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"A Lot of It Comes from the Heart": The Nature and Integration of Ecological Knowledge in Tribal and Nontribal Forest Management

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This article explores the generation, transmission, and nature of ecological knowledge used by tribal and nontribal natural resource management agency personnel who collectively manage a 666,542-acre forest in northern Minnesota. Using key informant interviews and an adapted grounded theory analysis, we documented the forms of knowledge participants expressed in their descriptions of the forest and forest management, including traditional and western scientific ecological knowledge. We found that study participants across agencies use multiple forms of knowledge, that this knowledge is generated and transferred in distinct ways, and that participants acknowledge several challenges and opportunities to integration of traditional and western scientific knowledge in forest management. Overall, ecological knowledge expressed by study participants revealed multiple ways of knowing the forest. Knowledge varied most distinctly in the influence of cultural identity and spiritual or metaphysical connections to the forest on knowledge generation, transmission, and content. Formalizing existing informal knowledge integration efforts with attention to power structures, institutional culture, and knowledge application is recommended.

Keywords: traditional ecological knowledge, western scientific ecological knowledge, forest management, comanagement, adaptation

Interest in the comanagement of natural resources has increased dramatically in recent decades (Conley and Moote 2003, Borrini-Feyerbend et al. 2013). In the United States, this phenomenon can be attributed to the recognition that comanagement arrangements characterized by interagency cooperation and local stakeholder empowerment improve ecological and social outcomes. One central benefit of comanagement is multiplicity and diversity (Borrini-Feyerabend et al. 2004) or the integration of multiple and diverse values, beliefs, and knowledge about human interactions with the nonhuman environment.

The benefits of knowledge integration are particularly evident in comanagement arrangements in which indigenous groups actively generate and use what has been termed traditional ecological knowledge (TEK). A growing number of case studies have documented the contribution of TEK to more sustainable, productive, and locally accepted natural resource management around the globe in fisheries (King 2004), wildlife (Berkes and Turner 2006), and forests (Trosper 2007, Emery et al. 2014, Hummel and Lake 2015). In the United State, this form of knowledge integration most commonly occurs where federal, state, or local resource agency public land jurisdictions abut or overlap with existing sovereign territories of American Indian nations. In some cases, public land management agen-

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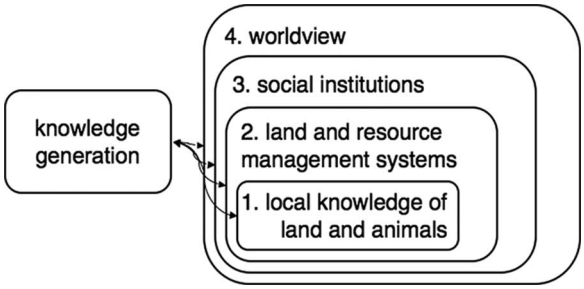

Figure 1. Model of traditional ecological knowledge (adapted from Berkes 2012).

cies now have explicit policies regarding inclusion of TEK in their deliberations. For example, the 2012 US Department of Agriculture (USDA) Forest Service Planning Rule directs officials in that agency to request information about native knowledge, land ethics, culture, and sacred and culturally significant sites as part of the tribal participation and consultation process in land management planning. Despite global success stories, the cocreation and integration of TEK and western scientific ecological knowledge (WSEK) in comanagement arrangements is complex and, in some cases, highly contentious, in part because of the unique ways in which TEK and WSEK are generated, used, and perceived by indigenous and nonindigenous resource managers.

This article investigates three research questions in the context of a comanagement arrangement between federal and tribal resource management agencies in Minnesota, USA: How is ecological knowledge generated and transferred in forest management? What is the nature of this knowledge? What are the challenges and opportunities inherent in ecological knowledge integration in forest management? Answers to these questions will support knowledge integration in forest and public land management that not only is compliant with federal law but also is diverse, holistic, systematic, and respectful.

Related Literature

Berkes' (1999, p. 197) definition of TEK has been widely cited and expounded on in natural resource management literature:

> Traditional ecological knowledge is a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.

This definition has three basic elements: knowledge generation, transmission, and content. A significant body of work exists relative to TEK generation and emphasizes local experience and direct observation (Barnhardt and Kawagely 2005, Berkes and Turner 2006). TEK transfers from generation to generation through oral history, demonstration, and continuity of practice (Deloria 2003, Barnhardt and Kawagely 2005). Finally, TEK often has strong social and spiritual elements and thus is culturally perpetuated (Barnhardt and Kawagely 2005, Murray et al. 2011).

Berkes (2012) recently offered a conceptual model depicting four interrelated layers of knowledge content (Figure 1). From the center to the periphery (i.e., specific to more general) are (1) local knowledge of land and animals (i.e., species characteristics and interspecies dynamics), (2) land and resource management systems (i.e., landscape manipulation for human or nonhuman benefit), (3) social institutions (i.e., ecological related economic, social, spiritual, and government structures), and (4) worldview. Worldview consists of those values and beliefs regarding humans' role in the world, thus constituting the foundation on which other ecological knowledge content levels are built. Aspects of this model are well supported by previous case studies and empirical analyses (King 2004, Medin et al. 2006, Houde 2007, Ross et al. 2007, Reo and Whyte 2012).

WSEK is grounded in the scientific traditions of hypothesis testing and positivistic approaches to isolating, controlling, and measuring phenomena (Weiss et al. 2012). In contrast to characterizations of TEK (e.g., holistic, integrated, and spiritual), WSEK has been characterized both positively and negatively as aspiritual, anthropocentric, atomistic, and amoral (Deloria 2003, Callicott and Nelson 2004, LaDuke 2005). Some argue that WSEK is inferior to TEK in many natural resource management contexts (Deloria 2003, Callicott and Nelson 2004, LaDuke 2005). However, in recent years, emphasis has shifted from debate about which knowledge system is better toward the ways in which both systems can support sustainable ecological management. It is now generally accepted that, although each system has unique characteristics, the systems share many traits, including a reliance on firsthand observation. Furthermore, many contemporary theorists argue that both knowledge forms are necessary for effective ecosystem management and adaptation (Barnhardt and Kawagely 2005, Murray et al. 2006, 2011, Ross et al. 2007, 2011, Carroll 2015).

The relationship between TEK and WSEK has attracted attention because of increased interest in how community ecological knowledge affects community response to environmental disturbance. Several characteristics of TEK generation including its immediacy (Parlee et al. 2006, Trosper 2007), holistic orientation (Callicott and Nelson 2004, LaDuke 2005, Murray et al. 2006), and local community grounding (Parlee et al. 2006) are believed to enhance

Management and Policy Implications

Forest values, beliefs, and knowledge can vary dramatically and sometimes clash among natural resource professionals involved in comanaged forests, particularly those managed by tribal and nontribal agencies. Findings from in-depth interviews with tribal and nontribal resource managers reveal both distinct and shared perspectives on a comanaged forest in northern Minnesota; most notable were the unique roles of cultural identity and spiritual or metaphysical connections in knowledge generation, transmission, and content. Resource managers interested in the integration of traditional and western scientific ecological knowledge may find success in formalizing ongoing informal activities including mutual learning or training in cross-cultural contexts, relationship building among agency and tribal leaders, cooperation in forest and cultural resource management projects, and collaborative forest planning. Still, attention to existing power structures, institutional cultural differences, and knowledge application practices will be important to these efforts.

community resilience. WSEK characteristics such as rigorous research design (Krech 2005, Murray et al. 2011), peer-review process (Hart 2010), global scope of knowledge generation (Murray et al. 2006), and isolation of disciplines (Krech 2005) are also believed to enhance resilience. Many authors who have written recently on the relationship between TEK, WSEK, and adaptation to change acknowledge that each environmental worldview brings different tools to the table (Bengston 2004, Krech 2005, Murray et al. 2006, Hart 2010, Lewis 2010, Hummel and Lake 2015).

Several scholars also have argued the value of integrating local and traditional knowledge and practices into forest research, management, and policy (Emery 2001). In a review of TEK, local ecological knowledge (LEK), and forest management literature in the Pacific Northwest, Charnley et al. (2007) examined the way American Indians, family forest owners, and commercial nontimber forest products harvesters view biodiversity and practice forest management. These authors found that while historic and prehistoric TEK information is fairly accessible, contemporary TEK and LEK is less documented because of multiple social, economic, and political constraints. They identify five means of American Indian TEK integration into biodiversity conservation: landscape-scale comanagement, collaborative species-specific management, integrated scientific panels, formal institutional liaisons, and ecological modeling of traditional practices. One example of species-specific collaborative management is evidenced in the Great Lakes region where TEK and WSEK have been merged to improve the USDA Forest Service Forest Inventory and Analysis program. The Great Lakes Indian Fish and Wildlife Commission and the USDA Forest Service cooperated to develop a "TEK-Based Field Guide" to train inventory crews in monitoring paper birch (*Betula papyrifera*) bark supply for traditional uses (Emery et al. 2014). Similarly, TEK and WSEK were "blended" to compare qualitative and quantitative forest site classification systems (Hummel and Lake 2015). Forest scientists partnered with expert tribal basket weavers to classify forest sites in California, Oregon, and Washington based on potential for beargrass (*Xerophyllum tenax*) harvest.

Our research builds on this body of work and examines the generation, transmission, and content of ecological knowledge and the challenges of and opportunities for knowledge integration in forest management from the perspective of US and tribal natural resource management agency personnel who collectively manage a 666,542-acre forest in northern Minnesota.

Study Area and Background

The Leech Lake Indian Reservation (LLIR), the sovereign territory of the Leech Lake Band of Ojibwe (LLBO), is the largest and most populous American Indian reservation in Minnesota; however, today the Band owns less than 10% of the original reservation lands. Former Tribal Chair Arthur Larose described the Band's strengths and challenges in maintaining cultural integrity, social cohesion, and economic well-being in front of the US Senate in 2012:

> We have retained a strong and vibrant culture and continue to exercise and protect our treaty rights to hunt, fish, and gather on the lands promised as our permanent homelands. While our culture and way of life remains strong, our community faces high unemployment, concerns with substance abuse, and challenges in providing adequate. health care and education to our people. (Larose 2012, p. 6)

The water resource-rich landscape of the LLIR includes portions of four Minnesota counties and extends across Great Lakes pine forest (*Pinus* spp.), jack pine (*Pinus banksiana*) forest, upland prairie, and peatland natural vegetation types. The task of managing natural resources on behalf of the LLBO is assigned to the Leech Lake Division of Resources Management (DRM), an agency within the LLBO tribal government. The DRM defines its mission as

> The protection of the water, land, forest, fish, wildlife, plants, and other natural and cultural resources present on the Leech Lake Reservation. (Leech Lake Band of Ojibwe n.d.)

According to the DRM, the agency's responsibilities are to

> enforce fish and game laws, regulate logging, wild rice harvesting, plant resources, and generally protect the Band's many resources for the use of future generations. (Leech Lake Band of Ojibwe n.d.)

LLBO members are active forest gatherers. A 2004 report (McAvoy et al. 2004) on interviews conducted with 59 LLBO members known to be forest users revealed that 88% gathered wild rice (*Zizania palustris*), 86% fished or netted, 81% picked berries, and 80% hunted. In addition, more than 50% of participants gathered pine cones, medicinal plants, sugar maple (*Acer saccharum*) sap, and birch bark.

The DRM is directly responsible for managing three types of forestland parcels: those held by the LLBO, those held in trust for the Minnesota Chippewa Tribe (of which the LLBO is a part), and those owned by heirs to allotments (units of land transferred from general tribal ownership to private ownership by tribal individuals through the Dawes Act of 1887). Together these three types of parcels constitute roughly 7% of the forest within the reservation. The remaining 93% of land inside LLIR is owned and managed by state, federal, and private entities, although the LLBO maintains basic treaty rights on all lands within reservation boundaries.

One half of the Chippewa National Forest (CNF) lies within LLIR, whereas 90% of the reservation is within national forest boundaries (Figure 2). CNF, the smaller of the two national forest units in Minnesota, traces its roots to the Morris Act of 1902. This act created the Minnesota Forest Reserve at Cass Lake nearly 50 years after the core areas of what would become the LLIR were established through the 1855 Treaty with the Chippewa (also known as the Treaty of Washington). CNF's 2004 Forest Plan identifies 13 forest management and planning goals, including promoting ecosystem health and conservation using a collaborative approach, providing for sustained forest product uses in an environmentally acceptable manner, enhancing social and economic benefits, and contributing to efforts to sustain the American Indian way of life, cultural integrity, social cohesion, and economic well-being.

The DRM and CNF have cooperated and shared knowledge in several forest management projects, although their relationship is complex. The CNF is mandated by Executive Order 13175 (US Department of Energy 2000) to maintain "government-to-government relationships" including "regular and meaningful consultation and collaboration" on proposals and policies that have "tribal implications." Memorandums of understanding exist between the agencies that detail procedures for cooperation (USDA Forest Service 2004). Most commonly, consultation consists of the DRM providing guidance onsite-level projects including identification of culturally significant species (e.g., blueberries (*Vaccinium* spp.), sweetgrass (*Hierochloe odorata*), and areas (e.g., wild rice harvest areas) for protection. The

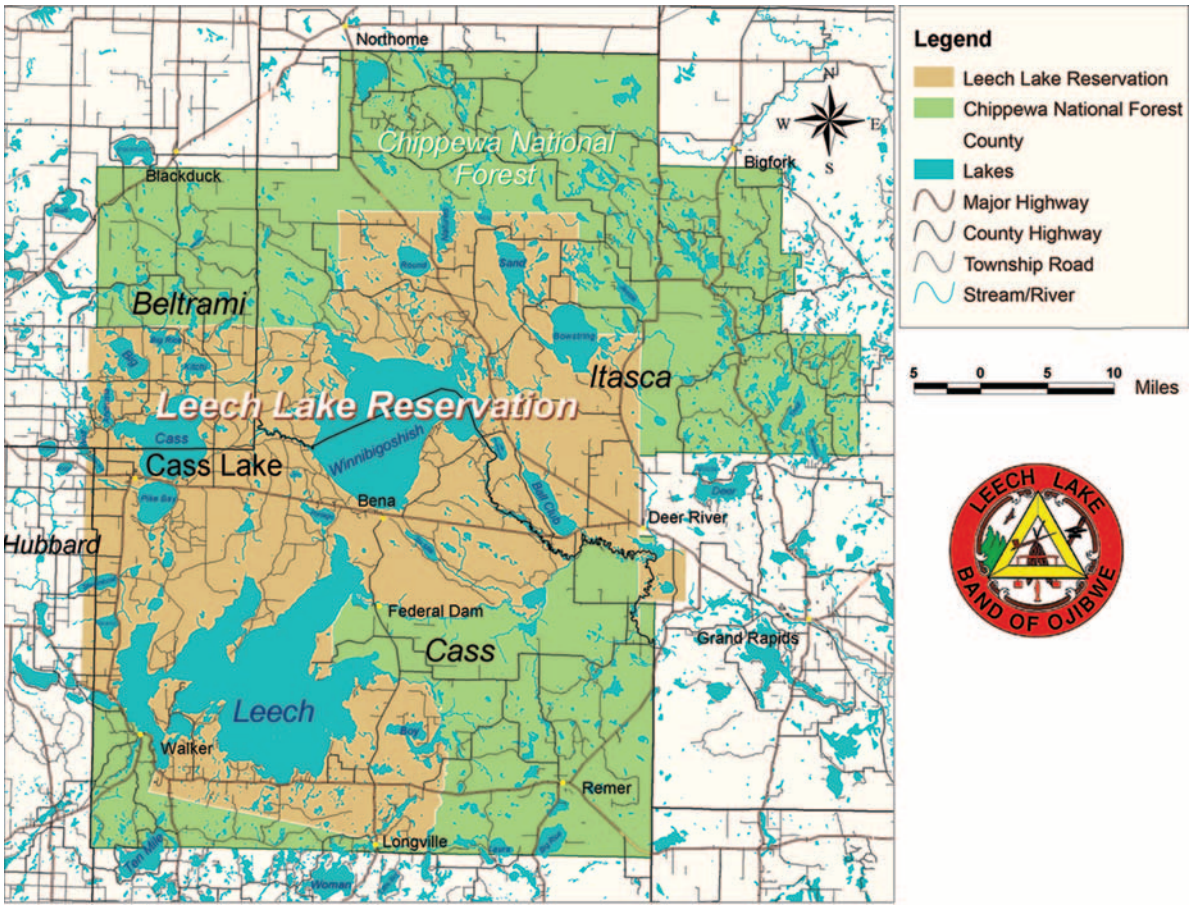

Figure 2. LLIR and CNF (Wells 2007).

CNF has maintained a Tribal Liaison position since 2007. The individual in this position is tasked with responsibilities such as outreach and recruitment, increasing cultural awareness, and building partnerships with LLBO. The agencies also have collaborated on several projects to maximize mutual benefits. For example, when the CNF approved a powerline development project, the agency coordinated with the DRM to spend mitigation funds to restore culturally significant fruiting shrubs and enhance forest composition. The agencies have shared knowledge and resources in heritage programming and prescribed burning projects. Still, conflict exists between agencies. One primary point of contention between the agencies has been in single-species (e.g., pine and aspen [*Populus* spp.]) stand management and differences in objectives for forest ecosystem structure (e.g., thinning versus maintaining understory) and species composition (e.g., commercially valuable species versus culturally significant species). LLBO member interviews conducted from 2001 to 2003 (McAvoy et al. 2004) indicated that more than half of participants identified timber harvesting "as disrupting and/or destroying their gathering opportunities in the forest" (p. 84).

Methods

The study research design was interpretive and inductive. To gain maximum insight into interpersonal and interagency dynamics, our data collection process involved the purposeful selection of a small number of participants, in-depth semistructured interviews, and adapted grounded theory data analysis procedures (Corbin and Strauss 2008).

Our interview guide consisted of a series of open-ended questions developed by University of Minnesota research personnel in consultation with representatives from the Leech Lake Tribal College and the USDA Forest Service. Key topics addressed include area history and characteristics, forest change, the generation and use of knowledge, the approaches of various agencies to forest management, and interagency relationships (Table 1).

In total, we interviewed 23 individuals, including 9 CNF staff and 14 current or former DRM staff (Table 2). We recruited individual staff members to participate based on their position with the agency and responsibilities associated with forest management or coordination with the other agency. The sample represents a balance of earlier and later career employees and American Indian ($n = 13$) and European American ($n = 10$) individuals. Although the sample includes more men ($n = 15$) than women ($n = 8$), these proportions are fairly consistent with the agencies overall. Participants held positions at various levels and included staff with roles in forestry, fisheries and wildlife, hydrology, education, historic preservation, and fire management. Agency administrators facilitated participant identification and recruitment. Participants were assured that their involvement was voluntary and that their personal identities would remain confidential (e.g., not revealed in publications). It should be noted that each agency employs both Native American and European American staff members. Still, the majority of Native American participants were affiliated with the DRM and the majority of

Table 1. Example interview questions.

1. What story would you tell someone who has never been here before about this place? Or, how would you describe the forest to someone who has never been here before?
2. What are some highlights about the history of this place?
3. What are some important things to know about the relationship people have with this place?
4. Has this area changed since you first got to know it?
5. What sources of information and knowledge does your agency use in managing the forest?
6. How would you describe your agency's approach to forest management?
7. Is your agency's approach to forest management similar to or different from other agencies that manage this forest? Please explain.
8. Is your agency taking steps to prepare for climate change?

Table 2. Participant profile.

Characteristic	Category	*n*
Agency affiliation	DRM	14
	CNF	9
Years with agency	0–4	6
	5–9	9
	10–19	6
	20+	1
Years in residence in local area	0–4	4
	5–9	4
	10–19	5
	20+	9
Age (years)	20–29	1
	30–39	5
	40–49	7
	50–59	8
	60–69	1
Race/ethnicity	Native American	13
	European American	10
Gender	Male	15
	Female	8

European American participants were affiliated with CNF.

A team of two to three researchers conducted interviews that averaged 1 hour in length. Interviews were not audio-recorded; rather, research team members took extensive independent interview notes, which were later synthesized into individual interview summaries. Summaries included and differentiated between interview paraphrases and direct quotations. Each participant had the opportunity to check their interview summary for accuracy. After this review phase, the summaries, as edited by participants, contained two types of data: approved direct quotes and approved paraphrases.

Interview summaries were analyzed in two phases. The first phase was an adapted grounded theory analysis (Corbin and Strauss 2008), an iterative, interpretive process of textual open coding (i.e., labeling discrete meaning units using QSR NVivo 10.0 analysis software) allowing for themes, patterns, and relationships to emerge from the data. Consistent with grounded theory techniques, we identified convergent and divergent themes and categories (i.e., groupings of like themes). As a validity check on coding, multiple analysts coded interview summaries independently and then compared and refined the codes for consistency. In the second phase of analysis, we further organized emergent themes into a framework that addressed study objectives and, when appropriate, concepts identified in previous research and theoretical models (e.g., Barnhardt and Kawagely 2005, Berkes 2012).

Excerpts of direct quotes and paraphrases are presented in the following section to demonstrate noteworthy themes. To retain study data richness while still maintaining participant confidentiality, participants' agency affiliation and race/ethnicity are not revealed in the quotes or paraphrases presented. The focus of our study was not to compare forms of ecological knowledge between organizations or communities but rather to describe and explore the nature and integration of ecological knowledge in a comanagement context. We have taken several steps to increase the "trustworthiness" of our study findings including member checks, intercoder validity checks, and negative case analysis (Marshall and Rossman 1999). However, limitations are inherent in the design and sampling strategy. The nonprobability sample is not statistically representative of a broader population. Findings are not intended to be generalized to other forest comanagement contexts. At the same time, the study provides an inductively derived, nuanced, and fluid understanding of ecological knowledge that may serve to explain or further elucidate the nature and integration of ecological knowledge in other forest comanagement settings.

Findings

Findings are organized by the three research questions of this study and describe the generation and transmission of ecological knowledge, the content of ecological knowledge, and challenges of and opportunities for knowledge integration in forest management.

The Generation and Transmission of Ecological Knowledge

We asked participants to describe the sources of information and knowledge their agency uses in managing the forest. Data analysis revealed multiple knowledge generation and transmission themes consistent with conventional conceptualizations of TEK and WSEK. TEK-associated themes reflect the creation of knowledge through long-term personal and cultural experiences and direct observations in local settings. Participants also described knowledge developed through metaphysical as well as physical connections to the land. For example, one participant recalled sharing knowledge about traditional subsistence practice areas with other agencies. The participant characterized this knowledge as coming "from the heart":

> When the Forest Service would propose an activity…our role was to use our connections to help guide them. We would tell them which spaces are someone's sugaring area, hunting area, or blueberry gathering area. So we use those traditional practices.…If it's something we use, then it should be protected. It's that simple. If it's a shrub or herbaceous plant, they should protect it. A lot of it comes from the heart, just living on the land and knowing what needs to be protected.

Another participant characterized two distinct worldviews or moral norms driving knowledge generation and relationships to other organisms:

> It's western science versus traditional knowledge and views. A tribal member will look at a turtle and see it for what it is. That's my brother. A white man scientist will go pick it up, turn it over, pull its leg, poke its eye, touch its teeth. That's not respect. I wouldn't want to be treated that way.

Some staff members of both agencies used knowledge that was disseminated through interpersonal, intergenerational, and oral communication, as is typical of TEK. One participant described a relationship with an elder who lived to be 110 years old:

> Imagine the changes she saw. When I first came here, I would talk to her and she would tell me the places to go.… She had an observation spectrum of 100 years; the changes she's seen must have been unbelievable.

Similarly, another participant described knowledge dissemination through person-to-person communication and interactions with elders in talking circles and with spiritual advisers:

> Some I've learned through my heritage, some through talking with elders, through being a part of talking circles, from my grandmother, and just being associated with spiritual advisers.

Wild rice harvesting (i.e., ricing) was important to several participants not just for subsistence gathering but also for connecting with youth and perpetuating TEK. Knowledge about ricing is disseminated orally through intergenerational interactions and demonstration:

> They have "Take a Kid Ricing Day" and talk about how the rice grows. They teach them what conditions it needs; explain it; bring up just one plant so they can see the roots. We don't usually pull wild rice, but we make a big deal so they understand that we don't destroy it. I think the DRM's work with youth is the most powerful tool they have.

WSEK-associated themes reflect the creation of knowledge through formal education and training, field observation, and professional experience including forest monitoring and scientific research. Both CNF and DRM staff acknowledged that important knowledge is transferred through written documentation (e.g., textbooks, reports, plans, laws, and treaties), recorded imagery (e.g., photographs and maps), and oral communication in formal workshops and webinars. For instance, one participant described knowledge generation and dissemination associated with the forest plan:

> We use a variety of information that is put together in our Forest Plan, our guiding tool. We use a lot of data provided by [Minnesota Department of Natural Resources], federal agencies like the United States Geological Survey, the Fish and Wildlife Service, and others.

Scientific knowledge generation in natural resource management also was described as discipline-based:

> What we do in natural resource management is a science. Every department has their science where they are expected to provide their expertise: soil, water, forestry, wildlife, botany. Relying on the science [and] allowing people to use their expertise in their fields and trusting their decisions…the results could be phenomenal.

The need for regional knowledge verification through scientific research also was emphasized:

> Do we really know what a hardwood stand looks like?…We need to do research to find out what the definition of a northern hardwood forest is or what it looked like.

A few participants emphasized the complementary roles of scientific research and direct field observation in knowledge generation:

> We use biological information for the decisions we make. We use the science, but it's more than that, it's observing. On-the-ground observation goes a long way.

The Content of Ecological Knowledge

Species Focus. Participants were asked questions that prompted expression of ecological knowledge, such as, What story would you tell someone about this place? Is this place unique from other areas in Minnesota? And, how would you describe your agency's approach to forest management? Species-focused knowledge emerged, and key differences were observed between TEK and WSEK-associated responses.

TEK-associated responses suggested intimate local and historical knowledge of species traditionally gathered for subsistence uses and valued for culturally or spiritually significant benefits. Participants focused on individual species sought in traditional subsistence practices including ricing, fishing, hunting, trapping, and maple sugaring. For instance, several participants described Manomin (i.e., wild rice) as central to the Anishinaabe people:

> How we came here as a tribe. It took four generations to get here, and they said when we migrated that we'd go to a place where food grows on water, and that's Manomin, wild rice. That's how we knew we had arrived.

Species knowledge associated with cultural uses and practices also was used to convey forest and landscape change. One participant recalled "living off the forest" when he was young. The participant noted a decline of rabbits (*Lepus curpaeums*) and concluded that there have been many changes in the forest:

> I grew up around here. Growing up we weren't rich. Nine kids in the same house means you can't be rich. My dad was a logger. My mom stayed at home. But we made a living off the forest. We'd snare rabbits and grow a garden. He made a living cutting aspen and birch.…But now going out there, I see no rabbits, no tracks. Maybe it's a cycle. The rabbits will come back; I'm sure they will. They've been here for 1,000 years.…Ricing too, we used to rice. In the evening, we would set snares, and we'd have rabbit stew or baked rabbit. There have been a lot of changes in the landscape.

One participant expressed concern about the loss of sweetgrass:

> [Sweetgrass is] used in religious practices and ceremonies. That has always been a real significant resource here for our native people. Other native people come here just to gather resources.

Other participants also described environmental change and, in particular, the cultural and health impacts of the decline of sugar maple:

> Red maple is replacing sugar maple. And you can tap it, but it's not as efficient. Maple sugar is a natural sugar. Our tribal members can eat it all day long and not get diabetes.

WSEK-associated perspectives shared by DRM and CNF staff included species knowledge based on statistical and spatial modeling, species-specific silvicultural principles, and an emphasis on commercially valuable species. For example, one participant identified species-specific management goals and how they drive implementation:

> The silviculturists write the prescription; then the forestry people implement. Say we have an aspen stand that we want to convert to white pine; that's one of the goals. We have an old aspen stand that we want to convert. We go out there and decide what has to be done. We'll harvest and then let it come back, maybe do some disking. And then there may be a few years where we are protecting the white pine from deer; they love white pine. So, we're bud capping then too.

Similarly, a few participants described the significance of aspen and pine species to timber production and aesthetic benefits attained from stand thinning:

> We look to harvest overmature aspen and jack pine; we have plenty of it on Tribal lands. We also have moved into Tribal plantations and have moved to thin the pine to a level where they are free to grow, improving timber quality and esthetics at the same time.

Several participants from both agencies acknowledged competing or conflicting values and knowledge systems when managing for single species. In particular, conventional silvicultural principles and practices (e.g., "getting the timber out") were juxtaposed with traditional species knowledge (e.g., spiritual importance of the lynx [*Lynx canadensis*]):

> We have a solid forest inventory; we've surveyed our high quality lands. Endangered species are surveyed. The heritage archaeology branch does a lot. We'd like to say we are using more traditional knowledge, but in reality we are trying to get timber out.

Species age and scarcity also were viewed as a source of values conflict:

> An example is old-growth jack pine. Our old stands of jack pine are beginning to fall apart. From a silvicultural perspective it's time to conduct a regeneration harvest. But, because there are so few of these stands on the landscape, other values conflict with what we would like to do silviculturally.

In another instance, a participant explained that balancing different forest species' spiritual and economic significance adds complexity to forest management:

> A [biologist] told me that there are no lynx here anymore. That's very disturbing because [the lynx] is a very important being for us spiritually. Why does the lynx have to be gone? So it's very complex to think about that and how to consider those values and spirituality and try to balance that with the economic drivers.

Forest Management and Healing. We asked participants to describe their own agency's approach to forest management, as well as the approaches of other agencies in the area. Both western scientific forest management knowledge and traditional ceremonial healing knowledge were noted in their responses. Participants conveyed TEK and WSEK-related perspectives in their descriptions of direct and indirect interventions, as well as decisions not to intervene in the forest ecosystem. Participants also expressed knowledge systems in discussions of broad management and healing principles, as well as more specific or strategic objectives.

WSEK-associated themes included management based on active silvicultural practices, an emphasis on maximum sustained yield, and management goals related to multiple human uses and benefits. For example, one participant described the thrill of seeing pine regeneration after a harvest:

> To see a fully stocked stand that has come back after it's been harvested…especially the pine, because we battle the deer. The deer are just incredible, so it's a real challenge. That's my favorite thing, to see a fully stocked pine stand that's regenerated.

Another participant characterized the role of forest management as "fixing" the forest after human interference in natural regeneration:

> We're not wrecking the forest; we are fixing it. The forest is broken. Wood barons took all the pine when they came through so many years ago, leaving a huge void in the seed source and effectively changing stands to a point where they cannot restore themselves without assistance.

TEK-associated themes were identified in discussions of ceremonial healing practices and using species the "right" way. One individual described interactions with healers during a water healing ceremony in which tribal members carry water from the river's source at Lake Itasca to its mouth near the Gulf of Mexico:

> Because we're healing waters in our own way, we're doing our part. We do ceremonies like the Mississippi Water Walkers ceremony. We get together with the healers. The women carry the water. The men carry the staff.

In other cases, "healing" practices were intimated but not explicitly described. A participant recalled a family story about using nature's resources the "right" way:

> My mom told me she was told by her father, an elder, that if you don't use something and use it right, it would be taken from you. Blueberries are like that. We were out with the [Minnesota Department of Natural Resources] and county and we saw a blueberry bush and there were no berries. They were scratching their heads. Now we have blueberry plants but no berries on them, because we haven't used them right and they were taken away….

Consistent with TEK, management goals and strategies for multiple cultural uses and traditional practices also were important. One participant explained,

> I make decisions based on our social structure, social needs. My needs are to get people back to native diet. I don't think that's aspen and pine plantation. It goes back to my core beliefs, and how I was brought up.

Similarly, another participant described the food and medicinal benefits of the forest as a primary value of interest to the DRM:

> [The DRM] still values traditional use. This is a livelihood for some tribal members; there are resources in the forest like food and medicine. That makes the DRM approach way different than…the Forest Service who [sees] it as a tree crop and recreation, but not a livelihood.

A few participants considered benefits to future generations and questioned the notion of active human intervention in forest management altogether:

> The idea that man can change things and make them better than Mother Nature: that is so backward.…When I make a decision, I look at it as sometimes us humans can do more for those generations down the road by the less we do.

More specifically, another participant referenced managing forest disturbance and questioned the morality of harvesting a blowdown area:

> Are you here to live with our gifts? All on equal footing? Or are they here for us to use how we want? It is not a waste to have trees blown down; trees have been blown down forever. The forest is a gift, but it is not just here for us to use.

Although not clearly a distinct expression of WSEK or TEK, several participants acknowledged ongoing tension between timber-driven (i.e., single, commercially valuable species) and ecosystem-driven management across and within agencies. For instance, one participant distinguished managing for jack pine and managing for a jack pine ecotype:

> Management has changed to get more pine back in the forest. But, a lot of this has been in plantations, not a pine ecotype. We…want a jack pine ecotype. Trees aren't as important. It could be a telephone pole, as long as the ecosystem structure is there. The Forest Service is Department of Ag. It's timber driven. The [Forest Service] has to work with the tribe on ecosystem management, climate change, but at the same time, they need to get the cut out.

Knowledge Integration: Challenges and Opportunities

Skepticism of Alternate Knowledge Forms. Several participants expressed reticence about integrating knowledge and were skeptical of the value of alternate knowledge forms to forest management, especially the credibility and reliability of that knowledge. At times, participants made comparisons between knowledge systems, and in other instances they described limits as inherent in one system irrespective of the other. For example, a few participants imparted the perception that TEK is not produced via replicable methods, is too subjective, and has become antiquated, because it is not actively perpetuated or generated today. One participant questioned the reliability of TEK and expressed more confidence in systematic, science-based inventories:

> What [species] are [tribal members] gathering? We look at a map and we know what is out there. That's a difference. [Tribal members] assume what's out there. We know. We have GIS [geographical information systems] and do inventory.

In contrast, WSEK was criticized for having a relatively short history compared with that of TEK, emphasizing commercial versus subsistence uses of the forest, excluding spiritual connections to the forest, and being difficult to adapt. For example, one participant argued that traditional teachings have a much longer history than forestry principles:

> Anishinaabe traditional teachings clash with forest management. Forestry is what, 90 years old? A maple basswood stand might be 1,000. To me [forestry is] just a theory.

Participants also were skeptical of the adaptability of the WSEK system. In one instance, a participant lamented long forest planning cycles and questioned investments in jack pine given current climate change scenarios:

> We know that jack pine is a species that won't do well in climate change scenarios, but we have a [forest] plan that has us investing in establishing jack pine. So does it make sense to do this?

Difficulty of TEK Transmission. Some participants identified TEK transmission as a distinct challenge to knowledge integration, because TEK is almost exclusively disseminated orally and TEK bearers are reluctant to share knowledge with nontribal members. Further, CNF staff turnover was observed as another barrier to long-term TEK transmission. One participant explained that TEK is a difficult thing to write about:

> Knowledge from healers is used but, it's a really tough thing to talk about or research. It needs to be made more accessible.…It's a difficult thing to talk or write about, traditional knowledge.

Still, some participants contended that despite TEK bearers' attempts to transfer knowledge to the Forest Service, it has been disregarded in decisionmaking:

> We consult with elders, and the Forest Service has ignored advice from elders…that a project will fail because of cyclical water flows. Thinking back to times when we bring the elders in to make their comments [on forest planning], it doesn't work. The elders are not giving scientific advice. The Forest Service sometimes ignores what they say.

Another participant described TEK transmission as constrained by tribal resource managers who are disinclined to speak about spiritual connections with nontribal resource managers. To one participant, forestry's "professional" language does not adequately convey the spiritual significance of the forest:

> I once heard [name withheld] refer in a meeting with the Forest Service to some pines as "grandfather pines" and I thought that was interesting, because he doesn't usually talk about his spirituality. He usually tries to talk more professionally. And I think we need to [talk more professionally] sometimes, because our way has never been valued. We try to use the terms that the Forest Service uses, but we're thinking something differently when we use their words.

One clear barrier to TEK transmission is CNF staff turnover. One participant explained,

> The Forest Service keeps turning over in staff. It seems like just as soon as somebody gets to know us, they're gone, and that really harms the relationship. When we help teach people about us and they leave, the band loses.

Cultural Change and Effects on TEK. Historical and contemporary TEK is culturally dependent, perpetuated through people rather than the written word, and thus grounded in community members' lifestyle and values system. Many participants believe lifestyles and values have dramatically changed in the tribal community.

A primary concern among several participants was cultural shifts away from "living off the land." Participants linked this phenomenon to other social and cultural problems facing the tribe, including the loss of the family structure, increased materialism, and a loss of spiritual connections to the forest. For example, one participant recalled harvesting poplar (*Populus* spp.) bark when he was a teenager and argued that the spiritual connection to the forest has diminished:

> When I was 13 or 14 years old we would peel poplar and had to go out into the woods to get it.…That whole family structure is really gone. You have to pay your kid 20 dollars just to cut the grass….The lifestyle of our tribe members has gotten further and further away from using resources to survive. The spiritual connection is gone; it really is.

Another participant lamented cultural change and observed that tribal teachings have been overlooked in favor of global norms:

> Tribal culture is changing. Now it's about what you have, like money and cell phones. It used to be that you were respected in the community, because you gave everything you had away to others. We're sliding away from traditional teachings toward a more global norm.

Relationship Building and Knowledge-Sharing Opportunities. Despite the challenges to knowledge integration, or perhaps in response to them, ongoing efforts have helped to perpetuate TEK and better integrate TEK and WSEK in forest management. Several participants characterized the relationship between the two agencies as improving because of "a sincere desire to work together for mutual goals" and increased DRM engagement in projects on the forest, "from planning to implementation." Participants described cooperation, mutual learning, and cultural understanding and commitment as promising avenues for relationship building.

Cooperation in wildlife protection, historic preservation, and fire management projects were characterized as areas of knowledge integration. Through various agreements, CNF and DRM personnel have conducted prescribed burns together, and several participants noted that these interactions have improved relationships and cooperation between the two agencies. One participant explained,

> We're involved with [DRM] in prescribed fire. We have a large program every spring, and burning wet meadows is something we do together. We work together on that really well; it comes together naturally.

Opportunities for mutual learning were predominating themes when participants talked about strengthening agency relationships. The DRM has been invited to CNF-hosted workshops and training opportunities so DRM "employees have a chance to come and listen and learn with [CNF] employees." Similarly, a participant acknowledged learning opportunities when out in the field with DRM employees:

> I don't really understand, sometimes, where the feelings [of the LLBO] are coming from, to do this or why not to do this. But, when I was out there with [a DRM employee], I could understand it better, because he was more specific.

Still, cultural understanding with commitment to knowledge integration is an area for continuous improvement. A few participants acknowledged a need for skill development on the part of CNF staff to build trust:

> there are additional…skills our employees need to develop to work with the Band. They are the individuals who are responsible for building and maintaining that relationship.

Similarly, another participant suggested that CNF employees should take "Anishinaabe 101 at the tribal college." A few participants acknowledged tribal member hires by CNF as a way to promote collaboration and knowledge sharing.

Several participants underscored a need for better cooperation in inventory and monitoring of cultural resources. CNF and DRM participants noted that the DRM has developed cultural resource inventories that track "probably 450 species that were tradi-

tionally gathered, that we don't really gather anymore" and

> about 24 to 25 resources that are still out there that are still routinely gathered. Our major one is wild rice. Then there's also a lot of hunting and trapping. . . .

Yet, the integration of these databases into formal monitoring programs has been lacking. One participant explained, "We should work together more, do studies together, and compare data." Another participant perceived advancements in the area of historic preservation and fire management but expressed frustration by the lack of cooperation in monitoring cultural resources.

> There are partnerships that have been developing, especially historic preservation with archaeology. That's been working out for years. Then firefighting, they help each other with the prescribed burning on both Forest Service and Tribal lands. CNF is constantly focusing on partnerships with the firefighters, timber people, botanists, and archaeologists to say that they are working with Leech Lake. But, that doesn't cover all the bases. That doesn't cover gathering traditional resources, and identifying and evaluating those resources. They avoid that issue of evaluating our traditional resources.

Finally, one participant suggested that better integration of TEK and tribal natural resource management goals earlier in CNF project planning was feasible and would go a long to demonstrate the agency's commitment to working together:

> Definitely early on in our process, when we're looking at projects, particularly in the harvesting aspects, it wouldn't hurt for us to try a little harder to come up with harvest type of treatments specific to the goals and objectives of the tribe. We do some; we could do more of that.

Discussion

Study findings reveal that ecological knowledge among tribal and nontribal natural resource managers interviewed in this study is generated through multiple, intertwining pathways consistent with WSEK and TEK, including deductive, discipline-specific, and quantitative means as well as inductive, holistic, and qualitative means. Knowledge is generated through study of universal principles and findings from scientific research and monitoring. Knowledge is generated through field experimentation and firsthand observation. Knowledge is generated through formal and informal professional interactions. Study participants described these multiple ways of knowing as integral to managing and healing the forest. Participants from both agencies, as well as Native American and non-Native American participants rely on and generate forest knowledge through these varied pathways.

Divergence in knowledge systems began to emerge in two interrelated ways. First, some participants described ecological knowledge generation as inextricably linked to their cultural identity and spiritual or metaphysical connection to the forest. Second, these same participants described ecological knowledge generation as rooted in a broad spectrum of cultural uses and practices. For other participants, their own culture or spiritual connection to the forest did not explicitly emerge as a primary source of their ecological knowledge used in forest management. In addition, although most participants acknowledged using the forest themselves outside their professional work, a smaller subset of participants described applying this daily living knowledge to forest management decisions and actions. These participants gained this knowledge based on a broad spectrum of historical and contemporary uses and practices that are ecosystem or species dependent. These uses and practices are most notably rooted in subsistence-based lifestyles (e.g., gathering), spiritual sustenance, and the maintenance of cultural identity, as opposed to outdoor recreation or aesthetic appreciation of the forest. Although there are similarities to LEK such as knowledge grounded in long-term observation and experience (Emery 2001, Charnley et al. 2007), the differences here extend to a spiritual and cultural relationship to the land and nonhuman beings.

Clear differences also emerged in the transmission of ecological knowledge and especially the transmission of TEK gained through spiritual and cultural connections to the forest. The basic foundations of western scientific forest knowledge are in plans, guidebooks, recorded images, databases, and scientific reports. The basic foundations of traditional forest knowledge are in people—elders, spiritual advisors, and other tribal members, and their social interactions. Thus, the most common pathways for knowledge transmission vary quite significantly. TEK is transferred almost exclusively through interpersonal relationships and cultural exchanges such as talking circles, storytelling, and demonstrations. WSEK is transferred primarily through the written word, but also through professional exchanges including informal story-telling, on-the-job training, and more formal training workshops.

Knowledge generation and transmission have important implications for knowledge content, which were clearly evidenced in this study. Consistent with Berkes' model (2012), cultural values, narratives, and worldviews appear to drive species-focused knowledge and knowledge about forest management and healing. Species knowledge expressed by some was strongly tied to traditional cultural uses and practices and the knowledge of many individual species (e.g., wild rice, sugar maple, sweetgrass, blueberries, lynx, rabbits, and wolves [*Canis* spp.]). For others, species knowledge was more solidly tied to commercial uses and practices and decidedly fewer species (e.g., jack pine and ash [*Fraxinus* spp.]). In addition, participants with strong cultural and spiritual connections to the forest expressed species knowledge that was more explicitly influenced by morality and ethics and revealed a relationship with nonhuman species based on respect and reciprocity: "that [turtle] is my brother" and "we haven't used [blueberries] right and they were taken away." Those expressing species-specific knowledge tied directly to timber management characterized a more human-centered or dominating relationship with those species: "fixing the forest" and "my favorite thing [is] to see a fully stocked pine stand that's regenerated."

It should be noted, however, that several participants expressed knowledge emphasizing ecosystems rather than individual species. Tension between species-focused and ecosystem-focused knowledge and management was evident within and between the two agencies, similar to tension noted elsewhere between forest practitioners and forest ecologists or conservation biologists (Charnley et al. 2007). Finally, for TEK-using managers, descriptions of specific species were often intertwined with discussions of change and concern about the loss of significant species. Concern about change was certainly not TEK or WSEK specific, but discernible linkages to TEK or other knowledge forms emerged in discussions of the species affected (e.g., wild rice, lynx, sugar maple, wolf, jack pine, ash, and walleye [*Sander vitreus*]) and numerous social impacts (e.g., cultural identity, human health, spirituality, economies, and recreation opportunities). As others have argued, TEK is communicated through daily living, social interactions, and long-term, historical accounts of ecological characteristics, which suggests that observations of change may be

more sensitive to historical trends (Parlee et al. 2006). Adaptation to ecological change, including climate change, is an area that will probably benefit from knowledge integration.

Multiple worldviews were further demonstrated in discussions of forest management and healing, as well as management decisions not to intervene, especially in the context of forest disturbance. A blowdown event, for example, was an area of divergent values and beliefs associated with active or more passive management. At the same time, fire management appeared to be a strong area of convergence between the two agencies for which they have leveraged resources, shared knowledge, and created lasting partnerships. As Emery et al. (2014) argue, enlisting local community experts and individuals with intercultural communication skills in discussions and decisionmaking about culturally significant species supports mutual understanding and integration of TEK and WSEK.

Several participants from both agencies acknowledged the limits of the current forest inventory and monitoring systems, because they do not adequately take into account systems and species significant for traditional cultural uses and practices. In some cases, it may be possible to adapt or reanalyze existing inventory and monitoring data to provide culturally relevant information. In other cases, managers may strengthen monitoring systems by tracking additional species and systems for impacts to cultural practices and identities, as well as economic and social impacts (Fresque-Baxter and Armitage 2012).

Nadasdy (1999) cautions, however, that the inclusion of TEK-related information in WSEK-based management systems may serve to disenfranchise tribal partners, especially if TEK is viewed as merely "a new form of data" (p. 1). Study findings reaffirm that knowledge integration is not simply a matter of fact-finding or database updating (Henn et al. 2010). How TEK is integrated and ultimately applied in forest management should take into account existing power structures and imbalances. Knowledge integration requires relationship-building, ongoing support for understanding multiple forms of knowledge, and a commitment to knowledge generation and perpetuation (Weiss et al. 2012, Emery et al. 2014). Participatory science that includes cross-cultural methodologies and data collection standards, as well as interagency coordination in research design and implementation, may help to balance power. For example, CNF and DRM could formalize existing informal mutual learning efforts in integrated scientific panels (Charnley et al. 2007) or cooperative development of a TEK-based field guide (Emery et al. 2014). The agencies may consider partnering in ecological modeling of traditional practices such as ricing and sweetgrass harvesting.

Conclusion

How one learns directly affects what one learns. How one learns and what one learns affect how one manages the forest. Overall, the ecological knowledge expressed by the study participants revealed multiple ways of knowing the forest. Knowledge varied most distinctly in the influence of cultural identity and spiritual or metaphysical connections to the forest on knowledge generation, transmission, and content of TEK and WSEK. It is important to note that this study's findings are highly contextual, drawn from interviews with 23 natural resource professionals working in one forest ecosystem. Although the specific findings may not be generalizable to other forests or comanagement arrangements, we believe there is great value in the particular perspectives and voices presented here to managers elsewhere. Moreover, the broader lessons learned about knowledge integration could inform managers in other parts of the world working in cross-cultural contexts. It is important to note that this study is cross-cultural at a community level (i.e., tribal and nontribal members) and an organizational level (i.e., federal USDA Forest Service and tribal LLBO DRM). Although this study does not attempt to disentangle or isolate sources of variation in knowledge forms as tribal/nontribal or CNF/DRM, future researchers should acknowledge and explore the influence of organizational culture on TEK.

Integrating these forms of ecological knowledge for forest management requires commitment on the part of both tribal and public land management professionals. Among the challenges inherent in such integration, two are evident in our results. First, some species and uses are widely known. Others may be the domain of individuals who play pivotal roles and have special training in traditional culture. It may be inappropriate for them to share the details of what species are used, how they are used, and where they are found with forest managers. In these cases, it may be necessary to develop strategies such as a habitat or ecosystem approach. Second, frequent changes in personnel challenge efforts to integrate TEK into public land management. The learning curve can be steep, and relationships are fundamental. Finding ways to broaden the pool of personnel involved in collaborative efforts so the departure of one individual does not set the process of shared knowledge back to the start may help address this difficult structural issue.

Despite these challenges, our research suggests opportunities for integrating the knowledge generation and transmission modalities of TEK and WSEK so that content may be shared. Tribal professionals are trained in the knowledge process and content of western science. Opportunities for public land managers to receive basic training in the cultures and ways of knowing common to indigenous peoples are available through colleges, universities, and federal training programs. Projects of mutual interest can create learning contexts and tangible results in which the value of each knowledge base is evident. In the case of northern Minnesota, prescribed burning provides such an opportunity. Other potential opportunities for collaboration include inventory and monitoring programs for culturally important species and/or habitats. Shared training on an ongoing basis also can support knowledge integration. Where tribal environmental professionals are willing, field training in which they take the lead will provide nontribal public land managers with experiences that can introduce the latter to traditional knowledge generation, transmission, and content. Over the long-term, the most effective bridge will be the presence of more indigenous people on the staffs of public land management agencies.

Tribal and public lands overlap and neighbor each other throughout the United States and elsewhere. There is much to be gained for the health and well-being of both types of land and for the citizens who depend on them from integrating TEK and WSEK. Tribal land management benefits from the information infrastructure including data, expertise, and equipment resident in public land management agencies. In the case of public lands management, at a minimum, incorporating TEK and concerns supports basic compliance with law. More ample benefits accrue from the intimate spatial and temporal knowledge of forest conditions developed through subsistence and

other traditional practices on the land. All lands benefit from well-informed, coordinated efforts to address landscape scale issues such as invasive species and fire. However, knowledge bearers must be speaking respectfully to each other for these benefits to be realized. In an era of rapid change, it may be particularly important for forest management to draw on such deep, diverse sources of knowledge.

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