tool for adaptive practice in this respect; they can lower the transaction costs for internal and external collaboration and coordination, and serve as critical nodes that link actors, expertise, and knowledge across scales of governance in complex institutional settings. As these considerations are derived from exploratory research focused on one land management agency, we suggest future research on adaptive practice in public organizations is needed. However, these topics are of growing importance, particularly as land managers are increasingly paying attention to climate driven changes that require assessment across scales. In an era of rapid change, multiscale monitoring is essential for adaptive land management planning and decision-making, and more work is needed to identify actionable policies and administrative strategies that can support it, or improve the knowledge to action linkage in public land management organizations (Wyborn and Dovers, 2014).

REFERENCES

Agranoff, R. (2006). Inside Collaborative Networks: Ten Lessons for Public Managers. *Public Administration Review*, *66*(1), 56–65.

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571.

Archie, K. M., Dilling, L., Milford, J. B., & Pampel, F. C. (2014). Unpacking the “information barrier”: Comparing perspectives on information as a barrier to climate change adaptation in the interior mountain West. *Journal of Environmental Management*, *133*, 397–410.

Berends, H., Boersma, K., & Weggeman, M. (2003). The Structuration of Organizational Learning. *Human Relations*, *56*(9), 1035–1056.

Biber, E. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4), art68.

Biber, E. (2009). Too Many Things to Do: How to Deal with the Dysfunctions of Multiple-goal Agencies. *Harvard Environmental Law Review*, *33*(1), 1–63.

Bolson, J., & Broad, K. . (2013). Early adoption of climate information: Lessons learned from south florida water resource management. *Weather, Climate, and Society*, *5*(3), 266–281.

Bornbaum, C. C., Kornas, K., Peirson, L., & Rosella, L. C. (2015). Exploring the function and effectiveness of knowledge brokers as facilitators of knowledge translation in health-related settings: a systematic review and thematic analysis. *Implementation Science: IS*, *10*, 162-188.

Brown, M. M., & Brudney, J. L. (2003). Study Organizations in the Public Sector ? Information of Police Agencies Advance Employing Knowledge Technology to. *Public Administration Review*, *63*(1), 30–43.

Burgess, N., & Currie, G. (2013). The knowledge brokering role of the hybrid middle level manager: The case of healthcare. *British Journal of Management*, *24*(S3), 132–143.

Carrington, P. J., Scott, J., & Wasserman, S. (2005). Models and Methods in Social Network Analysis. Cambridge University Press.

Carter, S. K., Hickey, J., & Wood, D. J. (2017). Understanding a Landscape Approach to Resource Management in the Bureau of Land Management. *Multiscale Guidance and Tools for Implementing a Landscape Approach to Resource Management in the Bureau of Land Management. Open-File Report*, (January), 79.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proc Natl Acad Sci U S A*, *100*(14), 8086–8091.

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120.

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*, *19*(3).

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative research. Sage Publications Ltd, London.*

Cheng, A. S., Gerlak, A. K., Dale, L., & Mattor, K. (2015). Examining the adaptability of collaborative governance associated with publicly managed ecosystems over time: Insights from the front range roundtable, Colorado, USA. *Ecology and Society*, *20*(1).

Contandriopoulos, D., Lemire, M., Denis, J. L., & Tremblay, É. (2010). Knowledge exchange processes in organizations and policy arenas: A narrative systematic review of the literature. *Milbank Quarterly*, *88*(4), 444–483.

Dawes, S. S., Cresswell, A. M., & Pardo, T. A. (2009). From “need to know” to “need to share”: Tangled problems, information boundaries, and the building of public sector knowledge networks. *Public Administration Review*, *69*(3), 392–402.

DeLuca, T. H., Aplet, G. H., Wilmer, B., & Burchfield, J. (2010). The Unknown Trajectory of Forest Restoration: A Call for Ecosystem Monitoring. *Journal of Forestry*, *108*(September), 288–295.

Dilling, L., Lemos, M. C., Carmen, M., Lemos, M. C., Carmen, M., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689.

Doremus, H. (2008). Data gaps in natural resource management: Sniffing for leaks along the information pipeline. *Indiana Law Journal*, *83*(2), 407–463.

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120. https://doi.org/10.1016/S0959-3780(00)00017-0

Cash, DW., WN, A., Berkes, F., Garden, P., Lebel, L., Young, O. (2006). Scale and cross-scale dynamics: governance and information in a multiscale world. *Ecology and Society*, *11*(2), 8–19. https://doi.org/8

Edelenbos, J., van Buuren, A., & van Schie, N. (2011). Co-producing knowledge: Joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science and Policy*, *14*(6), 675–684.

Failing, L., & Gregory, R. (2003). Ten common mistakes in designing biodiversity indicators for forest policy. *Journal of Environmental Management*, *68*(2), 121–132.

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C. L., … Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*, *40*(1), 19–36.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*(1), 441–473.

Fraser, E. D. G., Dougill, A. J., Mabee, W. E., Reed, M., & McAlpine, P. (2006). Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management*, *78*(2), 114–127.

Garmestani, A. S., Allen, C. R., & Benson, M. H. (2013). Can law foster social-ecological resilience? *Ecology and Society*, *18*(2).

Gregory, R., Failing, L., Ohlson, D., & Mcdaniels, T. L. (2006). Some Pitfalls of an Overemphasis on Science in Environmental Risk Management Decisions. *Journal of Risk Research*, *9*(7), 717–735.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, *142*(1), 14–32.

Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management*, *289*, 183–189.

Kim, S., & Lee, H. (2006). The impact of organizational context and information technology on employee knowledge-sharing capabilities. *Public Administration Review*, *66*(3), 370–385.

Lee, H., & Choi, B. (2003). Knowledge management enablers, processes, and organizational performance: An integrative view and empirical examination. *Journal of Management Information Systems*, *20*(1).

Lindenmayer, D. B., & Likens, G. E. (2010). The science and application of ecological monitoring. *Biological Conservation*, *143*(6), 1317–1328.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., & Griffith, R. (2010). Governance Principles for Natural Resource Management. *Society & Natural Resources*, *23*(10), 986–1001.

Mintzberg, H. (1980). Structure in 5's: A Synthesis of the Research on Organization Design. *Management Science*, *26*(3), 322–341.

Moir, W. H., & Block, W. M. (2001). Adaptive management on public lands in the United States: Commitment or rhetoric? *Environmental Management*, *28*(2), 141–148.

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(51), 22026–31.

Moynihan, D. P. (2008). Learning under uncertainty: Networks in crisis management. *Public Administration Review*, *68*(2), 350–365.

Moynihan, D. P. (2005). Goal-based learning and the future of performance management. *Public Administration Review*, *65*(2), 203–216.

Moynihan, D. P., & Landuyt, N. (2009). How Do Public Organizations Learn? Bridging Cultural and Structural Perspectives. *Public Administration Review*, *69*(6), 1097–1105.

Nguyen, V. M., Young, N., & Cooke, S. J. (2016). A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. *Conservation Biology*, *0*(0),

Nylen, N. G. (2011). To Achieve Biodiversity Goals, the New Forest Service Planning Rule Needs Effective Mandates for Best Available Science and Adaptive Management. *Ecology Law Quarterly*, *38*(2), 241–291.

Pee, L. G., & Kankanhalli, A. (2016). Interactions among factors influencing knowledge management in public-sector organizations: A resource-based view. *Government Information Quarterly*, *33*(1), 188–199.

Phillipson, J., Lowe, P., Proctor, A., & Ruto, E. (2012). Stakeholder engagement and knowledge exchange in environmental research. *Journal of Environmental Management*, *95*(1), 56–65.

Pollitt, C. (2009). Bureaucracies remember, post-bureaucratic organizations forget? *Public Administration*, *87*(2), 198–218. https://doi.org/10.1111/j.1467-9299.2008.01738.x

Popper, M., & Lipshitz, R. (2000). Organizational Learning: Mechanisms, culture, and feasibility. *Management Learning*, *31*(2), 181–196.

Rashman, L., Withers, E., & Hartley, J. (2009). Organizational learning and knowledge in public service organizations: a systematic review of the literature. *International Journal of Management Reviews*, *11*(4), 463–494.

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, *91*(8), 1766–1777.

Reed, M. S., Fazey, I., Stringer, L. C., Raymond, C. M., Akhtar-Schuster, M., Begni, G., …

Wagner, L. (2013). Knowledge management for land degradation monitoring and assessment : an analysis of contemporary thinking. *Land Degradation & Development*, *24*(4), 307–322.

Sabatier, P. A., Loomis, J., & McCarthy, C. (1995). Hierarchical Controls, Professional Norms, Local Constituencies, and Budget Maximization: An Analysis of U.S. Forest Service Planning Decisions. *American Journal of Political Science*, *39*(1), 204–242.

Sarewitz, D., & Pielke, R. a. (2007). The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science and Policy*, *10*, 5–16.

Schulz, Martin. 2001. The uncertain relevance of newness: Organizational learning and knowledge flows. *Academy of Management Journal,* (44)4, 661-681.

Schultz, C. A., Moseley, C., & Mattor, K. (2015). Journal of Natural Resources Policy Striking the balance between budgetary discretion and performance accountability : the case of the US Forest Service ' s approach to integrated restoration. *Journal of Natural Resource Policy Research*, (April), 37–41.

Spradley, J. P. (2016). *The Ethnographic Interview*.

Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.N.; Philpot, C. . (2003). Adaptive management and the Northwest Forest Plan: rhetoric and reality. *Journal of Forestry*, *101*(1), 40–46.

Sutherland, W. J., Shackelford, G., & Rose, D. C. (2017). Collaborating with communities: co-production or co-assessment? *Oryx*, *51*(4), 569–570.

Tulloch, A., Possingham, H. P., & Wilson, K. (2011). Wise selection of an indicator for monitoring the success of management actions. *Biological Conservation*, *144*(1), 141–154.

Tsai, W. (2002). Social structure of "coopetition" within a multiunit organization: Coordination, competition, and intraorganizational knowledge sharing. *Organization science*, *13*(2), 179-190.

Tsoukas, H., & Vladimirou, E. (2001). What is organizational knowledge?. *Journal of management studies*, *38*(7), 973-993.

Turnhout, E., Stuiver, M., Judith, J., Harms, B., & Leeuwis, C. (2013). New roles of science in society: Different repertoires of knowledge brokering. *Science and Public Policy*, *40*(3), 354–365.

Veblen, K. E., Pyke, D. A., Aldridge, C. L., Casazza, M. L., Assal, T. J., & Farinha, M. A. (2014). Monitoring of Livestock Grazing Effects on Bureau of Land Management Land. *Source: Rangeland Ecology & Management Rangeland Ecol Manage*, *67*(67), 68–78.

Wurtzebach, Z., & Schultz, C. (2016). Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. *BioScience*, *66*(6), 446–457.

Wyborn, C. a. (2015). Connecting knowledge with action through coproductive capacities: Adaptive governance and connectivity conservation. *Ecology and Society*, *20*(1).

Wyborn, C., & Bixler, R. P. (2013). Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management*, *123*, 58–67

Wyborn, C., & Dovers, S. (2014). Prescribing adaptiveness in agencies of the state. *Global Environmental Change*, *24*(1), 5–7.

Yang, T. M., & Maxwell, T. a. (2011). Information-sharing in public organizations: A literature review of interpersonal, intra-organizational and inter-organizational success factors. *Government Information Quarterly*, *28*(2), 164–175.

Yin, R. K. (2003). Case studies research: design and methods. *Thousand Oaks, Sage*.

CHAPTER FOUR: MULTILEVEL INVENTORY AND PROGRAMS IN THE NATIONAL PARK SERVICE AND BUREAU OF LAND MANAGEMENT

4.1. Introduction

In the face of current environmental management challenges, it is essential that institutional structures and processes that shape the actions of dominant governance actors support learning and adaptation (DeCaro et al., 2017). Yet there are often barriers to the generation, exchange and application of useable knowledge in environmental management contexts. Land managers often rely on tacit knowledge instead of scientific evidence, or they lack useable knowledge at relevant scales (Archie et al., 2014; Fazey et al., 2006). Despite decades of emphasis on its utility for supporting learning through practice, adaptive management has failed to realize its promise in practice (Westgate, 2013). These challenges are often a product of institutional boundaries between scientists and managers, mismatches between the scales of assessment and decision-making, and legal and administrative governance structures that emphasize stability and control at the expense of flexibility and adaptation (Cash and Moser 2000; Cash et al. 2006; Folke et al. 2005). Research in the fields of adaptive governance and knowledge exchange has emphasized the importance of networked and non-hierarchical forms of governance that promote learning and adaptation among diverse institutional actors across scales and levels of socio-ecological organization (Fazey et al., 2013; Chaffin et al., 2014). However, the emphasis on networks and non-state actors has meant that that there has been little attention to opportunities for improving adaptive governance in existing state institutions, which dominate North American land management, through purposive policy design (Dovers and Wyborn, 2014; Morrison et al., 2017). While some scholars have called attention to the importance of "enabling policies" that promote effective multi-scale knowledge management, within the literature these are often limited to general recommendations for collaboration, decentralized decision-making, or legal reform, unmoored from specific legal and administrative contexts (Cash and Moser, 2000; Lockwood et al., 2010; Craig et al., 2017).

One opportunity for improving the link between knowledge and action in existing state agencies is through policies that support multiscale ecological inventory and monitoring (I&M) (i.e. ecological inventory, assessment, and monitoring conducted at multiple temporal and spatial scales). Multi-scale I&M is a fundamental source of knowledge for evidenced-based environmental policy, planning, and decision-making in an era of rapid change (Hutto and Belote, 2013; Joyce et al., 2009; Lindenmayer and Likens, 2010). At fine to regional scales of decision-making, I&M information is the cornerstone of adaptive management, climate change adaptation planning, and cumulative effects analysis, although the scale at which data is collected and assessed varies according to resources and ecological drivers of interest (Archie et al., 2014; Sheelanere et al., 2013;). Indicators derived from multi-scale I&M programs also support climate change mitigation policy implementation at national and international levels (Korhonen-Kurki et al., 2013). However, while the challenges for implementing multiscale I&M in land management agencies are well documented, there has been little investigation of policies and governance regimes that can support it (Biber, 2013).

This article explores policy design processes and policy tools associated with multiscale I&M programs in the Bureau of Land Management and the National Park Service, two agencies that have recently developed and implemented policies for multiscale monitoring and adaptive management and planning (Fancy et al., 2009; Toevs et al., 2011) Using Schneider and Ingram's (1990) policy tool framework, we investigate and compare policy tools in each agency, the variables that shape policy tool choice, and their implications for implementation outputs and outcomes. Our analysis contributes to the literature examples of policy tools used to support multiscale I&M and knowledge management and the ways in which administrative context shapes policy design and implementation processes.

4.2. Literature Review

4.2.1 Policy Design and Policy Tools

Scholarship on policy design and governance increasingly uses a multilevel understanding of policy design to investigate policy processes in complex institutional settings (Howlett, 2009; Hill and Hupe, 2014; Lynn et al., 2000; Moulton and Sandford, 2017). Policies are often composed of a mix of goals and specific policy tools, which are the identifiable means "through which collective action is structured to address a public problem" (Salamon, 2002, 19; Howlett 2009). At the "macro" or institutional level of governance, policies are constituted through political processes by legislative or executive actors. At this level, policies usually take the form of administrative structures and resources, which in turn shape and coordinate the actions of actors at the organizational level of governance (e.g. hierarchical line bureaus, departments, and interorganizational networks) (Lynn and Robichau, 2013; Sandford and Moulton, 2017). At this organizational level, individual managers use their discretion and organizational resources to employ additional policy tools (e.g. collaboration, planning paradigms, or agreements) to "calibrate" and operationalize the technical settings of institutional policies to specific contexts (Howlett, 2009). These settings in turn structure implementation processes performed by street-level bureaucrats at the operational or ground level of governance (Hill and Hupe, 2014). Implementation processes produce outputs and outcomes, which provide feedback information used by administrative actors to further refine and adjust organizational policies and implementation processes, or are used by stakeholders and citizens to promote policy change at the institutional level of governance through democratic processes (Lynn et al., 2000).

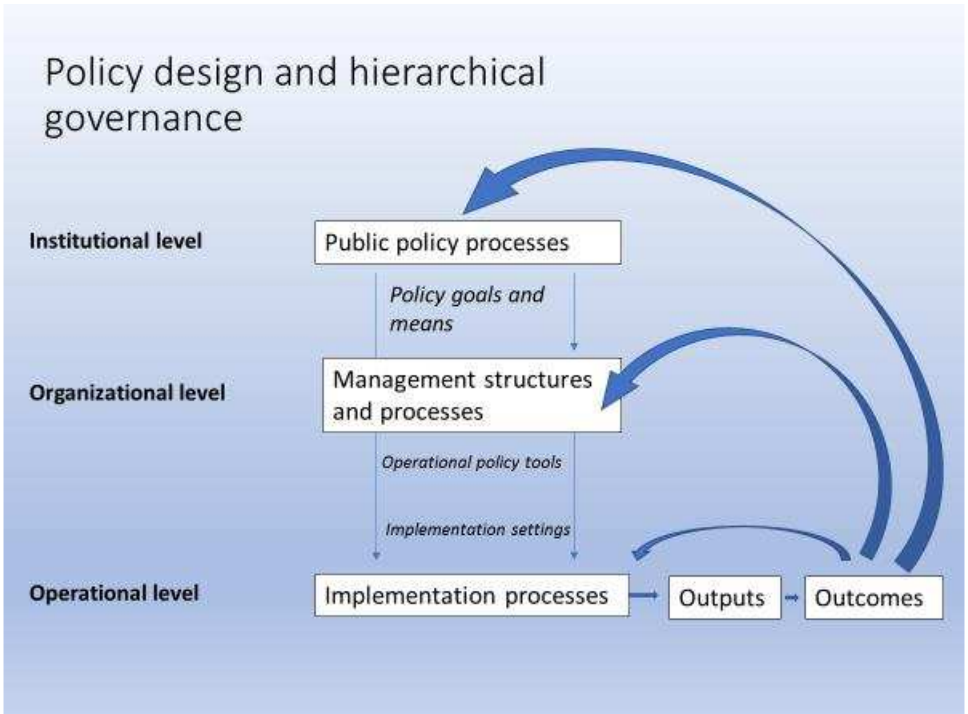

Figure 4.1. Policy Design and Hierarchical Governance. Small arrows represent direction of influence, large arrows represent "feedback" associated with governance outcomes.

Multiple types of policy tools can be employed at both the institutional and organizational levels of policy design. While there is broad agreement that policy tools are the building blocks of policies, there are numerous policy tool typologies (Salamon, 2002; Howlett, 2011). One approach is to classify them by the means through which they influence the behavior of policy targets (Elmore and McDonnell, 1987; Schneider and Ingram, 1990). Policy targets may be individuals or groups in the socioeconomic sphere, or intermediaries, such as officials in governmental or non-governmental organizations. Agents, the actors responsible for policy implementation, are also often policy targets (Moseley and Oliver, 2008). Many of the policy tools found in the policy design literature, which focuses on the institutional level of policy design, are also the tools of public management used at the organizational level (Howlett, 2011; Schneider and Ingram 1990; Sowa and Liu, 2017).

In this paper, we employ Schneider and Ingram's (1990) policy tool framework, which classifies tools according to the means through which tools are intended to alter the behavior of policy targets. Learning tools are procedural tools that shape policy processes (Howlett, 2000). They are predicated on the assumption that policy designers and implementing officials have the capacity and commitment to effectively select and design tools and implementation processes at different levels of governance. The creation of advisory boards, benchmarking processes, and collaboration with external partners are all examples of procedural or learning tools. Authority tools rely on the legitimacy and hierarchical structures of government to proscribe, compel, encourage or prohibit specific behaviors. They are predicated on the assumption that policy targets are compliant and responsive to orders and mandates, and that implementers have the capacity to use and enforce their authority. Incentive tools are used when there is an assumption that tangible benefits or sanctions are needed to promote desired behaviors. These tools rely on the assumption that targets are informed and motivated to work towards policy goals, but not without some {can you finish this}. Capacity tools are predicated on the assumption that policy targets are motivated to take a desirable course of action but they lack the knowledge, expertise, or resources needed to do so. Information technology, new organizational structures, additional funding, or implementation resources such as policy guidance are all examples of capacity tools (May, 2013; Hill, 2003). Hortatory or persuasion tools are based on the assumption that the behavior and actions of policy targets are often consistent with their values and beliefs They typically involve the use of strategic communication that links desired behaviors to symbolic or cultural values. In organizational contexts, the clear communication of organizational mission and goals can be understood as a hortatory tool used to develop cultural values that shape desired behaviors, thereby reducing the need for incentive or authority tools (Kaufman, 1960; Moynihan, 2005; Wilson, 1989).

While policy design involves matching tools to assumptions about target motivations and capacity, the selection and use of specific tools is also shaped by institutional variables and constraints, such as existing laws, politics, organizational resources and culture, and individual leadership (Howlett and Rayner, 2007; Moulton and Sandford, 2017). Variables associated with specific institutional contexts have important implications for the effectiveness, efficiency, equity, and legitimacy of specific policy tools—criteria that influence policy choice and policy institutionalization. Indeed, navigating tradeoffs among these values is often challenging. Authority tools, for instance, are often highly effective for achieving policy goals in many contexts, yet they entail greater administrative costs than hortatory tools, and are more coercive (and therefore more likely to engender political opposition) than incentive tools. This may complicate their use in contexts where resources are limited and government actors lack legitimacy (Salamon, 2002). There are also cross-level tensions and tradeoffs with new policy tools and existing policies that must be carefully negotiated. Integrated policies are those in which policy tools and policy goals are complementary and consistent within and across levels of governance, and aligned with the realities of institutional contexts (e.g. power of enforcement, capacity, and legitimacy of different approaches) (Howlett and Rayner, 2007; Howlett and Del Rio, 2017). Effective design in complex and multilevel institutional settings, in other words, requires selecting policy tools that are well matched to target behaviors and institutional contexts across multiple levels of governance.

4.2.2 Multiscale inventory and monitoring: implementation processes and challenges

Multiscale monitoring is unique in that implementation requires iterative processes that require coordination across multiple, hierarchical levels of governance (Chapter 2). The first and most critical process, to put in place multiscale monitoring, is the design of an I&M strategy. This is the step at which the technical "settings" of implementation processes are specified (Lindenmayer and Likens, 2010). Design involves the following: clarification of goals and relevant information needs for decision-making; the identification of measurable, relevant, and scientifically credible ecological indicators; the development of data collection protocols and sampling strategies that can generate credible information at appropriate temporal and spatial scales for decision-making; and the specification of roles, responsibilities, and timelines for data collection, data management, analysis, and reporting (Lovett et al., 2007). As these processes require significant interdisciplinary knowledge, scientific expertise, and understanding of the management context, all of which no single individual or group often has, collaborative and structured decision-making processes that promote deliberation among scientists, managers, and stakeholders are often essential (Failing and Gregory, 2003; Tulloch et al., 2014; Wurtzebach and Schultz, 2016). Collaboration among managers and scientists is also essential for ensuring information will be salient, credible, and legitimate—characteristics that increase the chances I&M outputs will be useable for decision-making (Cash et al., 2003). Once designed, monitoring requires consistent data collection across time and space, effective data management, and timely and regular analysis and reporting, which are expensive and time-consuming tasks (Lovett et al., 2007; Doremus, 2008: Lindenmayer and Likens, 2010).

There are additional processes associated with the analysis, exchange, and interpretation of data and information produced at spatial or temporal scales that are "mismatched" with those of specific decision-making contexts (Cash and Moser, 2000; Doremus, 2008). Upscaling I&M data from local to regional or national scales often requires use of consistent data collection protocols across units, effective data management, collaboration for effective organizational or interorganizational data exchange, and technical capacity for analysis (Veblen et al., 2014). The downscaling of data collected at broad-scales, such as coarse grain remote sensing data, requires capacity for additional data collection and sometimes the application of sophisticated modeling and decision-support tools (Degruijter et al., 2006). Scholars emphasize the importance of iterative communication and social relationships among knowledge producers and users for the effective communication or translation of useable information to actors operating in specific decision-making contexts. This is particularly important in contexts where end-users were not involved in information production (Dilling and Lemos, 2011). While these processes are important for generating implementation outputs, such as useable information, structured decision-making tools such as decision triggers and adaptive management are often needed to effectively link information to instrumental outcomes, such as changes in planning or decision-making that affect environmental systems (Gregory et al., 2006; Schultz and Nie, 2012).

The most widely cited behavioral challenges for I&M and, and associated adaptive management processes, which are designed to utilize monitoring information to inform decision-making, are commitment, capacity, and authority (Biber, 2011; Lindenmayer and Likens, 2010). Commitment is often an issue for administrative decision-makers, such as line officers, who often prioritize the production of tangible management outputs over data collection and analysis, particularly when resources are scarce, and management outputs are incentivized through performance management systems. This is a persistent challenge given the cost of monitoring in an era of flat or declining budgets (Biber, 2011). Organizational cultures characterized by risk aversion, parochialism, insularity, and preferences for experiential knowledge or problematic decision-making heuristics also create commitment challenges for I&M implementation processes (Biber, 2011; Stankey et al., 2003). Land management staff committed to I&M, such as agency biologists and resource specialists, often lack the capacity and authority needed to design and effectively implement robust monitoring and adaptive management strategies. Effective data management is often a critical capacity challenge in this regard (Lovett, 2007; Biber, 2011). Finally, the decentralized yet multilevel decision-making structures of many public land management organizations create challenges for coordinating I&M implementation across levels and jurisdictions (Doremus, 2008; Veblen et al., 2014). As a result, I&M implementation is often characterized by mismatches between the temporal and spatial scales of assessment and those of decision-making. The combined effect is that I&M is often focused at fine scales without broader coordination, discontinued when budgets are cut, and seldom linked to decision-making processes (Doremus 2010; Biber 2011). A central and as-yet unanswered question is how to design policies to support effective multiscale I&M processes and overcome the persistent, documented challenges in public organizations.

4.2.4. Institutional Context: the BLM and NPS

In the United States, the BLM and NPS have both developed multiscale I&M policies designed to support the generation of credible information for decision-making at scales above unit (e.g. individual park or district) levels (Taylor et al., 2014; NPS, 2012). While there have also been policies that support landscape-scale, collaborative, science-policy integration, such as the Landscape Conservation Cooperative program, we focus our investigation in this article on the design and implementation of programmatic agency-wide policies for multiscale I&M strategies that were initiated in the period 1999-2009. Each of these agencies has a different history and mandate. The NPS operates under the authority of the "Organic Act" of 1916 which emphasizes the preservation of Parks and Monuments for the use and benefit of the public. The 84 million acres in the NPS system are administered by staff in a National Office, nine Regional Offices, and individual National Park and Monument offices. As a large federal agency, there are two, primary levels of organizational governance: a national and middle management level. The National Park Service has also long been a "bureaucratic superstar", able to secure proportionately more funding per unit area than other land federal land management agencies (Clarke and McCool, 1996). The BLM, the largest land management agency in the United States in terms of acres under its jurisdiction, oversees the use of approximately 247 million acres, mostly in the Western United States. In terms of organizational structure, administrative functions are performed by staff in the National Operations Center in Denver and in BLM headquarters in Washington D.C., at each of the agency's 12 western State Offices, and in 45 Field Offices. It is governed by a multiple-use mandate under the Federal Land Management Policy Act of 1976 (FLPMA)(43 U.S.C. § 1701), and its core agency tasks involve the administration and management of energy development and livestock use (Skillen, 2008). In developing management plans and actions, both agencies must also comply with procedural requirements for environmental impact assessment associated with the National Environmental Policy Act of 1976 (42 U.S.C. § 432).

4.2.5. Summary and research questions

Multiscale inventory and monitoring is a fundamental component of adaptive land management planning and decision-making in an era of rapid environmental change. However, administrative actors often lack the capacity and commitment needed for effective implementation. While recent scholarship on knowledge management emphasizes the importance of social processes and institutional context, there has been little investigation of opportunities for building administrative capacity in existing institutions through administrative policy design. Our goal in this paper is to identify the core policy tools associated with I&M programs in the BLM and NPS, and investigate how they structure implementation processes, outputs and outcomes. Our research is guided by the following questions:

1) What are the policy tools used to support I&M policy design and implementation at different levels of governance?
2) What are some examples of policy outputs and outcomes, and how do they differ across agencies and levels of governance?

In our discussion, we then aim to use this information in order to clarify opportunities for promoting adaptive practice in state agencies through purposive policy design.

4.3. Methods

To answer our research questions, we utilized a comparative case study design. This approach is appropriate for descriptive studies whose goal is to describe the features, context, and process of a phenomenon (Yin 1994). We selected the NPS and BLM because both agencies have developed and implemented administrative I&M policies designed to achieve common goals, including to: promote adaptive management, generate efficiencies, and produce credible information for decision-making at scales greater than a single unit. However, the legal and administrative context of each agency is also very different; the NPS has a preservationist mandate, for instance, while the BLM is a multiple use agency. These differences provide an opportunity to understand how administrative variables influence policy design and policy tool selection for multiscale I&M (Wurtzebach and Schultz, 2016)

In developing our case studies, we relied on two different approaches: document content analysis and semi-structured interviews. Documents and literature associated with each program were our primary source of data. To identify core policy tools and develop an understanding of policy design processes associated with each agency's I&M policies, we utilized a "program-based" approach, and conducted a systematic review of relevant literature, agency budgets, laws, policies, guidance, and other supporting documents (Howlett et al., 2006). This effort was facilitated by each agency's dedication to transparency for I&M program implementation, and the accessibility of program policies and supporting documents on agency websites (http://www.landscapetoolbox.org/; https://science.nature.nps.gov/im/). We also reviewed documents associated with program implementation at subnational levels, such as I&M reports and NEPA documents. We limited our review of documents at this level to those associated with I&M implementation in the arid Intermountain West, a region where both the NPS and BLM have implemented I&M programs, to control for differences in ecological conditions, and compare I&M outputs.

To gain greater insight on policy design and the rationale behind policy tool selection, we also conducted supplementary interviews with inventory and monitoring staff in each agency. We first conducted in-person and telephone semi-structured interviews with executive staff responsible for I&M implementation in the NPS and BLM. We then used a purposive sampling approach to identify an additional sample of respondents familiar with I&M implementation processes at sub-national levels of governance (again limiting our sample to staff in the Intermountain West) by asking national staff to identify respondents who were familiar with I&M policy tools and implementation processes (Patton, 2002). Respondents in this sub-sample included NPS and BLM staff directly responsible for I&M implementation, and interviews occurred until we reached saturation, meaning we gained no new information (Total interviewees: NPS, n=13; BLM, n = 13). We asked respondents about policy tools and processes identified in our analysis of policy documents, additional examples of outputs and outcomes, their perceptions of strengths and weaknesses associated with different policy tools, and implementation challenges and successes. This methodological approach is consistent with those used in other studies of policy design and institutional adaptation (e.g. Howlett et al., 2006; Vogel and Henstra, 2015; Pahl-Wostl et al., 2013).

Interviews were recorded, transcribed, and coded with the qualitative data analysis software RQDA (Huang, 2014). Interview transcription passages were coded by themes derived from the literature on policy design and governance and interview questions (i.e. level of governance, administrative variables, policy tool categories, implementation processes, outputs, outcomes, challenges and successes). In analyzing codes, we utilized a process tracing approach. Process tracing is frequently used to infer causal processes in policy and political research using document analysis and elite interviews (Tansey, 2007; Collier, 2011). We organized codes by themes, and then developed memos for each case study that explored how administrative context and policy tools shape implementation processes, and outputs and outcomes.

4.4. Results

4.4.1. National Park Service Inventory and Monitoring Program

In the late 1990s, the National Park Service received significant national attention for its failure to effectively integrate science into park management and decision-making. In response, Congress enacted the 1998 Parks Omnibus Act, which provided a mandate for the agency to improve its science capacity and evaluate the long-term trends and conditions of park resources

(NPS, 2012; Parsons, 2004). The agency initiated and subsequently received congressional funding for its Natural Resource Challenge in 2001, an administrative initiative designed to meet the legislative intent of the Parks Omnibus Act, which led to the development of a National Inventory and Monitoring team. The national NPS I&M team subsequently utilized several learning tools to select multilevel policy tools associated with the I&M program. They conducted a comprehensive analysis of monitoring successes and failures within the NPS and other land management organizations, collaborated with scientific partners from federal and academic research organizations, and piloted funding and implementation approaches at regional and unit levels of administration (NPS, 2012).

After gathering and assessing information from this learning phase, the NPS put into place several capacity and authority tools to structure I&M implementation. One is human and financial resource capacity dedicated solely to I&M implementation at two levels of organizational governance: national and ecoregional. There is also an important authority tool associated with administrative capacity; national I&M staff retain authority for budgetary allocation and oversight for implementation. National I&M respondents indicated that this was essential for the equitable allocation of resources for I&M at lower levels of governance, and to ensure accountability for the use of I&M funding. An early lesson from pilots and program evaluations was that providing funding for I&M implementation to unit level or regional level line officers was ineffective, as they would merely use it for substantive management activities. As one national respondent explained, “As a resource management agency with an adaptive management mandate, everything we do has a monitoring component. So it becomes very easy to justify siphoning money off for projects that are not purely monitoring.”

The NPS also created 32 I&M "networks"—new administrative structures dedicated to I&M on multiple units at ecoregional scales (Fancy, 2009). Respondents from the national I&M office said this approach was driven by the need for efficiency; centralizing technical capacity for implementation at multi-unit levels allowed them to exploit economies of scale for implementation processes such as data management and analysis, yet also ensure I&M strategies were matched to diverse ecological resources. As one national I&M employee noted, "if you take our budget and disperse it out to the parks you'll end up with a minuscule amount at each park. I think they figured there were about two hundred and eighty parks with significant natural resources. So, how can we take a certain amount of money and use it most effectively? And that's where the whole concept of networks came up." Each network was initially staffed with two required positions: a network manager and a database manager. Respondents noted that capacity for database management and information technology has been a central focus of the program; each network is directed to spend at least 30% of its budget on data management (NPS, 2008). Network managers, rather than unit staff, also retain authority and significant discretion for I&M implementation within each network, including additional staffing decisions. According to a national I&M employee:

> There was never an attempt to say 'this is national level. This what you're going to do.' Instead it was, 'you determine within your network, from your parks, what the essential vital signs are that we need to monitor and we will give you that kind of local flexibility but there are certain side boards that you need to meet.' I think that's why it's been successful is, while there's been this top layer of a certain level standards and guidance and 'thou shalts,' there's always been that freedom to operate at a local level.

Respondents noted that this flexibility was important for building legitimacy for the program, and allowing Network managers to tailor staffing structures and implementation processes to ecoregional and management contexts associated with each Network. However, it has also meant that Network effectiveness has been highly dependent upon effective leadership by Network managers.

In terms of implementation, Networks first developed ecological inventory products, such as credible maps of natural resources, before initiating design processes for long-term monitoring. National respondents noted that though there was some variation in the processes used to develop technical I&M implementation processes in each Network, there were some common learning tools used by network managers that were diffused by national I&M staff through formalized guidance as subsequent networks became operational (NPS, 2012). In a "typical" Network design process, such as the Southern Colorado Plateau Network, I&M staff utilized financial contracts with external scientists and collaborated with unit managers and resource specialists to identify credible and relevant indicators and measurement protocols through iterative collaborative processes (see O'Dell et al., 2006). Conceptual models of ecosystems were common learning tools used to identify a holistic set of ecological indicators. According to one Park Supervisor, these learning tools and processes were useful because "they stretched everyone's minds to begin to think about this outside of this specialty they have, and at multiple scales of space and time". The resulting "short list" of potential indicators and an estimated budget is then sent to three oversight committees for approval or modification: a Technical Advisory Committee (composed of network managers, Park resource specialists, and external scientists), a Board of Directors (composed of park supervisors and network manager), and finally the National Office for final authorization and budgetary allocation. Respondents from across levels of the agency indicated these procedural learning tools were essential for building legitimacy and buy-in for the program among line officers, ensuring I&M programs were feasible to implement, and mediating different interests and preferences for monitoring.

However, there were challenges with staffing technical advisory boards with external scientists. According to one national I&M employee, “there just wasn't enough scientific capacity basically in the country to populate all of those boards with the level of people that we wanted”. Specific monitoring protocols were subsequently developed by resource specific working groups composed of network and external scientists, and peer reviewed.

Once formalized, there are several capacity tools used to structure implementation processes. Networks use teams of seasonal agency employees or third party contractors to collect data consistently across each Park in a network. Data management, analysis, and reporting is then conducted by full time Network staff. Respondents from the National I&M office indicated that some networks have also hired full time science communication specialists, positions “worth their weight in gold”. While Networks provide information to managers, however, there are no formal authority tools used to link information to decision-making. Respondents noted that efforts to do so through “State of the Park Reports” have been met with resistance from park managers, who fear they will be evaluated on detrimental changes in ecological conditions.

There are several outputs and outcomes associated with the NPS I&M program. Networks in the Intermountain West have developed up to date inventory and mapping products, and robust data on ecological resource trends and conditions. While most Networks in this region have monitoring protocols associated with common terrestrial and aquatic systems, they also have monitoring protocols associated with rare but important resources, such as desert springs and wildlife species (Garret et al., 2006; Thomas et al., 2007; Odell et al., 2007). Information on monitoring trends and conditions is also available in diverse formats, such as two-page resources for managers and stakeholders, interactive data visualization products, and newsletters (NPS, 2016). I&M data is also increasingly used to support scientific research published in peer-reviewed journals (Miller et al., 2017). The NPS I&M program also produces information for political principals in Congress. While the initial primary audience or "policy target" was unit managers, I&M respondents noted that it soon became apparent that they would need to generate information for Congress to demonstrate accountability for congressional budgetary allocations. While this task was somewhat complicated by the decentralized Network structure (due to differences in "vital signs" and vital sign data collection protocols across networks), national I&M staff were able to develop an approach for aggregating information associated with common resources, such as water and air quality (NPS, 2012).

Respondents from the NPS also noted that I&M staff increasingly participate informally in Park management planning processes, which has resulted in substantive outcomes in some cases, such as changes in Park management goals and priorities. Respondents from the national I&M office indicated that while partnerships with external actors are critical, investment in internal capacity for I&M has been especially important for integrating I&M information into decision-making. As one noted:

> You have to relationships with the planners. You have to have relationships with the managers. If you're not sitting at the table with them, talking with them, you can give them all the reports in the world, but until you sit down with them and talk to them, they won't use your stuff. Period. If you've got contractors and people who are ephemeral doing that work, those relationships don't get built and then information doesn't get used.

In addition to providing unit staff with monitoring information, respondents noted that Network staff also provide significant informal consultation to unit staff, and the program has significantly increased the agency's science capacity.

4.4.2 Bureau of Land Management Assessment, Inventory and Monitoring (AIM) program

The BLM's Assessment, Inventory, and Monitoring program was developed in response to an Office of Management and Budget (OMB) evaluation in 2004 that highlighted "gaps in the monitoring of resource conditions needed to support management decisions" and the inability of the agency to effectively report on the condition of public lands above the local level (Taylor et al., 2012). In response, the BLM created work groups and advisory teams that conducted a multi-year assessment of existing monitoring practices and procedures in collaboration with staff from multiple levels of the agency. Capacity, commitment, and coordination across units and different programs were identified as critical challenges for generating credible information for resource allocation and management decision-making, and fulfilling regulatory requirements associated with FLPMA and NEPA (BLM, 2007) The BLM Assessment, Inventory, and Monitoring Strategy (AIM) was then developed with the explicit goal of improving the efficiency and effectiveness of multi-scale inventory and monitoring, and supporting science-based decision-making (Toevs et al., 2011).

The BLM has used a few core policy tools to structure policy design and implementation processes. One important tool is the centralization of administrative capacity. An initial investment in financial and technical capacity in its National Operations Center allowed the BLM to leverage the expertise of key external partners, such as the USDA's Agricultural Resource Service's Jornada Institute, through contracts and agreements. Formal collaborative process involving over 200 scientists and managers, conceptual models of ecological systems, and structured decision-making processes were important learning tools subsequently used to develop I&M implementation settings (Taylor et al., 2014). These include: a set of core indicators of terrestrial and aquatic ecological integrity that are relevant for planning and decision-making across the BLM's ownership (e.g. measures of bare ground and vegetative cover); standardized measurement and sampling protocols; centralized database management systems and electronic tablet-based data capture; and formalized guidance and processes for linking AIM information to decision-making (Taylor et al., 2014). Respondents from the BLM noted that the decision to develop nationally standardized implementation processes was driven by the need for efficiency and scalability; this was essential given the agency's limited resource capacity. AIM staff subsequently implemented several pilots at national, regional, state, and unit levels of administration (BLM 2014). Lessons from these early pilots were used to refine and develop additional policy tools for systematic implementation.

There are a few core policy tools used to support AIM implementation at different levels of administration. In terms of capacity, the national AIM office is composed of individuals with expertise in statistics, ecology, program management, and database management (BLM, 2018). Respondents said these staff retain authority for I&M budgetary allocation, which allows them to allocate resources for AIM implementation at lower levels based on need. They also supervise and provide guidance to AIM coordinators and project leads, the individuals responsible for coordinating AIM implementation at state and multi-unit levels. Respondents also highlighted the importance of clear goals linked to agency mission, mandates and tasks, and effective communication of program benefits by AIM coordinators-- an important hortatory tool. Until 2016, there were few authority tools that targeted resource managers at organizational and operational levels of governance; the decision to utilize AIM was left to the discretion of state and field office managers, though the national office provided funding to support implementation. Respondents from the BLM noted that their initial voluntary approach was important for building legitimacy, and institutionalizing the program incrementally. In explaining the logic of this strategy, a National BLM AIM respondent noted that:

> We really think that standardized monitoring is absolutely necessary if you're going to try to do anything multi-scale because otherwise you're dealing with apples and oranges at different scales. At the same time, for it to be completely top down, at least in our agency, which tends to be more of a bottom up agency historically,

> we've got to win hearts and minds essentially. People need to want to do this. They actually do, which is great.

The BLM subsequently developed an authority tool in 2016: regulations that link AIM implementation to regulatory requirements associated with Sage Grouse conservation planning and land management planning under the authority of FLPMA (BLM, 2016).

These policy tools have been essential for structuring implementation at multiple scales of agency decision-making. National AIM staff, AIM coordinators, and project leads, for instance, all participate in different steps in the implementation process (BLM, 2017a). National AIM staff coordinate the implementation of the West-Wide Terrestrial Landscape Monitoring Framework (LMF) and aquatic Western Rivers and Streams (WRS) framework in collaboration with other federal and university partners (BLM, 2017b). The LMF and the WRS are the high-level tier of a sophisticated multiscale implementation strategy. The BLM uses a “master sample,” which is a multiscale and spatially balanced sample frame, that allows AIM staff and at lower levels of governance to match data collection and sampling intensification strategies to multiple scales of assessment and decision-making. There is also some flexibility in the use of indicators; while “core” indicators are collected at all plots, supplementary indicators can be added if needed (Taylor et al., 2014). At regional scales, for instance, terrestrial AIM is a critical source of scientific information for the regional Sage Grouse conservation strategy, an interagency initiative designed to prevent the listing of the species under the Endangered Species Act. National and state-level AIM staff have worked with state and unit-level line officers, external scientific partners, and staff from state and federal agencies to utilize AIM for Sage Grouse Habitat assessment at multiple scales of the species distribution (BLM, 2016; Stiver et al., 2015).

At unit and management scales, respondents emphasized the importance of capacity tools such as formal implementation guidance and AIM staff for helping unit-level design AIM implementation strategies for specific unit level decision-making needs. Once designed, data collection and initial quality control and assessment procedures are typically conducted by contract field crews from external governmental or non-governmental agencies, such as the Great Basin Institute at the University of Nevada. Referencing the importance of dedicated field crews, one national respondent noted that “when they're doing the monitoring over and over every day through field season…that's just a much better check on consistency than someone who might be monitoring one day and then they get pulled into the office for a couple of weeks and then they go back out two weeks later”. National AIM staff analyze and generate information at regional and national scales, while state and field office staff are responsible for analysis and reporting at lower levels of governance (BLM, 2017). Quantitative benchmarks identified during design help to ensure AIM information is linked to planning and management decision-making. When linked to NEPA decision documents, these are also authority tools. Sage Grouse amendments to multi-unit and unit scale land management plans, for instance, have hard and soft “triggers” associated with AIM habitat metrics built into NEPA documents; if AIM data indicates a habitat threshold has been crossed, managers must implement predetermined changes to planning or management decisions (BLM, 2016; Stiver et al., 2015).

While AIM is still in the early stages of system wide implementation, there are several important outputs and outcomes associated with the program. One important output is credible data for decision-making for Congress and the executive branch. AIM’s core and contingent set of indicators are also used to generate relevant information for decision-making across multiple programs (i.e. rangeland, energy, and wildlife management) at fine to regional scales. However, given that regulations requiring the use of AIM for land management planning have only recently been promulgated, implementation at unit or management scales has been mediated by manager buy-in and support, funding support from the national office, and the presence of Sage Grouse habitat. BLM units under the jurisdiction of the Nevada office, for instance, have all intensified AIM data collection because of early leadership support in the Nevada State office (Figure 1). There also remain challenges for linking AIM information to decision-making; some respondents noted that on many units the primary output is data, rather than interpretable information, and unit staff do not always have the requisite statistical expertise to effectively analyze and interpret AIM data

In addition to substantive outputs, there are indications of institutional outcomes. AIM's sophisticated multiscale sample design is highly efficient; data collected at management scales can be credibly aggregated and integrated with data collected to larger scales, a consideration reflected in the informal AIM motto, "collect data once, use it many times." Respondents from the BLM also highlighted the program's benefits for efficiency in meeting regulatory requirements associated with environmental assessment under NEPA; the presence of easily accessible and credible data reduces the need for costly environmental assessment. The explosive growth and increasing adoption of AIM across units are also evidence of the program's increasing legitimacy and success, and respondents noted that they felt that program had been effectively institutionalized.

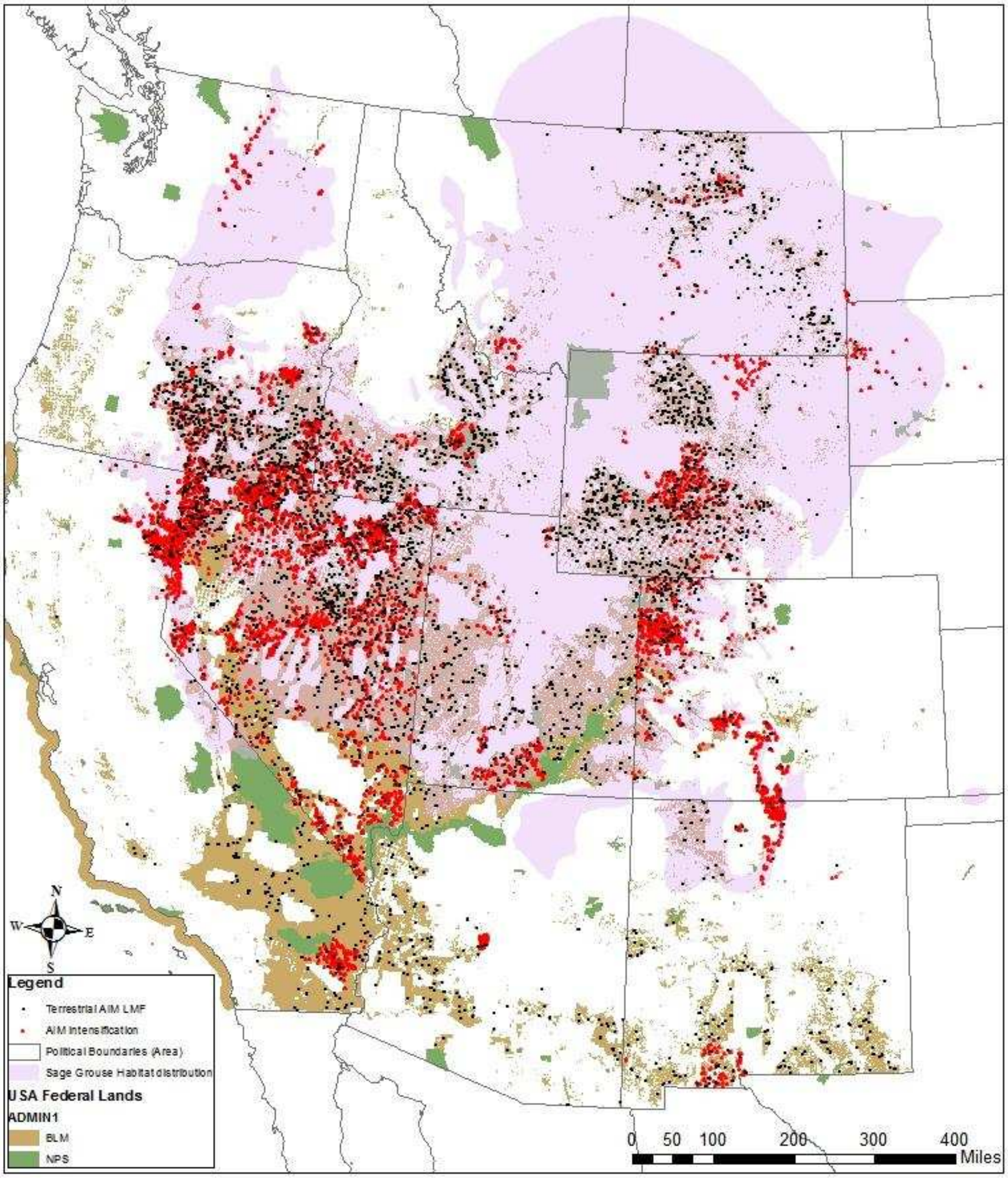

Figure 4.2. Terrestial AIM implementation. Note how intensification of AIM plots per unit area is clustered in areas with Sage Grouse habitat, and the state of Nevada.

4.5. Discussion

Our case studies highlight several policy tools that support multiscale monitoring in land management agencies. Here, we discuss similarities and differences in policy tools used by each agency to structure multiscale I&M, the institutional factors that explain variation in tool choice, and the implications of tool choice for outputs and outcomes. In doing so, we also highlight several propositions and considerations for the design of multiscale I&M programs. We then discuss the implications of our findings for future research on policy design and public management, adaptive governance.

4.5.1. Comparing I&M Policy Tools, Outputs, and Outcomes in the BLM and NPS

There are several commonalities associated with target behaviors, policy design processes, and I&M policy tools in both of our case studies. Policy designers often purposively select policy tools based on assumptions about policy targets (Schneider and Ingram, 1990). Administrative policy makers in the NPS and BLM were both faced with a similar behavioral challenge: limited capacity and commitment for effective implementation, particularly among operational level staff. To address these issues, administrative actors in each agency used "windows of opportunity" provided by legislation or focusing events to secure authority and resources for I&M policy design (Kingdon, 1984). This capacity allowed them to utilize several common learning tools to select and calibrate the "settings" of I&M policy tools and implementation processes: participatory and multi-level evaluations of existing I&M programs, implementation pilots, and formal collaborative structures and processes.

The NPS and BLM also use a similar mix of capacity, hortatory, and authority tools to structure implementation: a clear mission and goals for I&M linked to agency mission and legal mandates (i.e. a hortatory tool); funding and specialized staffing positions dedicated to inventory and monitoring at multiple levels of administration (i.e. a capacity tool); and centralized authority for implementation and budgetary allocation (i.e. an authority tool)—I&M staff at lower levels of governance are supervised by national I&M staff, rather than line officers, which helps to ensure they can remain focused on I&M implementation. Funding, clear goals, and implementation guidance allow lower level staff to flexibly match implementation processes to specific management contexts, and exploit the capabilities of external partners through additional capacity tools such as contracts and agreements (Hill, 2003). A particularly important feature of capacity structures in both agencies is positions dedicated to implementation at multi-unit levels. AIM coordinators and project leads and NPS network staff serve as "boundary spanners;" they are positioned at scales that allow them to build commitment among operational staff through iterative social interaction, and promote effective coordination and communication horizontally across units and external organizations, and vertically across levels of administration (Pablo et al., 2007; Weber and Khademian, 2008). I&M staff from multiple levels of governance also participate in decision-making and implementation processes—an important feature of adaptive institutions (Pahl-Wostl, 2009). Put simply, both agencies created autonomous, internal organizational structures dedicated to I&M implementation. They created new agents responsible for I&M implementation at multiple levels of governance, and shifted the role of operational staff from being agents to policy targets.

These tools have had significant benefits in terms of the effectiveness, equity, and efficiency of I&M implementation processes. In both cases, procedural tools such as decision-making discretion and collaborative processes that engage administrative decision-makers and external scientists have been particularly important for building organizational commitment and legitimacy for I&M implementation, and ensuring I&M information will be relevant for decision-making, scientifically credible, and cost-effective to implement (Hicklin and Godwin, 2009; Howlett, 2011; Fancy and Bennets, 2012). Hierarchical and multilevel administrative structures dedicated to IM have also allowed the NPS and BLM to efficiently and equitably allocate resources for I&M, coordinate and "match" I&M strategies to the scale of cross-boundary or multi-unit resources, and ensure commitment and capacity for implementation.

In addition to similarities, there are also important differences in I&M policy tools, and the level of governance at which they have been deployed. One key difference is the level at which each agency invested in technical capacity (i.e. scientific expertise and data management infrastructure) and utilized learning tools to develop I&M implementation procedures. The NPS, for instance, invested in technical capacity in each of its 32 ecoregional networks. Learning tools, such as managerial discretion and collaboration were also used at network levels to "match" I&M implementation settings to specific ecoregional contexts. In contrast, the BLM invested in technical capacity and developed I&M implementation procedures at the national level. These differences reflect variation in administrative capacity and legislative mandate. The NPS, for instance, was able to invest in technical capacity in each of its 32 networks as a result of funding provided by Congress. Given the wide variation in ecological systems across the NPS system, Network-level discretion for implementation was also essential for ensuring I&M strategies addressed individual unit resources. In contrast, the BLM is multiple-use agency with far less funding and capacity per unit area. The decision to invest in centralized technical capacity and standardized protocols was driven by the need for efficiency and scalability. The BLM was also able to develop standardized protocols at national levels because of the relative homogeneity in ecological drivers, stressors, and ecological attributes of relevance for management decision-making across its holdings in the arid interior west. In both cases, the level at which each agency invested in technical capacity and developed implementation settings was the lowest level at which they could both afford to do so, and “match” I&M implementation settings to the scale of resources of relevance for decision-making and compliance with legislative mandates (i.e. rare species on National Parks, BLM field offices, Sage Grouse habitat). This implies there is strong relationship between the scale of assessment, institutional capacity, and ecological heterogeneity. Thus, we suggest that investment in technical capacity needed for I&M design increases towards lower levels of governance with the diversity and spatial heterogeneity of measureable ecological attributes of relevance for decision-making.

There are also important differences in policy tools used at the operational level of governance. Within the NPS, there are few formal tools used to coordinate implementation among unit-level staff; Network staff provide information to unit staff. In contrast, the BLM uses a mix of policy tools that target operational staff, such as requirements for using AIM for Sage Grouse conservation and unit-level land management planning, needs based funding, and implementation guidance. The decision to utilize AIM at management scales also remains with line-officers. Indeed, the use of AIM for management effectiveness monitoring and adaptive management is highly context-dependent (Gregory et al., 2006). AIM is costlier to implement than qualitative assessments of ecological condition, such as the BLM’s indicators of land health, and flexibility and discretion are needed to link implementation strategies to specific decision-making contexts. Capacity tools, such as AIM coordinators, implementation guidance, and needs-based funding are therefore essential for linking knowledge to action.

These differences in policy tools are a product of each agency’s unique administrative context and constraints (Howlett, 2011). The NPS’ preservationist mission and limited management footprint reduces the need for management effectiveness monitoring, and formal tools for linking monitoring to management decision-making. Once designed, long-term monitoring is by nature inflexible. The BLM on the other hand, is a multiple-use agency with a large management footprint, and flexibility for management effectiveness monitoring is essential for informing management and planning decisions. As a result, additional capacity and authority tools that target unit-level staff are needed to support implementation, and link monitoring information to decision-making. This suggests that different tools are needed at different levels of governance to support multiscale I&M. While centralized capacity and authority for implementation is needed to coordinate long term and broad-scale monitoring, and generate information for decision-makers at constitutional and organizational levels of governance, an additional mix of authority and capacity tools that target operational staff are needed to support management effectiveness monitoring.

Differences in administrative contexts, policy tools, and implementation processes are reflected in the scale, scope, and distribution of I&M outputs and outcomes. The BLM's standardized implementation approach, for instance, has allowed the agency to generate information on ecological trends and conditions at multiple scales (250 acres to west-wide). However, there are tradeoffs in terms of the scope of outputs produced. AIM information products are limited to core attributes of ecological aquatic and terrestrial ecological integrity of relevance for management decision-making across the agency's ownership. The primary output at unit levels is also often data, rather than interpretable information, and some respondents noted that there remain challenges for effective interpretation and analysis by unit level staff. The more voluntary and needs- based funding approach to AIM adoption initially pursued by the BLM has also meant that AIM intensification has been mediated by variables such as the presence of Sage Grouse, commitment and leadership from line officers, and funding support from the national office. In contrast, systematic funding and network capacity in the NPS I&M program has resulted in outputs that encompass a broader scope of ecological resources. In addition to indicators of aquatic and terrestrial health, many networks in the arid Intermountain West also monitor climate change, air quality, wildlife species, and unique ecosystems such as desert springs. Information is also often packaged in formats tailored to a broader scope of policy targets (i.e. managers, scientists, and stakeholders). However, while the network- based structure has allowed for the generation of outputs on a broad scope of resources, it has also created tradeoffs with scalability; aggregating information associated with common vital signs to national levels has been complicated by differences in measurement protocols across networks. Thus, different policy designs have tradeoffs in terms of the scale and scope of information outputs that must be carefully balanced with information needs at different levels of governance.

There are also tradeoffs with outcomes. In the NPS, the program's autonomy and singular emphasis on long-term monitoring has created challenges for linking monitoring information to fine-scale management decision-making. Additional funding for management effectiveness monitoring has not materialized as originally expected (Fancy and Bennetts, 2012). Formal tools for linking monitoring information to decision-making processes have also been contested by line officers, an issue some respondents noted may create challenges for ensuring information is linked to park management decision-making. In contrast, the BLM has utilized authority and capacity tools to link AIM implementation to regulatory requirements for land management planning. However, the use of authority tools that compel management action have been politically contentious; the Trump administration has questioned the need for hard and soft "triggers" that compel changes in management actions, and has filed a notice of intent to revise Sage Grouse plan amendments (Streater, 2017). This suggests that there are tradeoffs with the use of formal and informal tools for linking knowledge to action; while informal processes may be less politically contentious, they may be less effective for ensuring systematic knowledge utilization.

In summary, our findings suggest that centralized and autonomous multilevel administrative structures, and formalized collaborative processes dedicated to I&M represent important policy tools for multiscale knowledge management in federal land management agencies. However, different "mixes" of policy tools must be tailored to specific administrative contexts, and policy tool choice has important implications for the scale, scope, and distribution of outputs and outcomes.

4.5.2. Implications for research on public policy, environmental governance, and knowledge management

Scholars of public policy note that outside of broad generalities, little is known about what constitutes well-designed policies, or how policy tools influence implementation processes, outputs, and outcomes in different administrative settings (May, 2013; Voncoppennelle et al., 2014). This research used Schneider and Ingram's policy tool framework to investigate the micro-level policy tools embedded across multiple levels of larger "macro-level" policy tools (such as direct government action and organizational design) and the ways in administrative settings shape policy tool selection and "calibration" (Salamon, 2002; Howlett, 2009). While Schneider and Ingram's framework is typically used to investigate policy tools that target actors in the private sphere, our findings suggest it is useful for analyzing implementation structures in public agencies. This approach is also useful for linking scholarship on policy design and public management, an important research agenda (Sowa and Liu, 2017; Weible et al., 2017); the case studies presented herein illustrate how authority and capacity tools interact with managerial discretion to influence implementation processes, outputs, and outcomes (Lynn et al., 2000; Moulton and Sandford, 2017). Our research also highlights the importance of conceptualizing policy design and implementation as iterative and interactive processes (Howlett, 2011). Despite the importance of this consideration, the two are often treated separately (Saetren, 2014). Knowledge management and learning in public organizations is also an understudied topic (Rashman et al., 2010; Siciliano, 2016). Our research contributes to the literature an example of policy tools and administrative practices that promote effective knowledge management across multiple levels of a federal organization. Given the recent attention to evidence based policy and decision-making in public sector organizations (e.g. Newman et al., 2017), we suggest policy design for multilevel knowledge management is an important area of inquiry for future research in this respect.

Adaptive governance scholars often emphasize the importance of legal reform for linking knowledge to action across scales of governance (DeCaro et al., 2017). Administrative laws that effectively balance stability and accountability with flexibility learning are thought to be essential for promoting adaptive practice (Benson and Garmestani, 2012; Chaffin et al., 2014). In our case studies, however, existing laws such as NEPA and the ESA have been enabling factors, rather than barriers (see Thomas, 2003). Indeed, our findings suggest there are important opportunities for improving adaptive practice in existing institutions through administrative rather than legislative policy. This is an important consideration given the challenges for legal reform in the gridlocked U.S. context. Even if new “adaptive” legislation should come to pass, administrative policy design processes will nonetheless be essential. While legal scholars emphasize the importance of “guidelines” that provide flexibility for adaptive decision-making (Craig et al., 2017), guidelines for I&M and adaptive management are highly technical, and their development requires administrative knowledge and expertise. Operationalizing concepts such as resilience also requires partnerships and significant administrative capacity (Timberlake and Schultz, 2017; Moseley et al., 2016). Agency-specific legislation that provides clear guidance and funding for effective knowledge management may be more appropriate than the broad-scale reform of administrative law. As our findings demonstrate, policy tools must be tailored to unique institutional contexts, and research is needed on the organizational and operational policy tools to support adaptive within public agencies.

Scholars of adaptive governance and organizational knowledge management also emphasize the importance of decision-making flexibility for learning and adaption (Lockwood et al., 2010; Chaffin et al., 2014). Governance regimes and organizations characterized by centralized decision-making and highly formalized procedures are thought to lack flexibility for learning and adaptation (Chaffin et al., 2014; Pahl-Wostl et al., 2014). However, the use of decision-making flexibility as a learning tool is predicated on the assumption that policy actors have both the requisite capacity and commitment to use it as intended (Schneider and Ingram, 1990). This has been a persistent issue for ecological monitoring in the BLM and NPS; managers use their flexibility and decision-making discretion to allocate resources for short term management objectives, rather than knowledge management initiatives than can improve long-term performance (Biber, 2011). The BLM and NPS both addressed this issue by creating new centralized administrative structures dedicated to I&M knowledge management (see Cash and Moser, 2000). However, while authority for I&M implementation has been centralized, unit level staff still retain significant flexibility for management decision-making. This is an important consideration. While local decision-making flexibility is needed to support adaptive management and efficiently respond to disturbances and sudden events, vulnerabilities to climate change are unevenly distributed, and credible and comparable information is needed to inform resource allocation decisions for mitigation and adaptation at higher levels of governance (Hill and Engle, 2013). We suggest that centralized and hierarchical structures for knowledge management coupled with decision-making flexibility at local levels represent an importance balance between "top-down and bottom up" approaches for adaptive governance in state institutions. However, more research is needed to investigate this assertion, and the ways in which hierarchical governance structures undergird and interact with decentralized and polycentric decision-making regimes in complex institutional settings (Morrison et al., 2017).

Scholars of knowledge exchange and adaptive governance also emphasize the importance of networks and non-state intermediaries for the co-production, exchange, and application of knowledge (Fazey et al., 2013; Chaffin et al., 2014). An underlying assumption is that networks and intermediaries have the capacity, legitimacy, and commitment to steer collaborative processes and knowledge management initiatives across scales of governance. In our case studies, this has not been the case; administrative policy tools have been essential for leveraging external capacity and expertise and steering collaborative governance for multi-scale I&M in specific administrative contexts (Ansell and Gash, 2008). Furthermore, while networks and collaboration are essential for the design of I&M implementation strategies, effective monitoring requires consistent data collection and effective data management— routinized processes for which bureaucratic organizations often have advantages (Kettl, 2006; Pollitt, 2006). Administrative "knowledge brokers" located at scales that promote face-to-face interaction may also have advantages over external intermediaries for knowledge utilization, given their knowledge of administrative contexts, and legitimacy with managers. Administrative capacity for knowledge management is particularly important in spatially distributed governance contexts, such as the BLM's, where external scientific expertise is scarce or spatially heterogeneous. Indeed, our research suggests there are scale dependent advantages (and tradeoffs) associated with investment in knowledge brokering actors and processes at different levels of state institutions. However, as our findings are drawn from two federal land management agencies in the U.S., more research is needed to investigate opportunities for improving environmental knowledge exchange in other land management contexts (Wyborn and Dovers, 2014).

REFERENCES

Archie, K. M., Dilling, L., Milford, J. B., & Pampel, F. C. (2014). Unpacking the "information barrier": Comparing perspectives on information as a barrier to climate change adaptation in the interior mountain West. *Journal of Environmental Management*, *133*, 397–410.

Biber, E. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4), 68-84.

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network vital signs monitoring plan. (Natural resource report NPS/ROMN/NRR-2007/010.) Fort Collins: National Park Service

Bureau of Land Management, Wyoming State Office. (2016). *Wyoming Greater Sage Grouse Land Use Plan Amendment- Appendix D.* Washington, DC: BLM.

Bureau of Land Management. (2017). Terrestrial Assessment, Inventory, and Monitoring (AIM) 2017 Field Season Data Management Protocol. National Operations Center, Denver: Bureau of Land Management.

Bureau of Land Management. (2018). AIM Directory. Available at http://aim.landscapetoolbox.org/learn-3/contact/

Carter, S. K., Hickey, J., & Wood, D. J. (2017). Understanding a Landscape Approach to Resource Management in the Bureau of Land Management Prepared in cooperation with the Bureau of Land Management Multiscale Guidance and Tools for Implementing a Landscape Approach to Resource Management in the Bureau. *Open-File Report*, (January),

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., … Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proc Natl Acad Sci U S A*, *100*(14), 8086–8091. https://doi.org/10.1073/pnas.1231332100

Craig, R. K., Garmestani, A. S., Allen, C. R., Tony, A., Birgé, H., Decaro, D., … Gosnell, H. (2017). Balancing stability and flexibility in adaptive governance : The new challenges and a review of tools available, *22*(2), 1–31. https://doi.org/10.5751/ES-08983-220203

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship : synthesis and future directions A decade of adaptive governance scholarship : synthesis and future directions, *19.*

Clarke, J. N., & McCool, D. (1996). *Staking out the terrain: power and performance among* *natural resource agencies*. SUNY Press.

Collier, D. (2011). Understanding process tracing. *PS: Political Science & Politics*, *44*(4), 823-830.

DeCaro, D., Arnold, C., Frimpong Boamah, E., & Garmestani, A. (2017). Understanding and applying principles of social cognition and decision making in adaptive environmental governance. *Ecology and Society*, *22*(1).

Tansey, O. (2007). Process tracing and elite interviewing: a case for non-probability sampling. *PS: Political Science & Politics*, *40*(4), 765-772.

Dilling, L., Lemos, M. C., Carmen, M., Lemos, M. C., Carmen, M., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689.

Failing, L., & Gregory, R. (2003). Ten common mistakes in designing biodiversity indicators for forest policy. *Journal of Environmental Management*, *68*(2), 121–132.

Fancy, S. G., & Bennetts, R. E. (2012). Institutionalizing an effective long-term monitoring program in the U.S. National Park Service. *Design and Analysis of Long-Term Ecological Monitoring Studies*, 481–487.

Fancy, S. G., Gross, J. E., & Carter, S. L. (2009). Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1–4), 161–174.

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C. L., … Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*, *40*(1), 19–36.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of socioecological systems. *Annual Review of Environment and Resources*, *30*(1), 441–473.

Garrett, L. K., T. J. Rodhouse, G. H. Dicus, C. C. Caudill, and M. R. Shardlow. 2007. Upper Columbia Basin Network vital signs monitoring plan. Natural Resource Report NPS/UCBN/NRR—2007/002. National Park Service, Fort Collins, Colorado

Gregory, R., Failing, L., Ohlson, D., & Mcdaniels, T. L. (2006). Some Pitfalls of an Overemphasis on Science in Environmental Risk Management Decisions. *Journal of Risk Research*, *9*(7), 717–735.

Gregory, R., Ohlson, D., & Arvai, J. (2006). Deconstructing adaptive management: criteria for applications to environmental management. *Ecological Applications*, *16*(6), 2411-2425.

Lynn, L. E. J., Heinrich, C. J., Hill, C. J., & Jr (2000). Studying Governance and Public Management: Challenges and Prospects. *Journal of Public Administration Research and Theory*, *10*(2), 233–261.

Hicklin, A., & Godwin, E. (2009). Agents of change: The role of public managers in public policy. *Policy Studies Journal*, *37*(1), 13–20.

Hill, H. C. (2003). Understanding Implementation: Street-Level Bureaucrats' Resources for Reform. *Journal of Public Administration Research and Theory*, *13*(3), 265–282.

Hill, M., & Engle, N. L. (2013). Adaptive Capacity: Tensions across Scales. *Environmental Policy and Governance*, *23*(3).

Hill, M. J., & Hupe, P. L. (2014). *Implementing public policy: governance in theory and practice*.

Howlett, M. (2009). Governance modes , policy regimes and operational choice and policy design, 73–89.

Howlett, M. (2010). *Designing public policies: Principles and instruments*. Routledge.

Howlett, M. (2000). Managing the "hollow state": procedural policy instruments and modern governance. *Canadian Public Administration*, *43*(4), 412–431.

Howlett, M., & Rayner, J. (2007). Design Principles for Policy Mixes: Cohesion and Coherence in "New Governance Arrangements." *Policy and Society*, *26*(4), 1–18.

Howlett, M., Kim, J., & Weaver, P. (2006). Assessing instrument mixes through program- and agency-level data: Methodological issues in contemporary implementation research. *Review of Policy Research*, *23*(1), 129–151.

Howlett, M., Vince, J., & Del Río, P. (2017). Policy Integration and Multi-Level Governance: Dealing with the Vertical Dimension of Policy Mix Designs. *Politics and Governance*, *5*(2), 69.

Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management*, *289*, 183–189.

Joyce, L. A., Blate, G. M., McNulty, S. G., Millar, C. I., Moser, S., Neilson, R. P., & Peterson, D. L. (2009). Managing for multiple resources under climate change: National forests. *Environmental Management*, *44*(6), 1022–1032.

Kettl, D. F. (2006). Managing boundaries in American administration: The collaboration imperative. *Public Administration Review*, *66*, 10–19.

Kingdon, J. (1984). *Agendas, alternatives and public policies*. New York, NY: Harper Collins.

Korhonen-Kurki, K., Brockhaus, M., Duchelle, A. E., Atmadja, S., Thuy, P. T., & Schofield, L. (2013). Multiple levels and multiple challenges for measurement, reporting and verification of REDD+. *International Journal of the Commons*, *7*(2), 344–366.

Lindenmayer, D. B., & Likens, G. E. (2010). The science and application of ecological monitoring. *Biological Conservation*, *143*(6), 1317–1328.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., & Griffith, R. (2010). Governance Principles for Natural Resource Management. *Society & Natural Resources*, *23*(10), 986–1001.

Lovett, G. M., Burns, D. A., Driscoll, C. T., Jenkins, J. C., Mitchell, M. J., Rustad, L., … Haeuber, R. (2007). Who needs environmental monitoring ? *Frontiers in Ecology and the Environment*, *5*(5), 253–260.

Lynn, L. E. J., Heinrich, C. J., Hill, C. J., & Jr, L. E. L. (2000). Studying Governance and Public Management: Challenges and Prospects. *Journal of Public Administration Research and Theory*, *10*(2), 233–261.

Lynn, L. E. J., & Robichau, R. W. (2013). Governance and organisational effectiveness: towards a theory of government performance. *Journal of Public Policy*, *33*(2), 201–228.

McDonnell, L. M., & Elmore, R. F. (1987). Getting the Job Done: Alternative Policy Instruments. *Educational Evaluation and Policy Analysis Summer*, *9*(2), 133–152.

Miller, K. M., Dieffenbach, F. W., Campbell, J. P., Cass, W. B., Comiskey, J. A., Matthews, E. R., ... & Schmit, J. P. (2016). National parks in the eastern United States harbor important older forest structure compared with matrix forests. *Ecosphere*, *7*(7).

Moseley, A., & James, O. (2008). Central state steering of local collaboration: Assessing the impact of tools of meta-governance in homelessness services in England. *Public Organization Review*, *8*(2), 117–136.

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(51), 22026–31.

Moulton, S., & Sandfort, J. R. (2017). The Strategic Action Field Framework for Policy Implementation Research. *Policy Studies Journal*, *45*(1), 144–169.

Morrison, T. H., Adger, W. N., Brown, K., Lemos, M. C., Huitema, D., Hughes, T. P., … Hulme, M. (2017). Mitigation and adaptation in polycentric systems: sources of power in the pursuit of collective goals. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(5), 1–16.

Moynihan, D. P. (2005). Goal-based learning and the future of performance management. *Public Administration Review*, *65*(2), 203–216.

National Park Service. (2008). *Data management guidelines for Inventory and Monitoring Networks*. Natural Resource Report. NPS/NRPC/NRR—2008/035. National Park Service. Fort Collins, Colorado.

National Park Service. (2012). *Guidance for designing an integrated monitoring program.* Natural Resource Report NPS/NRSS/NRR–545. National Park Service, Fort Collins, Colorado

Newman, J., Cherney, A., & Head, B. W. (2017). Policy capacity and evidence-based policy in the public service. *Public Management Review*, *19*(2), 157-174.

Nguyen, V. M., Young, N., & Cooke, S. J. (2016). A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. *Conservation Biology*, *0*(0),

Pablo, A. L., Reay, T., Dewald, J. R., & Casebeer, A. L. (2007). Identifying, enabling and managing dynamic capabilities in the public sector. *Journal of Management Studies*, *44*(5), 687–708.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365.

Pahl-Wostl, C., & Knieper, C. (2014). The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*, *29*, 139–154.

Pahl-Wostl, C., Becker, G., Sendzimir, J., & Knieper, C. (2013). How multi-level societal learning processes facilitate transformative change: a comparative case study analysis on flood management. *Ecol Soc*, *18*(4).

Parsons, D. J. (2004). Supporting basic ecological research in U.S. National Parks: challenges and opportunities. *Ecological Applications*, *14*(1), 5–13.

Patton, M. (2002). *Qualitative research & evaluation methods* (Third ed.). Thousand Oaks, CA: Sage Publications.

Pollitt, C. (2009). Bureaucracies remember, post-bureaucratic organizations forget? *Public Administration*, *87*(2), 198–218.

Rashman, L., Withers, E., & Hartley, J. (2009). Organizational learning and knowledge in public service organizations: a systematic review of the literature. *International Journal of Management Reviews*, *11*(4), 463–494.

Reed, M. S., Fazey, I., Stringer, L. C., Raymond, C. M., Akhtar-Schuster, M., Begni, G., … Wagner, L. (2013). Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development*, *24*(4), 307–322.

Saetren, H. (2014). Implementing the third generation research paradigm in policy implementation research: An empirical assessment. *Public Policy and Administration*, *29*(2), 84–105.

Salamon, L. M. (2002). The Tools of Government: A Guide to the New Governance. *The New Governance and the Tools of Public Action*, 1–47.

Schneider, A., Ingram, H., & Schneider and Helen Ingram, A. (1990). Behavioral Assumptions of Policy Tools. *Journal of Politics*, *52*(2), 510.

Sheelanere, P., Noble, B. F., & Patrick, R. J. (2013). Institutional requirements for watershed cumulative effects assessment and management: Lessons from a Canadian trans-boundary watershed. *Land Use Policy*, *30*(1), 67–75.

Siciliano, M. D. (2016). Ignoring the Experts: Networks and Organizational Learning in the Public Sector. *Journal of Public Administration Research and Theory*, 1-16.

Skillen, J.R. (2009). *The nation's largest landlord: The Bureau of Land Management in the American West*. University Press of Kansas.

Sowa, J. E., & Liu, J. (2017). Policy and Management: Considering Public Management and Its Relationship to Policy Studies. *Policy Studies Journal*, *45*(1), 74–100.

Streater, S. (2017). Zinke review team calls for big changes to Obama-era plans. *Environment & Energy Publishing*. Retrieved from http://www.eenews.net.

Taylor, J.J., Kachergis, E.J., Toevs, G.R., Karl, J.W., Bobo, M.R., Karl, M., Miller, S., and Spurrier, C.S. (2014). *AIM-monitoring: a component of the BLM assessment, inventory, and monitoring strategy. Technical Note 445.* US Department of Interior, Bureau of Land Mangement, National Operations Center, Denver, CO. BLM/OC/ST-14/003+ 1735.

Thomas, Craig W. (2003). *Bureaucratic Landscapes: Interagency Cooperation and the Preservation of Biodiversity*. Cambridge, MA: MIT Press.

Thomas, L, Marguerite N., Lauver, C., Monroe, A., Tancreto, J. Steven L. Garman1, Mark E. Miller. (2006) Vital Signs monitoring report for the southern Colorado Plateau. National Park Service, Southern Colorado Plateau Network.

Toevs, G.R., Karl, J.W., Taylor, J.J., Spurrier, C.S., Karl, M.S., Bobo, M.R., and Herrick, J.E. (2011). Consistent indicators and methods and a scalable sample design to meet assessment, inventory, and monitoring information needs across scales. *Rangelands*, 33(4), 14-20.

Tulloch, A., Possingham, H. P., & Wilson, K. (2011). Wise selection of an indicator for monitoring the success of management actions. *Biological Conservation*, *144*(1), 141–154.

Vancoppenolle, D., Sætren, H., & Hupe, P. (2015). The Politics of Policy Design and Implementation: A Comparative Study of Two Belgian Service Voucher Programs. *Journal of Comparative Policy Analysis: Research and Practice*, *17*(2), 157–173.

Veblen, K. E., Pyke, D. A., Aldridge, C. L., Casazza, M. L., Assal, T. J., & Farinha, M. A. (2014). Monitoring of Livestock Grazing Effects on Bureau of Land Management Land. *Source: Rangeland Ecology & Management Rangeland Ecol Manage*, *67*(67), 68–7768.

Vogel, B., & Henstra, D. (2015). Studying local climate adaptation: A heuristic research framework for comparative policy analysis. *Global Environmental Change*, *31*, 110–120.

Weber, E., & Khademian, AM. (2008). Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review*, *68*(2), 334–349.

Westgate, M. J., Likens, G. E., & Lindenmayer, D. B. (2013). Adaptive management of biological systems: A review. *Biological Conservation*, *158*, 128–139

Wurtzebach, Z., & Schultz, C. (2016). Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. *BioScience*, *66*(6), 446–457.

Wyborn, C., & Dovers, S. (2014). Prescribing adaptiveness in agencies of the state. *Global Environmental Change*, *24*(1), 5–7.

CHAPTER 5: CONCLUSION

5.1. Summary

Adaptive governance is predicated on the effective creation, transmission, and use of ecological knowledge from multiple scales across multiple levels of institutional decision-making (Folke et al., 2005). Within the context of public land management agencies, this will require careful attention to policies that support effective monitoring programs and the development of collaborative networks. A key question is how agencies can move towards adaptive governance and what internal and external variables support this evolution. This research pursued this line of inquiry by investigating challenges and opportunities for improving knowledge management for multiscale ecological inventory and monitoring in the US Forest Service, the Bureau of Land Management, and the National Park Service.

In chapter 2 and 3, I investigated institutional challenges and opportunities for improving multiscale knowledge management in the context of national forest planning. My analysis highlighted several institutional challenges for each of the following steps of the knowledge management process: design, data collection, data management, analysis, translation and communication, interpretation, and application. I found that internal and external human and technological resource limitations, incentives for management outputs, decentralized decision-making structures, and a culture of local autonomy all complicate effective forest plan and broader scale monitoring in the U.S. Forest Service. Despite these challenges, there are several strategies forests and Regions have utilized to support effective knowledge management for forest planning. At forest levels, collaboration with boundary organizations and local stakeholders have resulted in monitoring strategies that are feasible, cost-effective, and relevant for forest planning. At regional levels, investment in "administrative knowledge brokers"— staff dedicated to monitoring coordination, data management, and analysis— has generated efficiencies, and alleviated scalar mismatches between monitoring and decision-making. Formalized processes that involve line officers and external scientists and partners have also been essential for the development of innovative multi-unit monitoring strategies linked to planning components. However, given the absence of additional funding for implementation, the development of these strategies is contingent upon leadership commitment and support. The benefits for efficiency and effectiveness, however, may make investment in nested knowledge management structures and processes actionable under existing budgetary constraints.

My findings also highlight several problematic assumptions and conceptualizations found in the literature on environmental knowledge management literature. Scholars of knowledge management often conceptualize different actors as knowledge users, producers, and intermediaries. However, these distinctions are heavily blurred in the context of multiscale ecological monitoring. I suggest that it is more useful to analyze the different capabilities diverse actors have for specific steps in the knowledge management processes. Given the complexity of this challenge, and the absence of external capacity for knowledge brokering in many land management contexts, investment in administrative knowledge brokers is essential for linking internal and external knowledge and expertise to knowledge management and decision-making processes.

In chapter 4, I utilized Schneider and Ingram's (1990) framework to investigate the policy design processes and policy tools used to support multiscale inventory and monitoring programs in the Bureau of Land Management and the National Park Service. Both agencies were faced with a similar problem: limited commitment and capacity for I&M implementation among staff at the operational level of governance. In each case, administrative actors utilized windows of opportunity provided by legislation (in the case of the NPS) or criticism from the executive branch (in the case of the BLM) to secure resources and a mandate for policy design. This allowed them to utilize several learning tools to develop the core policy tools associated with each program. There were several common tools used by each agency: a clear mission and goals for I&M linked to agency mission and legal mandates (i.e. a hortatory tool); funding and specialized staffing positions dedicated to inventory and monitoring at multiple levels of administration (i.e. a capacity tool); and centralized authority for implementation and budgetary allocation (i.e. an authority tool). These tools allow I&M staff to ensure accountability, capacity, and commitment for long term and broad-scale monitoring implementation. However, there are also differences in policy tools and the level at which they are utilized—a product of each agency's unique administrative context and constraints. The BLM centralized technical capacity and developed standardized implementation settings at the national level of organizational governance, while the NPS invested in technical capacity and developed implementation settings in each of it's 32 Networks. The BLM also uses an additional mix of capacity tools that target staff at the operational level of governance, contexts where flexibility is needed for management effectiveness monitoring. These include targeted funding, formalized implementation guidance, and regulations linking implementation and monitoring information to statutory requirements for planning and species conservation. These differences in policy tools are evident in tradeoffs associated with the scale and scope of information outputs and outcomes.

5.2. Research Considerations

My multiscale, qualitative case studies were useful for identifying institutional challenges, cross-level interactions, and policy tools for multiscale knowledge management in the BLM, USFS, and NPS. There are few studies of public sector knowledge management that examine interactions across levels of administration (Rashman et al., 2010), and my findings suggest this approach is important for understanding knowledge management dynamics in complex multilevel administrative contexts. There are also some limitations associated with my research approach. First, federal land management organizations in the U.S. are unique, and therefore my findings may not be applicable in other contexts. Secondly, while my qualitative and exploratory approach was useful for identifying critical barriers and policy tools for effective knowledge management, I was unable to systematically investigate the relative influence of different variables, such as managerial discretion, internal and external capacity, and organizational structure and culture on knowledge management outputs and outcomes. Future research that utilizes large N surveys of public sector employees may be useful for investigating the influence and interrelationship between critical institutional variables associated with knowledge management in other administrative contexts, particularly at the operational level of governance. Furthermore, given that my research focused on scientific knowledge associated with ecological monitoring, I was unable to investigate the ways tacit and experiential knowledge is integrated with formal scientific knowledge during monitoring design and interpretation. This remains an important area for future research for both practice and theory (Raymond et al. 2010). Guidelines for when to use different types of assessment and monitoring strategies (either qualitative and individual, or scientific and collective), and strategies for evaluating and interpreting diverse sources of information from different resources and scales are needed to help land management staff effectively link knowledge to action at the operational level of governance.

Collectively, my findings highlight important opportunities for integrating scholarship on policy design and public management with scholarship on adaptive governance and environmental knowledge management. For instance, my research suggests that public policy and administration frameworks, and a focus on state institutions is useful for operationalizing broad indicators of adaptive governance and adaptive capacity such as learning and flexibility for policy and practice—an important research agenda (Decaro et al., 2017; Dovers and Wyborn, 2014; Engle and Lemos, 2010; Morrison et al., 2017). In the context of ecological monitoring, for instance, my research suggests it is more appropriate to characterize "learning" as a set of implementation processes, and to treat knowledge as a commodity or "output". This draws attention to the policy tools, capabilities and tasks needed to link each step in the knowledge management process (Gerlak and Heikkila, 2013).

A policy design and public management lens is also useful for investigating fine-grain structures of discretion and hierarchical authority (i.e. flexibility and stability) in multiscale governance regimes (see Young, 2002). As my research demonstrates, there are important distinctions associated with authority and discretion for specific governance functions across levels of governance, even within an individual agency. One important distinction is between authority and discretion for substantive management functions and knowledge management functions; centralized knowledge management structures, for instance may coexist with and undergird decentralized management decision-making structures. Even within knowledge management structures, "flexibility" may refer to discretion for budgetary allocation, implementation design, or actual implementation, and there are important implications for outputs and outcomes associated with who has discretion for these functions at different levels of governance. However more research is needed to investigate this proposition in other contexts, and the ways in which top-down policy and state authority undergird and support novel forms of collaborative environmental governance (Morrison et al, 2017). The BLM's AIM program, for instance, is a fundamental source of information in the polycentric governance context of Sage Grouse conservation.

Another important consideration for future research is the distinction is between different types of capacity, and its relationship to structures of authority and discretion. Within the context of knowledge management, technical and managerial capacity needed for analysis, data management, and partnership coordination, for instance, may be contrasted with basic human resource capacity needed for data collection--a routinized process. The former is far scarcer, internally and externally to organizations, then the latter. Yet it is essential for the effective use of decision-making flexibility for adaptive practice; effective knowledge management and adaptive decision-making fundamentally depend on the capacity and ability of institutional actors to generate knowledge, and use it to develop new practices and procedures that can be implemented with basic human resources. This is essential for linking knowledge to action (Dovers and Wyborn, 2014). Therefore, as flexibility for decision-making within a governance institution increases towards lower levels of governance, so to do technical and managerial capacity requirements needed for adaptive practice; my findings suggest managerial requirements increase with the availability of external expertise, while internal technical capacity requirements increase in its absence. This raises an interesting question for future research on institutional adaptation and adaptive governance: to what extent are centralized governance regimes and rigid practices and procedures a cause of maladaptive governance, or merely a symptom of limited institutional capacity?

My research also suggests that the need for flexibility for knowledge management and adaptive practice in environmental contexts is shaped by the scalar nature of the resources being governed; as the diversity and spatial heterogeneity in measurable resources of relevance for decision-making increases, so does the need for flexibility and technical and managerial resource capacity for knowledge management. The level at which technical and managerial capacity for knowledge management is located in an institutional setting should therefore reflect a balance between available expert capacity, and the scalar dimensions of relevant resources. Indeed, my research suggests that rather than match the scale of governance regimes to the scale of "bioregions" or ecological resources (Huitema et al., 2009), it is more feasible and efficient to develop knowledge management systems and centralize technical and managerial capacity at a level of governance that encompasses the scale of measurable attributes of relevance for decision-making across multiple venues. Measures of stream temperature, canopy cover, and bare ground are all important indicators of ecological health, and if measured the same way, can be used to generate comparable and consistent information across decision-making venues. This is an important consideration in an era of climate change; scalable and comparable information on ecological trends and conditions is needed to inform efficient and effective resource allocation decisions for climate change adaptation. These considerations imply the need for top-down and nested knowledge management institutions, with administrative knowledge brokers at lower levels responsible for the design and coordination of knowledge management strategies within specific decision-making venues. However, more research will be needed to verify these propositions for multiscale knowledge management systems in other contexts.

A public policy perspective is also important for investigating issues associated with politics and power often neglected by scholars of adaptive governance and institutional adaptation (Morrison et al., 2017). Ecological inventory and monitoring, for instance, is in many ways a “policy without a public” (May, 1992). It is highly technical, often associated with abstract concepts such as ecological integrity, and its effects are not immediately evident--characteristics of issues that lack public salience, and receive limited attention on legislative agendas (Cobb and Elder 1972; May 1992). This suggests research on administrative policy design processes represents an important area for future research on knowledge management and adaptive governance. As the example of the BLM illustrates, there are important opportunities for building adaptive capacity in existing institutions through administrative rather than legislative policy. However, while policies without publics provide opportunities for apolitical administrative policy design, mobilizing constituencies is often imperative for institutionalization (May 1992). Multiscale, rather than single scale knowledge management systems may have advantages in this regard, given their ability cultivate “instrument constituencies” by generating information for decision-makers at multiple levels of governance. However, mobilizing additional constituencies, such as members of the public, requires effective communication strategies (Weiss 1994). This was cited as a particularly important consideration by the respondents in this study, and more research is needed to investigate and the ways in which citizen science, communication strategies, or co-production can be used to build political support for adaptive policies in state institutions. Similarly, there are different politics associated with knowledge generation versus knowledge application; the latter is often more politically contentious, as it may result in substantive changes to goods and services that affect actors in the private sphere (Biber, 2013. Indeed, scholars often distinguish between knowledge networks and political networks (Klijn and Koppenjan, 2012). The latter pursue policy change in existing institutions by expanding the scope of conflict, constructing constituencies for change across scales of social organization through strategic messaging, advocacy, networking and coalition building. They also engage in “venue shopping”, strategically pursuing policy change in decision-making venues in which it is most likely to occur (Pralle, 2006). Indeed, emergent collaboration for crossboundary resource governance often unavoidably requires agenda setting, and the mobilization of bias for collective action within each decision-making venue. Our understanding how these processes work in administrative contexts remains limited, and there are fruitful research opportunities for investigating how political networks and advocacy coalitions mobilize political support for cross-scale ecosystem management across polycentric decision-making venues, or build support for knowledge utilization and science application.

Policy diffusion and public sector innovation frameworks represent another important analytical lens for research on adaptive practice in state institutions (Devries et al., 2016; Shipan and Volden, 2012). The BLM, for instance, sought to learn from the NPS implementation approach during the early phases of policy design, and adopted several similar policy tools. However, there has been little research that investigates policy diffusion associated with administrative rather than legislative policy processes. Similarly, while decentralized and polycentric decision-making regimes may promote policy innovation and dissemination through networks, there may be challenges for scaling up innovations in the absence of hierarchical authority, particularly as non-state networks may lack legitimacy with actors in state institutions (Wyborn and Bixler, 2013). Research that investigates how innovations are promoted in public agencies may be an important area for future research in this regard, and insights from social psychology and behavioral economics may be instructive in this respect. The BLM, for instance, used a “bandwagon effect” to spur AIM adoption (Geels 2005). In the early phases of implementation, the agency utilized a voluntary approach to AIM adoption, relying on leadership and targeted funding. Some respondents noted that resistance to AIM soon diminished because “other units were all doing it”. Once sufficiently established and accepted, the BLM then used an authority tool to mandate adoption for land management planning system-wide. By building support slowly and incrementally, they were available to avoid internal resistance to a coercive top-down mandate. A similar “band-wagon” effect has been also observed in other multiscale monitoring contexts (Wurtzebach and Schultz, 2016).

Finally, my findings underscore the importance of understanding the actual behaviors of policy targets, and the agency of government actors in structuring collective action. This consideration is often ignored in normative theories of adaptive institutional design, though it is often emphasized in scholarship on policy design and implementation (Elmore, 1979; Folke et al., 2005; Howlett, 2011; Morrison et al., 2017). Research on adaptive governance, for instance, often utilizes a “top-down” and prescriptive macro-level approach. Yet a central finding of policy implementation research is the limitations of statutory language alone in influencing governance outcomes (Sabatier, 1986). Indeed, there are implicit behavioral assumptions embedded within current conceptualizations of adaptive governance that are problematized by my research. The primary role of non-state actors and bridging organizations, for instance, is predicated on the assumption that they have the capacity and commitment to link knowledge to action across scales of governance. Similarly, calls for the devolution of authority imply institutional actors have the capacity and commitment to use their discretion accountably. As administrative actor’s behaviors are shaped by the unique institutional contexts in which they are embedded, further research on policy design and implementation in state institutions that utilize both “bottom-up” and “top-down” approaches is needed to identify policy tools for adaptive practice that are appropriate for specific contexts.

5.3. Conclusion

Adaptive governance emphasizes “the ability to observe and interpret essential processes and variables in ecosystem dynamics to develop the social capacity to respond to environmental feedback and change” (Folke et al., 2005:445). This requires institutions with the ability to generate and link knowledge on ecological trends and conditions to planning and decision-making processes at different levels of governance (Raymond et al., 2010; Fazey et al., 2014). However, there has been little investigation of opportunities for improving the knowledge to action gap in existing state institutions through purposive policy design and administrative practice (Wyborn and Dovers, 2014; Morrison et al., 2017).

This dissertation investigated challenges and opportunities for closing the knowledge to action gap in federal public land management through the design and implementation of multiscale ecological monitoring policies. In chapters 2 and 3, I show how administrative knowledge brokers and knowledge brokering processes are essential for coordinating complex knowledge management processes among diverse actors internal and external to the US Forest Service. In Chapter 4, I show how the NPS and BLM developed policy tools to address scalar challenges for monitoring implementation. Collectively, these findings contribute to the natural resource management literature examples of policy tools and administrative practices that can support effective ecological monitoring at multiple levels of decision-making—a critical gap in the literature (Biber, 2013). My findings suggest that there are scale dependent advantages for investment in multiscale knowledge brokering structure and processes internal to land management institutions at different levels of governance, though there are tradeoffs with different mixes and arrangements of policy tools that must be carefully negotiated in different administrative contexts.

This research also highlights several important considerations for future research on environmental governance. A current focus in much of the literature is on decision-making flexibility, legal reform, and the roles of non-state actors and networks—variables that are thought to promote adaptive decision-making, and allow governance regimes to "fit" the scale of resource challenges through emergent collaboration and coordination (Folke et al., 2005; Chaffin et al., 2014). However, my research highlights the important role of policy and hierarchical governance for adaptive practice in state institutions. Administrative policy makers are perfectly capable of designing multiscale mixes of policy tools needed to address scalar mismatches, facilitate collaboration with external actors, and link knowledge to action across levels of governance—tools that are coherent and consistent with existing legal frameworks, and tailored for specific administrative contexts. Policy tools such hierarchical authority and administrative capacity are needed to exploit external sources of knowledge and expertise, and coordinate knowledge management processes across scales of governance. However, more research on knowledge management and adaptive governance focused on the organizational level of governance in state institutions is needed to investigate these assertions in other institutional settings.

REFERENCES

Biber, Eric. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4).

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120.

Chaffin, B. C., Gosnell, H., Cosens, B. A., Works, M., & Situating, A. G. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society*, *19*(3), 56.

Decaro, D., Chaffin, B. C., Schlager, E., Garmestani, A. S., & Ruhl, J. B. (2017). Legal and Institutional Foundations of Adaptive Environmental Governance. *Ecology and Society*, *22*(1), 1689–1699.

De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the public sector: A systematic review and future research agenda. *Public Administration*, *94*(1), 146-166.

Elmore, R. F. (1979). Backward mapping: Implementation research and policy decisions. *Political Science Quarterly*, *94*(4), 601–616.

Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*, *20*(1), 4–13.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*(1), 441–473.

Heikkila, T., & Gerlak, A. K. (2013). Building a conceptual approach to collective learning: Lessons for public policy scholars. *Policy Studies Journal*, *41*(3), 484–512.

Geels, F. W. (2005). Processes and patterns in transitions and system innovations: refining the co-evolutionary multiscale perspective. *Technological forecasting and social change*, *72*(6), 681-696

Howlett, Michael. (2009). Governance modes, policy regimes and operational plans: A multiscale nested model of policy instrument choice and policy design. *Policy Sciences*, *42*(1), 73–89.

Howlett, M. (2011). *Designing public policies: Principles and instruments*. Routledge.

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: assessing the institutional prescriptions of adaptive (co-)

management from a governance perspective and defining a research agenda. *Ecology and Society*, *14*(1), 26.

Klijn, E.H., & Koppenjan, J. (2012). Governance Network Theory: Past , Present and Future. *Policy and Politics*, *40*(4), 187–206.

May, P. J. (1992). Policy Learning and Failure. *Journal of Public Policy*, *12*(4), 331.

Morrison, T. H., Adger, W. N., Brown, K., Lemos, M. C., Huitema, D., Hughes, T. P., Hulme, M. (2017). Mitigation and adaptation in polycentric systems: sources of power in the pursuit of collective goals. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(5), 1–16

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, *91*(8), 1766–1777.

Sabatier, P. (1986). Top-Down and Bottom-Up Approaches to Implementation Research: a Critical Analysis and Suggested Synthesis. *Journal of Public Policy*, *6*(1), 21.

Shipan, C. R., & Volden, C. (2008). The mechanisms of policy diffusion. *American journal of political science*, *52*(4), 840-857.

Voß, J.-P. P., & Simons, A. (2014). Instrument constituencies and the supply side of policy innovation: the social life of emissions trading. *Environmental Politics*, *23*(5), 735–754.

Weiss, J. A., & Tschirhart, M. (1994). Public information campaigns as policy instruments. *Journal of Policy Analysis and Management*, *13*(1), 82–119.

Wurtzebach, Z., & Schultz, C. (2016). Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. *BioScience*, *66*(6), 446–457.

Wyborn, C., & Dovers, S. (2014). Prescribing adaptiveness in agencies of the state. *Global Environmental Change*, *24*, 5–7.

BIBLIOGRAPHY

Agranoff, R. (2006). Inside Collaborative Networks: Ten Lessons for Public Managers. *Public Administration Review*, *66*(1), 56–65.

Ansell, C., & Gash, A. (2008). Collaborative governance in theory and practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571.

Archie, K. M., Dilling, L., Milford, J. B., & Pampel, F. C. (2014). Unpacking the "information barrier": Comparing perspectives on information as a barrier to climate change adaptation in the interior mountain West. *Journal of Environmental Management*, *133*, 397–410.

Benson, M. H., & Garmestani, A. S. (2011). Can we manage for resilience? The integration of resilience thinking into natural resource management in the United States. *Environmental Management*, *48*(3), 392–399

Berends, H., Boersma, K., & Weggeman, M. (2003). The Structuration of Organizational Learning. *Human Relations*, *56*(9), 1035–1056.

Biber, E. (2009). Too Many Things to Do: How to Deal with the Dysfunctions of Multiple-goal Agencies. *Harvard Environmental Law Review*, *33*(1), 1–63.

Biber, E. (2013). The Challenge of Collecting and Using Environmental Monitoring Data. *Ecology and Society*, *18*(4), art68.

Bolson, J., & Broad, K. (2013). Early adoption of climate information: Lessons learned from south florida water resource management. *Weather, Climate, and Society*, *5*(3), 266–281.

Bornbaum, C. C., Kornas, K., Peirson, L., & Rosella, L. C. (2015). Exploring the function and effectiveness of knowledge brokers as facilitators of knowledge translation in health-related settings: a systematic review and thematic analysis. *Implementation Science: IS*, *10*, 162-188.

Brown, M. M., & Brudney, J. L. (2003). Study Organizations in the Public Sector ? Information of Police Agencies Advance Employing Knowledge Technology to. *Public Administration Review*, *63*(1), 30–43.

Britten, M., E. W. Schweiger, B. Frakes, D. Manier, and D. Pillmore. 2007. Rocky Mountain Network vital signs monitoring plan. (Natural resource report NPS/ROMN/NRR-2007/010.) Fort Collins: National Park Service

Bureau of Land Management, Wyoming State Office. (2016). *Wyoming Greater Sage Grouse Land Use Plan Amendment- Appendix D.* Washington, DC: BLM.

Bureau of Land Management. (2017). Terrestrial Assessment, Inventory, and Monitoring (AIM) 2017 Field Season Data Management Protocol. National Operations Center, Denver: Bureau of Land Management.

Burgess, N., & Currie, G. (2013). The knowledge brokering role of the hybrid middle level manager: The case of healthcare. *British Journal of Management*, *24*(S3), 132–143.

Carrington, P. J., Scott, J., & Wasserman, S. (2005). Models and Methods in Social Network Analysis. Cambridge University Press.

Carter, S. K., Hickey, J., & Wood, D. J. (2017). Understanding a Landscape Approach to Resource Management in the Bureau of Land Management. *Multiscale Guidance and Tools for Implementing a Landscape Approach to Resource Management in the Bureau of Land Management. Open-File Report*, (January), 79.

Cash, D. W., & Moser, S. C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, *10*(2), 109–120. .

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proc Natl Acad Sci U S A*, *100*(14), 8086–8091.

Cash, DW., WN, A., Berkes, F., Garden, P., Lebel, L., Young, O. (2006). Scale and cross-scale dynamics: governance and information in a multiscale world. *Ecology and Society*, *11*(2), 8–19.

Chaffin, B. C., Gosnell, H., & Cosens, B. A. (2014). A decade of adaptive governance scholarship: Synthesis and future directions. *Ecology and Society*, *19*(3).

Chaffin, B. C., Gosnell, H., Cosens, B. A., Works, M., & Situating, A. G. (2014). A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society*, *19*(3), 56.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative research*. Sage Publications Ltd, London.

Cheng, A. S., Gerlak, A. K., Dale, L., & Mattor, K. (2015). Examining the adaptability of collaborative governance associated with publicly managed ecosystems over time: Insights from the front range roundtable, Colorado, USA. *Ecology and Society*, *20*(1).

Clarke, J. N., & McCool, D. (1996). *Staking out the terrain: power and performance among natural resource agencies*. SUNY Press.

Collier, D. (2011). Understanding process tracing. *PS: Political Science & Politics*, *44*(4), 823-830.

Contandriopoulos, D., Lemire, M., Denis, J. L., & Tremblay, É. (2010). Knowledge exchange processes in organizations and policy arenas: A narrative systematic review of the literature. *Milbank Quarterly*, *88*(4), 444–483.

Corona, P. (2010). Integration of forest mapping and inventory to support forest management. *IForest*, (*3*), 59–64.

Craig, R. K., Garmestani, A. S., Allen, C. R., Tony, A., Birgé, H., Decaro, D., … Gosnell, H. (2017). Balancing stability and flexibility in adaptive governance : The new challenges and a review of tools available, *22*(2), 1–31. https://doi.org/10.5751/ES-08983-220203

Dawes, S. S., Cresswell, A. M., & Pardo, T. A. (2009). From "need to know" to "need to share": Tangled problems, information boundaries, and the building of public sector knowledge networks. *Public Administration Review*, *69*(3), 392–402.

Dawes, S. S., Cresswell, A. M., & Pardo, T. A. (2009). From "need to know" to "need to share": Tangled problems, information boundaries, and the building of public sector knowledge networks. *Public Administration Review*, *69*(3), 392–402.

De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the public sector: A systematic review and future research agenda. *Public Administration*, *94*(1), 146-166.

Decaro, D., Chaffin, B. C., Schlager, E., Garmestani, A. S., & Ruhl, J. B. (2017). Legal and Institutional Foundations of Adaptive Environmental Governance. *Ecology and Society*, *22*(1), 1689–1699.

DeLuca, T. H., Aplet, G. H., Wilmer, B., & Burchfield, J. (2010). The Unknown Trajectory of Forest Restoration: A Call for Ecosystem Monitoring. *Journal of Forestry*, *108*(September), 288–295.

DeWalt, K. M., & DeWalt, B. R. (2002). *Participant Observation: A Guide for Fieldworkers*. *Participant Observation A guide for fieldworkers*. Rowman Altamira.

Dilling, L., Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, *21*(2), 680–689.

Doremus, H. (2008). Data gaps in natural resource management: Sniffing for leaks along the information pipeline. *Indiana Law Journal*, *83*(2), 407–463.

Edelenbos, J., van Buuren, A., & van Schie, N. (2011). Co-producing knowledge: Joint knowledge production between experts, bureaucrats and stakeholders in Dutch water management projects. *Environmental Science and Policy*, *14*(6), 675–684.

Elmore, R. F. (1979). Backward mapping: Implementation research and policy decisions. *Political Science Quarterly*, *94*(4), 601–616.

Engle, N. L., & Lemos, M. C. (2010). Unpacking governance: building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change*, *20*(1), 4–13.

Failing, L., & Gregory, R. (2003). Ten common mistakes in designing biodiversity indicators for forest policy. *Journal of Environmental Management*, *68*(2), 121–132.

Fancy, S. G., & Bennetts, R. E. (2012). Institutionalizing an effective long-term monitoring program in the U.S. National Park Service. *Design and Analysis of Long-Term Ecological Monitoring Studies*, 481–487.

Fancy, S. G., Gross, J. E., & Carter, S. L. (2009). Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment*, *151*(1–4), 161–174.

Fazey, I., Evely, A. C., Reed, M. S., Stringer, L. C., Kruijsen, J., White, P. C. L., Trevitt, C. (2013). Knowledge exchange: a review and research agenda for environmental management. *Environmental Conservation*, *40*(1), 19–36.

Fernandez, S., & Rainey, H. (2014). Theory to Practice Managing Successful Organizational Change in the Public Sector. *Public Administration Review*, *66*(2), 168–176.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources*, *30*(1), 441–473.

Fraser, E. D. G., Dougill, A. J., Mabee, W. E., Reed, M., & McAlpine, P. (2006). Bottom up and top down: Analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. *Journal of Environmental Management*, *78*(2), 114–127.

Garmestani, A. S., Allen, C. R., & Benson, M. H. (2013). Can law foster social-ecological resilience? *Ecology and Society*, *18*(2).

Garrett, L. K., T. J. Rodhouse, G. H. Dicus, C. C. Caudill, and M. R. Shardlow. 2007. Upper

Geels, F. W. (2005). Processes and patterns in transitions and system innovations: refining the co-evolutionary multiscale perspective. *Technological forecasting and social change*, *72*(6), 681-696

Goggin, M. L. (1990). *Implementation theory and practice: Toward a third generation*. Scott Foresman & Co.

Gregory, R., Failing, L., Ohlson, D., & Mcdaniels, T. L. (2006). Some Pitfalls of an Overemphasis on Science in Environmental Risk Management Decisions. *Journal of Risk Research*, *9*(7), 717–735.

Gregory, R., Ohlson, D., & Arvai, J. (2006). Deconstructing adaptive management: criteria for applications to environmental management. *Ecological Applications*, *16*(6), 2411-2425.

Heikkila, T., & Gerlak, A. K. (2013). Building a conceptual approach to collective learning: Lessons for public policy scholars. *Policy Studies Journal*, *41*(3), 484–512.

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, *142*(1), 14–32.

Hicklin, A., & Godwin, E. (2009). Agents of change: The role of public managers in public policy. *Policy Studies Journal*, *37*(1), 13–20.

Hill, H. C. (2003). Understanding Implementation: Street-Level Bureaucrats' Resources for Reform. *Journal of Public Administration Research and Theory*, *13*(3), 265–282.

Hill, M. J., & Hupe, P. L. (2014). *Implementing public policy: governance in theory and practice*. Sage Publishing, London.

Hill, M., & Engle, N. L. (2013). Adaptive Capacity: Tensions across Scales. *Environmental Policy and Governance*, *23*(3).

Holthausen, R., Czaplewski, R. L., DeLorenzo, D., Hayward, G., Kessler, W. B., Manley, P., & Van Horne, B. (2005). Strategies for monitoring terrestrial animals and habitats. *US Department of Agriculture, Forest Service, Rocky Mountain Research Station*.

Howlett, M. (2000). Managing the "hollow state": procedural policy instruments and modern governance. *Canadian Public Administration*, *43*(4), 412–431.

Howlett, M. (2009). Governance modes, policy regimes and operational plans: A multi-level nested model of policy instrument choice and policy design. *Policy Sciences*, *42*(1), 73-89.

Howlett, M. (2011). *Designing public policies: Principles and instruments*. Routledge.

Howlett, M., & Rayner, J. (2007). Design Principles for Policy Mixes: Cohesion and Coherence in "New Governance Arrangements." *Policy and Society*, *26*(4), 1–18.

Howlett, M., Kim, J., & Weaver, P. (2006). Assessing instrument mixes through program- and agency-level data: Methodological issues in contemporary implementation research. *Review of Policy Research*, *23*(1), 129–151.

Howlett, M., Vince, J., & Del Río, P. (2017). Policy Integration and Multi-Level Governance: Dealing with the Vertical Dimension of Policy Mix Designs. *Politics and Governance*, *5*(2), 69.

Howlett, Michael. (2009). Governance modes, policy regimes and operational plans: A multiscale nested model of policy instrument choice and policy design. *Policy Sciences*, *42*(1), 73–89.

Huitema, D., Mostert, E., Egas, W., Moellenkamp, S., Pahl-Wostl, C., & Yalcin, R. (2009). Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society*, *14*(1), 26.

Hutto, R. L., & Belote, R. T. (2013). Distinguishing four types of monitoring based on the questions they address. *Forest Ecology and Management*, *289*, 183–189.

Joyce, L. A., Blate, G. M., McNulty, S. G., Millar, C. I., Moser, S., Neilson, R. P., & Peterson, D. L. (2009). Managing for multiple resources under climate change: National forests. *Environmental Management*, *44*(6), 1022–1032.

Kettl, D. F. (2006). Managing boundaries in American administration: The collaboration imperative. *Public Administration Review*, *66*, 10–19.

Kim, S., & Lee, H. (2006). The impact of organizational context and information technology on employee knowledge-sharing capabilities. *Public Administration Review*, *66*(3), 370–385.

Kingdon, J. (1984). *Agendas, alternatives and public policies*. New York, NY: Harper Collins.

Klijn, E.H., & Koppenjan, J. (2012). Governance Network Theory: Past ,Present and Future. *Policy and Politics*, *40*(4), 187–206.

Korhonen-Kurki, K., Brockhaus, M., Duchelle, A. E., Atmadja, S., Thuy, P. T., & Schofield, L. (2013). Multiple levels and multiple challenges for measurement, reporting and verification of REDD+. *International Journal of the Commons*, *7*(2), 344–366.

Lee, H., & Choi, B. (2003). Knowledge management enablers, processes, and organizational performance: An integrative view and empirical examination. *Journal of Management Information Systems*, *20*(1).

Lindenmayer, D. B., & Likens, G. E. (2010). The science and application of ecological monitoring. *Biological Conservation*, *143*(6), 1317–1328.

Lindenmayer, D., Richard, J., Montague-, R., Alexandra, J., Bennett, A., Cale, P., Fischer, J. (2008). A checklist for ecological management of landscapes for conservation. *Ecology Letters*, *11*(1), 78–91.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., & Griffith, R. (2010). Governance Principles for Natural Resource Management. *Society & Natural Resources*, *23*(10), 986–1001.

Lovett, G. M., Burns, D. A., Driscoll, C. T., Jenkins, J. C., Mitchell, M. J., Rustad, L., Haeuber, R. (2007). Who needs environmental monitoring? *Frontiers in Ecology and the Environment*, *5*(5), 253–260.

Lynn, L. E. J., & Robichau, R. W. (2013). Governance and organisational effectiveness: towards a theory of government performance. *Journal of Public Policy*, *33*(2), 201–228.

Lynn, L. E. J., Heinrich, C. J., Hill, C. J., & Jr (2000). Studying Governance and Public Management: Challenges and Prospects. *Journal of Public Administration Research and Theory*, *10*(2), 233–261.

May, P. J. (1992). Policy Learning and Failure. *Journal of Public Policy*, *12*(4), 331.

May, P. J. (2012). Policy Design and Implementation. *The Sage Handbook of Public Administration*, 279–291.

McDonnell, L. M., & Elmore, R. F. (1987). Getting the Job Done: Alternative Policy Instruments. *Educational Evaluation and Policy Analysis Summer*, *9*(2), 133–152.

Miller, K. M., Dieffenbach, F. W., Campbell, J. P., Cass, W. B., Comiskey, J. A., Matthews, E. R., & Schmit, J. P. (2016). National parks in the eastern United States harbor important older forest structure compared with matrix forests. *Ecosphere*, *7*(7).

Mintzberg, H. (1980). Structure in 5's: A Synthesis of the Research on Organization Design. *Management Science*, *26*(3), 322–341.

Moir, W. H., & Block, W. M. (2001). Adaptive management on public lands in the United States: Commitment or rhetoric? *Environmental Management*, *28*(2), 141–148.

Morrison, T. H., Adger, W. N., Brown, K., Lemos, M. C., Huitema, D., Hughes, T. P., … Hulme, M. (2017). Mitigation and adaptation in polycentric systems: sources of power in the pursuit of collective goals. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(5), 1–16.

Moseley, A., & James, O. (2008). Central state steering of local collaboration: Assessing the impact of tools of meta-governance in homelessness services in England. *Public Organization Review*, *8*(2), 117–136.

Moser, S. C., & Ekstrom, J. A. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(51), 22026–31.

Moulton, S., & Sandfort, J. R. (2017). The Strategic Action Field Framework for Policy Implementation Research. *Policy Studies Journal*, *45*(1), 144–169.

Moynihan, D. P. (2005). Goal-based learning and the future of performance management. *Public Administration Review*, *65*(2), 203–216.

Moynihan, D. P. (2008). Learning under uncertainty: Networks in crisis management. *Public Administration Review*, *68*(2), 350–365.

Moynihan, D. P., & Landuyt, N. (2009). How Do Public Organizations Learn? Bridging Cultural and Structural Perspectives. *Public Administration Review*, *69*(6), 1097–1105.

National Park Service. (2008). *Data management guidelines for Inventory and Monitoring Networks*. Natural Resource Report. NPS/NRPC/NRR—2008/035. National Park Service. Fort Collins, Colorado.

National Park Service. (2012). *Guidance for designing an integrated monitoring program*. Natural Resource Report NPS/NRSS/NRR–545. National Park Service, Fort Collins, Colorado.

Newman, J., Cherney, A., & Head, B. W. (2017). Policy capacity and evidence-based policy in the public service. *Public Management Review*, *19*(2), 157-174.

Nguyen, V. M., Young, N., & Cooke, S. J. (2016). A roadmap for knowledge exchange and mobilization research in conservation and natural resource management. *Conservation Biology*, *0*(0),

Nie, M. A., & Schultz, C. A. (2012). Decision-Making Triggers in Adaptive Management. *Conservation Biology*, *26*(6), 1137–1144.

Niemeijer, D., de Groot, R. S., Groot, R. S. De, & de Groot, R. S. (2008). A conceptual framework for selecting environmental indicator sets. *Ecological Indicators*, *8*(1), 14–25.

Nylen, N. G. (2011). To Achieve Biodiversity Goals, the New Forest Service Planning Rule Needs Effective Mandates for Best Available Science and Adaptive Management. *Ecology Law Quarterly*, *38*(2), 241–291.

Pablo, A. L., Reay, T., Dewald, J. R., & Casebeer, A. L. (2007). Identifying, enabling and managing dynamic capabilities in the public sector. *Journal of Management Studies*, *44*(5), 687–708.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365.

Pahl-Wostl, C., & Knieper, C. (2014). The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change*, *29*, 139–154.

Pahl-Wostl, C., Becker, G., Sendzimir, J., & Knieper, C. (2013). How multi-level societal learning processes facilitate transformative change: a comparative case study analysis on flood management. *Ecol Soc*, *18*(4).

Parsons, D. J. (2004). Supporting basic ecological research in U.S. National Parks: challenges and opportunities. *Ecological Applications*, *14*(1), 5–13.

Patton, M. (2002). *Qualitative research & evaluation methods* (Third ed.). Thousand Oaks, CA.

Pee, L. G., & Kankanhalli, A. (2016). Interactions among factors influencing knowledge management in public-sector organizations: A resource-based view. *Government Information Quarterly*, *33*(1), 188–199.

Phillipson, J., Lowe, P., Proctor, A., & Ruto, E. (2012). Stakeholder engagement and knowledge exchange in environmental research. *Journal of Environmental Management*, *95*(1), 56–65.

Pollitt, C. (2009). Bureaucracies remember, post-bureaucratic organizations forget? *Public Administration*, *87*(2), 198–218.

Popper, M., & Lipshitz, R. (2000). Organizational Learning: Mechanisms, culture, and feasibility. *Management Learning*, *31*(2), 181–196.

Potter, K. M., Koch, F. H., Oswalt, C. M., & Iannone, B. V. (2016). Data, data everywhere: detecting spatial patterns in fine-scale ecological information collected across a continent. *Landscape Ecology*, *31*(1), 67–84.

Rashman, L., Withers, E., & Hartley, J. (2009). Organizational learning and knowledge in public service organizations: a systematic review of the literature. *International Journal of Management Reviews*, *11*(4), 463–494.

Rashman, L., Withers, E., & Hartley, J. (2009). Organizational learning and knowledge in public service organizations: a systematic review of the literature. *International Journal of Management Reviews*, *11*(4), 463–494.

Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, *91*(8), 1766–1777.

Reed, M. S., Fazey, I., Stringer, L. C., Raymond, C. M., Akhtar-Schuster, M., Begni, G., … Wagner, L. (2013). Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development*, *24*(4), 307–322.

Sabatier, P. (1986). Top-Down and Bottom-Up Approaches to Implementation Research: a Critical Analysis and Suggested Synthesis. *Journal of Public Policy*, *6*(1), 21.

Sabatier, P. A., Loomis, J., & McCarthy, C. (1995). Hierarchical Controls, Professional Norms, Local Constituencies, and Budget Maximization: An Analysis of U.S. Forest Service Planning Decisions. *American Journal of Political Science*, *39*(1), 204–242.

Saetren, H. (2014). Implementing the third generation research paradigm in policy implementation research: An empirical assessment. *Public Policy and Administration*, *29*(2), 84–105.

Salamon, L. M. (2002). The Tools of Government: A Guide to the New Governance. *The New Governance and the Tools of Public Action*, 1–47.

Sarewitz, D., & Pielke, R. a. (2007). The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science and Policy*, *10*, 5–16.

Schneider, A., Ingram, H. (1990). Behavioral Assumptions of Policy Tools. *Journal of Politics*, *52*(2), 510.

Schultz, C. (2010). Challenges in Connecting Cumulative Effects Analysis to Effective Wildlife Conservation Planning. *BioScience*, *60*(7), 545–551.

Schultz, C. A., Moseley, C., & Mattor, K. (2015). Journal of Natural Resources Policy Striking the balance between budgetary discretion and performance accountability: the case of the US Forest Service ’ s approach to integrated restoration. *Journal of Natural Resource Policy Research*, (April), 37–41.

Scott, J., Carrington, P. J., & Scott, J. (2011). The SAGE Handbook of social network analysis. Introduction. *The SAGE Handbook of Social Network Analysis*.

Sheelanere, P., Noble, B. F., & Patrick, R. J. (2013). Institutional requirements for watershed cumulative effects assessment and management: Lessons from a Canadian trans-boundary watershed. *Land Use Policy*, *30*(1), 67–75.

Shipan, C. R., & Volden, C. (2008). The mechanisms of policy diffusion. *American journal of political science*, *52*(4), 840-857.

Siciliano, M. D. (2016). Ignoring the Experts: Networks and Organizational Learning in the Public Sector. *Journal of Public Administration Research and Theory*, 1-16.

Skillen, J.R. (2009). *The nation's largest landlord: The Bureau of Land Management in the American West*. University Press of Kansas: Lawrence.

Sowa, J. E., & Liu, J. (2017). Policy and Management: Considering Public Management and Its Relationship to Policy Studies. *Policy Studies Journal*, *45*(1), 74–100.

Stankey, G. H., Bormann, B. T., Ryan, C., Shindler, B., Sturtevant, V., Clark, R. N., & Philpot, C. (2003). Adaptive management and the northwest forest plan. *Journal of Forestry*, (*101*), 40–46.

Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.N.; Philpot, C. . (2003). Adaptive management and the Northwest Forest Plan: rhetoric and reality. *Journal of Forestry*, *101*(1), 40–46.

Streater, S. (2017). Zinke review team calls for big changes to Obama-era plans. *Environment &*

Sutherland, W. J., Shackelford, G., & Rose, D. C. (2017). Collaborating with communities: co-production or co-assessment? *Oryx*, *51*(4), 569–570.

Tansey, O. (2007). Process tracing and elite interviewing: a case for non-probability sampling. *PS: Political Science & Politics*, *40*(4), 765-772.

Tsai, W. (2002). Social structure of "coopetition" within a multiunit organization: Coordination, competition, and intraorganizational knowledge sharing. *Organization science*, *13*(2), 179-190.

Tsoukas, H., & Vladimirou, E. (2001). What is organizational knowledge?. *Journal of management studies*, *38*(7), 973-993.

Tulloch, A., Possingham, H. P., & Wilson, K. (2011). Wise selection of an indicator for monitoring the success of management actions. *Biological Conservation*, *144*(1), 141–154.

Turnhout, E., Stuiver, M., Judith, J., Harms, B., & Leeuwis, C. (2013). New roles of science in society: Different repertoires of knowledge brokering. *Science and Public Policy*, *40*(3), 354–365.

Vancoppenolle, D., Sætren, H., & Hupe, P. (2015). The Politics of Policy Design and Implementation: A Comparative Study of Two Belgian Service Voucher Programs. *Journal of Comparative Policy Analysis: Research and Practice*, *17*(2), 157–173.

Veblen, K. E., Pyke, D. A., Aldridge, C. L., Casazza, M. L., Assal, T. J., & Farinha, M. A. (2014). Monitoring of Livestock Grazing Effects on Bureau of Land Management Land. *Rangeland Ecology & Management. 67*(6), 68–77.

Vogel, B., & Henstra, D. (2015). Studying local climate adaptation: A heuristic research framework for comparative policy analysis. *Global Environmental Change*, *31*, 110–120.

Voß, J.-P. P., & Simons, A. (2014). Instrument constituencies and the supply side of policy innovation: the social life of emissions trading. *Environmental Politics*, *23*(5), 735–754.

Weber, E., & Khademian, AM. (2008). Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review*, *68*(2), 334–349.

Weiss, J. A., & Tschirhart, M. (1994). Public information campaigns as policy instruments. *Journal of Policy Analysis and Management*, *13*(1), 82–119.

Westgate, M. J., Likens, G. E., & Lindenmayer, D. B. (2013). Adaptive management of biological systems: A review. *Biological Conservation*, *158*, 128–139

White, M. A., Cornett, M. W., & Wolter, P. T. (2017). Two scales are better than one: Monitoring multiple-use northern temperate forests. *Forest Ecology and Management*, *384*, 44–53.

Wurtzebach, Z., & Schultz, C. (2016). Measuring Ecological Integrity: History, Practical Applications, and Research Opportunities. *BioScience*, *66*(6), 446–457.

Wyborn, C. a. (2015). Connecting knowledge with action through coproductive capacities: Adaptive governance and connectivity conservation. *Ecology and Society*, *20*(1).

Wyborn, C., & Bixler, R. P. (2013). Collaboration and nested environmental governance: Scale dependency, scale framing, and cross-scale interactions in collaborative conservation. *Journal of Environmental Management*, *123*, 58–67

Wyborn, C., & Dovers, S. (2014). Prescribing adaptiveness in agencies of the state. *Global Environmental Change*, *24*(1), 5–7.

Yang, T. M., & Maxwell, T. a. (2011). Information-sharing in public organizations: A literature review of interpersonal, intra-organizational and inter-organizational success factors. *Government Information Quarterly*, *28*(2), 164–175.

Yin, R. K. (2003). Case studies research: design and methods. *Thousand Oaks, Sage*.

APPENDIX A:
INTERVIEWEES, INTERVIEW GUIDES, CODING

Chapter 2 and 3 Interview Guides and Coding

Interview guide: External government agencies and NGO's

We will do our best to remove any identifying information from any publications or presentations of the results of this research. However, we also recommend you avoid providing information that may be used to identify or may be personally damaging to you or others.
Share blurb on project, ask for any questions.

For External agencies
For NGOs
Appropriate for all left un-highlighted

General questions, USFS and monitoring

1. **Can you talk about your thoughts, perceptions, or experience with USFS monitoring efforts? What's your general opinion of USFS monitoring?**
2. **Can you think of past or current, ongoing broad-scale monitoring efforts (been engaged in or not)? What worked? What didn't?**
3. **Could you tell me in more detail about your current monitoring strategies within your organization that apply either across a region, landscapes or to multiple units?** *(if yes, do 2nd set of questions below)*
4. When you think of the Forest Service developing a BSMS now, what are you hopes for it? What would it ideally do? What could it contribute to what's done now? What are your concerns about the Forest Service developing a BSMS?
5. Are there resource areas for which broad-scale monitoring is particularly necessary?
6. Are there types of data that should be collected at broad-scales for certain resources that are different than the data collected at a forest-scale? (may need to develop examples)
7. What kinds of data, questions, or indicators would be in a BSMS?
8. In your mind are there obvious impediments to broad-scale monitoring? Follow up: Are there things we would have to change about agency structure, culture, or funding to make this successful?
9. When you think of broad-scale versus forest-level monitoring, what are the differences in what these would focus on? How could broad-scale monitoring inform forest plans and their ongoing implementation? Can you envision an effective multi-scale (i.e. forest versus broader scale) approach? Do you think this is needed?
10. How should local forest monitoring needs be balanced with regional monitoring needs and consistency?

Building a broad-scale monitoring program *(if engaged in development or existing strategy…)*

1. **What drove the development of your broad-scale monitoring strategy? What internal or external factors were important?**
2. **How were local management questions and monitoring priorities identified and considered? What stakeholders or staff were involved, and how?**
    a. **What structures or processes were used to identify monitoring program priorities and strategies? What external partners did you work with in identifying monitoring priorities across units? How was participation or involvement coordinated? (note: this is where we want to hear about committees, workshops, other processes, etc.)**
    b. **How was high quality scientific information incorporated into the identification of monitoring priorities and protocols (e.g. literature review, peer-review, or expert participation)?**
3. **How do you coordinate or address monitoring implementation at different biophysical scales (i.e. local versus regional)? Who is responsible for implementing and analyzing monitoring at different scales? What incentives or rules are there for ensuring consistent monitoring and reporting at different scales? What are the tradeoffs?**
4. **Do you have any suggestions for engaging partners and field staff to be successful? For encouraging collaboration with partners (NGOs and other agencies)?**
5. **What types of data/information are used in your monitoring strategy (e.g. unit-level data, data collected from a regional/centralized staff, or information from other agencies or partners)? What resources or positions are needed for coordination or collection of relevant information?**
6. Are there barriers to collaboration and interagency coordination for sharing monitoring information?
7. How is relevant data or information managed and stored in your organization? What resources/positions are needed to support effective database management and analysis?
8. What are (or were) some of the strengths of your monitoring program? What are some of the weaknesses? What would you improve?
9. What have been some of the impediments to developing a broad scale monitoring strategy? What factors have contributed to success (e.g. agency structure, culture, or funding)?

Communicating results

1. How is broad scale monitoring information reported or communicated to relevant actors? What is the format? Who is the intended audience?
2. What resources and positions are needed for implementing communication and reporting strategies? What are the strengths and weaknesses of your reporting strategy?
3. What would be a useful format for reporting or communicating the results of a BSMS?

Use of broad-scale monitoring information

1. **How is monitoring information used? Is it incorporated into unit-level planning and decision-making? If so, how? What types of monitoring information are currently useful for unit level planning and decision-making?**
2. **What information provided by the USFS or other agencies is *currently* useful for your organization? What *additional* information from a USFS BSMS would be useful to you and your organization? What would you like to see?**
3. **Do you or your organization have information that can be incorporated into a broad scale monitoring program? Is there potential for aggregating information collected by your organization or other stakeholders for use in a BSMS?**
4. **What information do you wish you had for long term planning and decision making to anticipate climate change impacts?**

Wrap up

1. **Is there anything else you'd like to tell me or discuss? Anything I should have asked about that you think I'm overlooking?**
2. **Who else would you recommend I talk to about this?**

Interview guide: USFS Line Officers and Resource Specialists

We will do our best to remove any identifying information from any publications or presentations of the results of this research. However, we also recommend you avoid providing information that may be used to identify or may be personally damaging to you or others.
For Line Officers
For Resource Staff, including Planners
Appropriate for all left un-highlighted

General monitoring and broad-scale questions

1. What's your general opinion of Forest Service monitoring—where it's been, where it needs to go?
2. Can you tell me about any specific monitoring efforts you've been part of in the past?
3. What types of monitoring information do you use most often? What types are most helpful? Where do you think the gaps are?
4. Can you think of past or current, ongoing broad-scale monitoring efforts? What worked? What didn't?
5. When you think of the Forest Service developing a BSMS now, what are your hopes for it? What would it ideally do? What could it contribute to what's done now?
6. What kinds of data, questions, or indicators would be in a BSMS?
    a. Follow up with climate change – if not mentioned.
7. What are your concerns about the Forest Service developing a BSMS?
8. In your mind are there obvious impediments to broad-scale monitoring? Follow up: Are there things we would have to change about agency structure, culture, or funding to make this successful?
9. Are there consistencies in monitoring protocols? Why or why not?

Questions regarding BSMS and forest planning

1. When you think of broad-scale versus forest-level monitoring, what are the differences in what these would focus on?
2. How could broad-scale monitoring inform forest plans and their ongoing implementation?
3. Can you envision an effective multi-scale (i.e. forest versus broader scale) approach? Do you think this is needed?
4. Are there resource areas for which broad-scale monitoring is particularly necessary?
5. Are there types of data that should be collected at broad-scales for certain resources that are different than the data collected at a forest-scale? (may need to develop examples)
6. Do you currently have the capacity to effectively analyze monitoring information and use it in planning? At the forest level? At the regional level? If not, what additional resources are needed?
7. How should local forest monitoring needs be balanced with regional monitoring needs and consistency?

Questions regarding partnerships and data sharing

1. How is monitoring information currently stored and shared? How useful are existing corporate databases for storing or accessing monitoring information? Are they being utilized? What could be improved?
2. What role should the BSMS have in combining data from multiple forests? How would this data be used?
3. Do you partner with Forest Service staff outside your forest or external organizations in monitoring? What kind of monitoring efforts are they involved with or interested in?
4. Do you have any suggestions for engaging partners and field staff to be successful?

Wrap up

1. Is there anything else you'd like to tell me or discuss? Anything I should have asked about that you think I'm overlooking?
2. Who else would you recommend I talk to about this?

Washington Office

1. What was the intent of the planning rule BSMS
2. How do you see this working?
3. What are biggest barriers at regional levels?

Table 6.2 Workshop Attendees

Attending Organization	Workshop attended
Arizona Game and Fish Dept.	AZ
Arizona Game and Fish Dept. - Natural Heritage program	AZ
Arizona State Forestry	AZ
Bird Conservancy of the Rockies	CO, NM, WY
BKS Environmental Association, Inc.	WY
Black Hills Forest Resource Association	WY
Bureau of Land Management	AZ, CO, NM
Bureau of Land Management National Operations Center	CO
Cochiti Pueblo	NM
Colorado Forest Restoration Institute	CO, NM, WY
Colorado Natural Heritage Program	CO
Colorado Parks and Wildlife	CO
Colorado Plateau Research Station/Northern Arizona University	AZ
Colorado State Forest Service	CO
Colorado State University	CO, WY
Dept. of Interior - Southwest Climate Science Center	AZ
Dept. of Interior - North Central Climate Science Center	CO
Desert Landscape Conservation Cooperative	AZ
Ecological Restoration Institute	AZ, CO, NM, WY
Environmental Protection Agency Region 8	CO
EnviroSystems Management	NM
Grand Canyon Trust	AZ
Little Snake River Conservation District	WY
National Park Service	CO, NM
National Parks Service - Valles Caldera National Preserve	NM
Natural Resource Ecology Laboratory	CO
Nebraska National Forest and Grasslands	WY
New Mexico Department of Agriculture	NM
New Mexico Department of Game & Fish	NM
New Mexico Forest and Watershed Restoration Institute	NM
New Mexico State Forestry	NM
Pueblo of San Felipe	NM
Pueblo of Tesuque	NM
Ruckelshaus Institute, Haub School of Environment and Natural Resources, University of Wyoming	WY
The Nature Conservancy	AZ, CO, NM, WY
The Wilderness Society	CO
Trout Unlimited	WY
University of New Mexico	NM
University of Wyoming	WY
US Fish and Wildlife Service	NM
US Geological Survey	AZ, CO, NM, WY

USDA - Natural Resources Conservation Service	CO, WY
USDA – Agricultural Research Service, Rangeland Resources Research Unit	CO
United States Forest Service (USFS)	AZ, CO, NM, WY
USFS Apache-Sitgreaves National Forests	AZ
USFS Arapaho-Roosevelt National Forest	CO
USFS Bighorn National Forest	WY
USFS Black Hills National Forest	WY
USFS Bridger-Teton National Forests	WY
USFS Carson National Forest	NM
USFS Cibola National Forest & National Grasslands	NM
USFS Coconino National Forest	AZ
USFS Coronado National Forest	AZ, NM
USFS Gila National Forest	NM
USFS Grand Mesa, Uncompahgre and Gunnison	CO
USFS Kaibab National Forest	AZ
USFS Lincoln National Forest	NM
USFS Medicine Bow/Routt NFs & Thunder Basin NG	WY
USFS Prescott National Forest	AZ
USFS Region 1 Office	CO
USFS Region 2 Office	AZ, CO, WY
USFS Region 3 Office	AZ, CO, NM
USFS Region 4 Office	CO
USFS Rio Grande National Forest	CO
USFS Rocky Mountain Research Station	AZ, CO, WY
USFS Remote Sensing Applications Center (RSAC)/RedCastle Resources contracted to USFS RSAC	CO, NM
USFS San Juan National Forest	CO, WY
USFS Santa Fe National Forest	NM
USFS Tonto National Forest	AZ
USFS Washington Office	AZ, CO, NM
USFS White River National Forest	CO
USFS Forest Inventory and Analysis	AZ, NM, WY
Western New Mexico University	NM
Wyoming Department of Agriculture	WY
Wyoming Game & Fish Dept	WY
Wyoming Natural Diversity Database, University of Wyoming	WY
Wyoming Office of the Governor	WY
Wyoming State Forestry Division	WY

Interview Transcription Codes

Level of governance
- Forest
- Regional
- National

Resource area
- Forest/Veg
- Wildlife
- Water/soils
- Climate
- Range
- Socioecomic/recreation

Challenges
- Culture
- Internal Capacity
- External capacity
- Data management
- Leadership/commitment
- Turnover
- Scale mismatches
- Planning processes/requirements
- Incentives

Opportunities
- Knowledge brokers
- Collaboration/boundary organization
- Formal guidance/processes
- Partnerships
- Funding agreements
- Oversight/accountability
- Leadership

Chapter 4 Interviewees and coding

Table 6.3 Chapter 4 Interviewees

	Interviewees	
BLM		
National I&M staff	5	
State AIM coordinators	3	
State Resource planner	1	
State Resource Specialist	1	
Project Coordinators	3	Total BLM: 13
NPS		
National I&M staff	4	
Network Staff	7	
Park Superintendant	1	Total NPS: 12

Interview Guide

1. What led to the development of your agency's I&M program? What were some challenges the e I&M program was intended to address?

2. How was the I&M program designed? Who was involved?

3. What are some of the core elements of your program? In terms of…
    a. Goals and objectives
    b. Staffing, funding, information technology
    c. Roles and responsibilities for different implementation processes
    d. Rules and regulations
    e. Partnerships and collaboration

4. Walk me through the implementation process. How do you match monitoring strategies to specific decision-making processes? Who is involved at different steps? (i.e. design, data collection, data management, data analysis, interpretation, application.

5. What are some of the core products and benefits associated with your program (i.e. useable information)? Who are the intended audiences?

6. How is I&M information used to support decision-making at different levels of administration? Are there formal or informal processes associated with information use?

7. What are some of the key factors that have influenced implementation? What leads to variation in implementation processes? E.g…
    a. Leadership
    b. Organizational culture
    c. Politics (internal and external)

d. Laws and statutory mandates

8. What are two strengths and two weaknesses of the program? Are there any things you wish were different?

9. What does the future hold? Do you have any concerns about the long term viability of the program?

Coding Framework

Policy Design Process

- Drivers
- Actors
- Learning tools

Table 6.4. Policy Tools Codes

	Level of administration		
Policy tools	National	Network/state	Unit/management
Learning			
Authority			
Capacity			
Incentive			
Hortatory			
Outputs			
Outcomes			

Policy Implementation

- Processes
    - Design, data collection, data management, analysis, communication, application
- Level of governance
- Challenges
- Enabling factors